

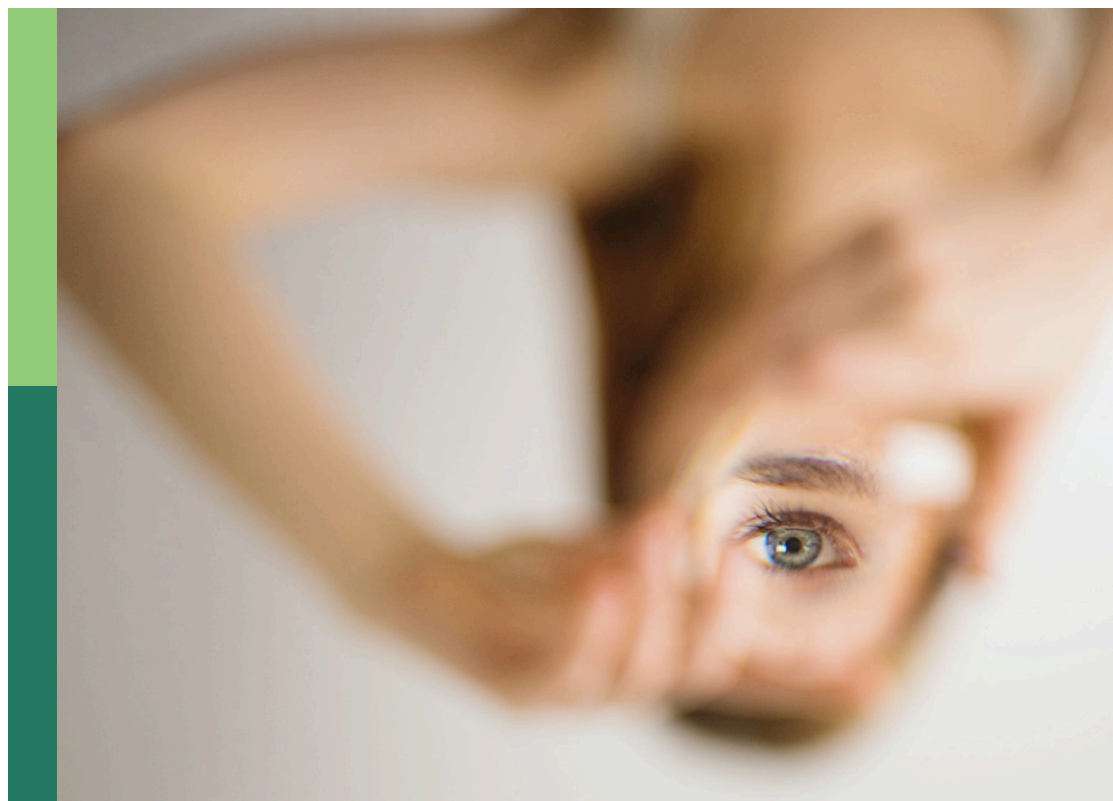
Best practice approaches for mixed methods research in psychological science, volume II

Edited by

Gudberg K. Jonsson, Mariona Portell, M. Teresa Anguera,
José Luis Losada and Judith Schoonenboom

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Best practice approaches for mixed methods research in psychological science, volume II

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Editorial: Best practice approaches for mixed methods research in psychological science, volume II

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symmetry, quantizing, mixed methods, record transformation, Qual–Quan integration, complexity

Editorial on the Research Topic

Best practice approaches for mixed methods research in psychological science, volume II

Introduction

The evolution of mixed methods research in psychological science marks a pivotal shift from the historically entrenched divide between qualitative and quantitative paradigms. Mixed methods emerged in the late twentieth century as a reconciliatory approach. By integrating diverse methodologies, it enriched psychological inquiry and gained momentum. Over the past decades, its adoption has expanded exponentially across disciplines, reflecting its versatility in addressing complex research questions. Yet, this growth has also introduced challenges, including conceptual ambiguities, heterogeneous design taxonomies, and inconsistent quality in application. As the field matures, establishing methodological rigor and standardized criteria remains critical to ensure the credibility and coherence of mixed methods research.

The way psychological and educational research is conducted has changed significantly over the last two decades. Researchers are increasingly working across disciplines and internationally, and new technologies have enabled them to develop new methods. As a result of these two tendencies, research projects and research questions have become much more complex and dynamic. It has become increasingly necessary to use more than one method to answer these questions, leading to a steady increase in mixed methods studies. Moreover, mixed methods research itself has become more complex, interdisciplinary, and collaborative. Previously, the basic idea of mixed methods research involved a combination of qualitative and quantitative data collection, analyzed separately, and then brought together by a single researcher or a small team at the end of the study. However, this is no longer the case.

Volume II of Best practice approaches for mixed methods research in psychological science reflects this increase of these diverse forms of complexity. It builds on the highly

successful inaugural volume of “*Best practice approaches for mixed methods research in psychological science*” (Anguera et al., 2020). We will discuss the relation between the two further below.

Developments in mixed methods research with different forms of data collection

The complexity of mixed methods research grows as more studies are conducted by interdisciplinary teams. Poth et al. champion integrative teamwork in mixed methods research, proposing strategies to harness disciplinary synergies. Their reflection on a literacy case study identifies enablers (e.g., shared frameworks) and barriers (e.g., methodological silos), advocating for collaborative capacity-building to tackle complex problems.

As psychological research moves away from performing cross-sectional research to develop theories about change and toward longitudinal research, complexity increases, but so do opportunities for mixed methods research. Lykkegaard and Qvortrup track tertiary students’ dropout considerations, revealing fluctuating motivations shaped by academic-personal alignment. Their mixed methods design captures both stable trends and individual variability, challenging linear assumptions about dropout pathways.

As for tracking data, the COVID pandemic brought new challenges as well as new digital interventions, including Corona apps. Fiol-deRoque et al. evaluated PsyCovidApp, a digital tool for healthcare workers. A questionnaire on the app’s use and perceived utility was enhanced by interviews with users that explored these topics in greater depth and identified barriers and suggestions for improvement. The latter topic was the subject of additional panels with experts. As a result, not only could the most important benefits and barriers be identified, but also suggestions for optimizing the process could be generated.

An innovative method combination involving questionnaire data is described by Buchholtz and Vollstedt. As in the two previous studies, Buchholtz and Vollstedt use interview data to study their questionnaire outcomes in depth, but they do so by utilizing an innovative intermediate step: interviewees were asked to Q-sort their questionnaire responses, which were analyzed quantitatively to develop different profiles.

Quantitization: building profiles and patterns from quantitized qualitative data

The articles discussed above involved innovative mixed methods studies that analyzed separate quantitative and qualitative data with the aim of understanding the process behind quantitative results, through the analysis of qualitative data separately collected, in this case interviews.

The majority of articles in this Research Topic follow a different pattern. These articles employ a methodology in which qualitative data are quantitized. In contrast to the previous articles,

these articles start with qualitative data, which is coded in great detail. These codes are then counted, and correlational and temporal patterns are used to develop patterns and profiles. In these articles, there is only one round of data collection, namely qualitative data collection, which is subsequently quantitized and interpreted qualitatively. In mixed methods notation, the design of this methodology is QUAL→QUAN→QUAL (Anguera et al., 2020). Since there is only one round of data collection, these articles do not combine two methodologies. Instead, they rely on a single integrated methodology that takes qualitative data as input, quantifies it using detailed coding, and then interprets it qualitatively.

Although the pattern QUAL→QUAN→QUAL applies to all studies using this methodology, the collection methods, types of coding and patterns derived can vary hugely. This was already visible in the inaugural volume of “*Best practice approaches for mixed methods research in psychological science*” (Anguera et al., 2020), which comprised 32 manuscripts that advanced both methodological innovations and their applications across disciplines, of these 19 manuscripts that used this methodology. This Research Topic introduced technological breakthroughs in data collection methods, including sensor-based approaches and specialized analytical software such as LINC (Soto-Fernández et al., 2022), SAGT (Hernández-Mendo et al., 2016), GSEQ (Bakeman and Quera, 2001), HOISAN (Hernández-Mendo et al., 2012), and THEME (Magnusson, 1996, 2020; Magnusson et al., 2016). Many contributors adopted a mixed methods approach, drawing on the “connecting” notion (Creswell and Plano Clark, 2007) and on subsequent methodological developments of this same logic proposed by Anguera et al. (2017, 2018, 2021). The methodological approaches featured T-Pattern Analysis, polar coordinate analysis, and sequential analysis applied across domains spanning sports, education, clinical psychology, and conversation analysis, demonstrating the breadth of mixed methods utility in psychological inquiry.

The foundation of this methodology, quantitization, is described by Onwuegbuzie. Onwuegbuzie reimagines quantitizing—the transformation of qualitative data into quantitative forms—via the DIME-Driven Model (Descriptive, Inferential, Measurement, Exploratory). This meta-framework addresses philosophical and practical barriers to quantitizing, advocating for its strategic use to enrich analysis without compromising qualitative depth.

Using the QUAL→QUAN→QUAL methodology to build patterns and profiles, various articles in this Topic advance foundational techniques for integrating qualitative and quantitative data. Belza et al. delve into a necessary methodological step to identify key aspects of the choreography followed by Pikler educators during breakfast, with the aim of developing a targeted training plan. Molinero et al. propose a therapeutic communication laboratory leveraging digital tools (e.g., ELAN, THEME) to analyze psychotherapy sessions through a Qual–Quan–Qual framework. Their work highlights how automated transcription and labeling enhances collaboration between practitioners and researchers, bridging theory and practice.

Similarly, Hunyadi explores eye tracking paired with T-pattern analysis to detect grammatical violations, revealing how

behavioral patterns (e.g., gaze duration) correlate with syntactic processing. While initial hypotheses about total gaze duration were unsupported, the study suggests combining eye tracking with neurophysiological methods (e.g., ERP: Event-Related Potentials) for richer insights. Finally, [Chacón-Moscoso et al.](#) present a case study on workplace climate assessment, systematizing interview data through quantizing and polar coordinate analysis. Their approach demonstrates how mixed methods can unveil hidden dynamics in organizational settings, offering actionable strategies for improvement.

Quantitization: applications across contexts

Using the QUAL→QUAN→QUAL methodology to build patterns and profiles, various contributions illustrate mixed methods' versatility in addressing real-world challenges. In education, [Qiao et al.](#) identify group metacognition as a critical driver of collaborative learning outcomes, revealing three performance categories (H_T, EF, L_T) tied to metacognitive interactions. Their findings advocate pedagogical strategies that foster collective reflection. [Tronchoni et al.](#) analyse participatory interaction in university lectures using lag sequential analysis, uncovering 12 dialogical patterns that promote deep learning. Their work underscores the value of non-intrusive observation in refining instructional practices.

[Bonilla Rodríguez et al.](#) investigated conflict management strategies in secondary school classrooms using a mixed methods design based on indirect observation, following the QUAL→QUAN→QUAL framework, on teachers' focus groups. The findings revealed notable gaps in teachers' understanding of conflict dynamics and highlighted a reliance on intuitive rather than systematically trained strategies. The study advocates for enhancing teachers' cognitive and emotional skills to improve classroom conflict management and adaptive coping mechanisms. [Alarcón-Espinoza et al.](#) applies a similar procedure to analyze interactions between teachers and students, demonstrating how the detected diachronic regularities contribute to understanding emotional regulation and classroom climate in daily educational settings.

[Gläser-Zikuda et al.](#) examine reflective writing through concurrent MMR, combining linguistic analysis and content analysis. Their work sheds light on how levels of reflection can be both qualitatively and quantitatively assessed, offering insights into teacher education and pedagogical growth.

Cultural and clinical applications feature prominently. [El Khayat et al.](#) employ polar coordinate analysis to study Pakistani mothers in Catalonia, revealing how migration sustains traditional parenting values despite acculturation pressures. Meanwhile, [Santisteban et al.](#) decode motor behavior in piano performance through observational methodology, linking tactile techniques (e.g., pressed vs. struck touch) to pedagogical strategies.

[Farina and Pepe](#) correlate adolescents' metaphorical narratives with wellbeing during COVID-19, showing how alexithymia

exacerbates emotional confusion—a finding with implications for youth mental health interventions.

Systematic reviews and perspectives: synthesizing knowledge

The QUAL→QUAN→QUAL methodology can also be useful in systematic reviews. Whereas, systematic reviews commonly rely on the researchers coding articles on specific themes, the Systematic Review by [Kim and Cruz](#) synthesizes 150 studies on PE teachers' leadership using text mining and meta-analysis. Their review highlights autonomy-supporting behaviors as key to student motivation and engagement. Regional disparities in research focus (e.g., health in Asian/European studies) call for culturally tailored interventions.

Emerging themes and future directions

Three cross-cutting themes emerge:

- **Integration as Innovation:** Techniques like polar coordinate analysis, lag sequential analysis, and Q methodology demonstrate how blending qualitative depth with quantitative precision yields novel insights.
- **Technology as Catalyst:** Digital tools (e.g., LINCE, THEME) and automated processes enhance methodological rigor while democratizing access to mixed methods approaches.
- **Contextual Sensitivity:** From migrant parenting to pandemic-era mental health, studies emphasize the need for culturally and contextually adaptive frameworks.

Conclusion

This Research Topic exemplifies the transformative potential of mixed methods in psychological science. Building on the foundation laid by Volume I, this second volume addresses persistent methodological challenges through carefully selected studies that exemplify genuine integration of qualitative and quantitative approaches. The included studies transcend traditional methodological boundaries, advancing both theory and practice by emphasizing conceptual innovations, methodological advancements, and practical implementations across education, mental health, cultural adaptation, and organizational behavior.

Collectively, these works illuminate complex psychological phenomena, offering insights unattainable through single-method approaches while providing researchers with clear pathways for navigating mixed methods design. They offer scalable solutions for education, healthcare, and beyond.

As the field evolves, fostering methodological literacy and interdisciplinary dialogue remains paramount. The contributions herein not only reflect the current state of the art but also chart a course for future research that is integrative, context-sensitive, and technologically empowered.

Author contributions

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In memoriam

We dedicate this manuscript to our dear friend and coauthor, Prof. M. Teresa Anguera, who passed away on January 19th, 2025. Dr. Anguera was a pioneering force in observational methodology and program evaluation design. Her groundbreaking work led numerous competitive research projects and was widely published in leading international journals. Her innovative integration of qualitative and quantitative approaches helped shape the field of Mixed Methods research.

As founder and first coordinator of the research group GRID (Research and Innovation in Designs: Technology and Multimedia Applications to Observational Designs), she championed the application of multimedia and digital technologies in behavioral research. In addition to this group, recognized by AGAUR (Agency for Management of University and Research Grants, Generalitat de Catalunya, Spain), she also led a much larger group that gained recognition through the awarding of multiple research projects in competitive calls. Her efforts enabled highly precise coding and analysis of complex human behaviors. She was also a founding member of the research group MASI (Methodology for the Analysis of Social Interaction), established at the University René Descartes, Paris V, Sorbonne, in 1995. Originally created through a partnership among six European universities, MASI has since grown into an international network with over 40 member institutions across Europe and the Americas.

Dr. Anguera's work consistently bridged theory and practice, providing rigorous methodologies for the study of social interaction and human dynamics. At the University of Barcelona, she taught at all academic levels and contributed significantly to graduate programs in Spain and Portugal, where she was widely admired for

her clarity, rigor, and generosity as an educator. Her distinguished career earned her multiple honorary doctorates in recognition of her lasting academic impact.

Yet beyond her scholarly accomplishments, Teresa was deeply admired for her humility, ethical integrity, and unwavering commitment to mentorship. She inspired generations of researchers to pursue science with both intellectual precision and human empathy. An online interview, conducted by the Spanish Academy of Psychology, of which Teresa was a full member, allows us to preserve her voice and legacy, providing valuable insights into her vision and contributions to the field.

We mourn the loss of an exceptional colleague, mentor, and friend. Her wisdom, kindness, and dedication left a lasting imprint on the research community. Teresa's legacy lives on through the methodologies she developed, the collaborations she fostered, and the many lives she touched. Her memory will remain a guiding light for all who had the privilege of knowing her.

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Methodological procedure based on quantitizing/liquefying: a case study to assess work climate in an emergency department

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Introduction: In the assessment of health organizations, results-based indicators are mainly used, with no consideration of internal work dynamics. This type of assessment forfeits much of the rich, useful information needed to make decisions on improving the organization. In order to address this, a rigorous procedure based on mixed methods is laid out here on gathering, analyzing, and interpreting data associated with the implementation process.

Methods: A 55-year-old doctor was selected at random from among the staff who volunteered to be interviewed at the emergency department at a public hospital located in southern Spain for an interview. Qualitative data obtained from the in-depth interview (indirect observation) were progressively systematized (liquefied and quantitized) based on a theoretical framework until a code matrix was obtained, without losing or distorting any information. Afterwards, data quality was controlled using Cohen's kappa (κ) coefficient. A quantitative polar coordinate analysis was then carried out using the free software HOISAN (v. 1.6.3.3) to obtain robust results, vectorizing the relationships between codes and specifying whenever such relationships were statistically significant (and if they resulted in behavior activation or inhibition). Finally, a supplementary quantitative and qualitative assessment was carried out.

Results and discussion: The proposed method was applied to the needs assessment of teams in order to evaluate that work climate in the hospital's emergency department Health Services of a hospital. Data quality control yielded an adequate result ($\kappa = 0.82$). Significant activation and inhibition of behaviors occurred, both prospectively and retrospectively. For instance, *We seek to understand the needs of our clients* and *We readily adapt to new circumstances* showed a significant activation (vector length = 3.43, $p < 0.01$) both prospectively ($Z_{\text{sum}} = 0.48$) and retrospectively ($Z_{\text{sum}} = 3.4$). An adequate method to obtain detailed information about group dynamics in a work environment is presented, based on an in-depth interview. Practical applications for implementations to improve the functioning of organizations are presented.

KEYWORDS

mixed methods, indirect observational methodology, in-depth interview, polar coordinate analysis, single-case study, work climate, emergency department, hospital

1 Introduction

There have been three predominant theoretical approaches to the concept of work climate: (a) those that focus on the objective and structural characteristics of organizations (Li et al., 2022); (b) those that delve into the individual psychological characteristics of workers (Mozgovoy, 2022); and (c) those that adopt a perspective that considers both organizational and individual aspects (Altuntaş et al., 2021). This paper is based on the third approach, which is widely regarded as the most comprehensive given that it allows a multidimensional exploration of work climate.

In the context of healthcare services, the model proposed (Perry et al., 2005) conceptualizes work climate as an integral component of the organization primarily shaped by individual behavior and human interactions. According to this perspective, each working team within a hospital setting possesses a unique work climate, defined as the quality of the internal environment experienced by its members. It is believed to have a substantial influence on staff behavior. Therefore, any alteration in the work climate of a healthcare organization can lead to changes in other aspects of the organization, such as the effectiveness or quality of patient care (Santana and Pérez-Rico, 2023).

Hospital Emergency Departments (ED) exhibit distinctive features compared to other healthcare services. Professionals working in the ED confront any number of unique challenges: (a) they constitute the frontline of medical care for patients, playing a pivotal role in initial care (Trebach et al., 2021); (b) they provide care to a substantial volume of patients, irrespective of the severity of their condition (Holzinger et al., 2021); (c) they deal with traumatic situations that require immediate and critical decision-making on a daily basis (Bijani et al., 2021); (d) they experience heightened levels of stress and responsibility owing to the inherent nature of their work (Barth et al., 2022); (e) they face a higher risk of post-traumatic stress disorder and depression due to their workplace experiences (Taylor et al., 2023). In this specific context, an assessment of work climate offers insights into both workgroup characteristics and organizational aspects, providing insight into job satisfaction, productivity, goal achievement, interpersonal relationships, and job performance (Sanduvete-Chaves et al., 2018; Lozano-Lozano et al., 2021).

Results-based indicators are mainly used when evaluating healthcare organizations, with no consideration of internal work dynamics. This type of assessment forfeits much of the rich, useful information needed to make decisions on improving the organization. Therefore, this work presents a rigorous procedure based on mixed methods to gather, analyze, and interpret the data associated with the implementation process. Qualitative data obtained from an in-depth interview (indirect observation) were progressively systematized until a code matrix was obtained, without losing or distorting any information. A quantitative polar coordinate analysis was then carried out to obtain robust results, vectorizing the relationships between codes. Finally, a supplementary quantitative and qualitative assessment was carried out.

Observational methodology was optimal for this task, given that it is both rigorous and flexible (Chacón-Moscoso et al., 2014; Anguera, 2020). Specifically, indirect observation was used (Anguera, 2021). In terms of the information obtained in the in-depth interview, as noted in an earlier work,

...all these materials constitute an extremely rich source of information for studying everyday life, and they are continuously growing with the burgeoning of new technologies for data recording, dissemination, and storage. Narratives are an excellent vehicle for studying everyday life, and quantization is proposed as a means of integrating qualitative and quantitative elements. However, this analysis requires a structured system that enables researchers to analyze varying forms and sources of information objectively (Anguera et al., 2018c).

Indirect observation facilitates the analysis of diverse texts, as has been shown in works on self-registrations (Squires et al., 2011), teacher – student conversations (García-Fariña et al., 2018), therapist – teenager patient dialog (Arias-Pujol and Anguera, 2020), therapist – adult patient dialog (del Giacco et al., 2020), in-depth interviews with elite trainers (Nunes et al., 2022), in-depth interviews with professional coaches and players (Iván-Baragaño et al., 2023), panel discussions with professionals about the foreseeable consequences of COVID-19 (Moya et al., 2020), and in-depth interview with family firms where there is an intrafamilial conflict (Alvarado-Alvarez et al., 2021).

In-depth interviews, unlike other types of interviews, allow researchers to delve in detail into aspects that required the participant to recount them as they were experienced. Therefore, these interviews capture a wide range of opinions and experiences among a group of professionals. They provide more extensive and detailed data on the unique contextual factors of each participant, facilitating a comprehensive representation of professionals' daily experiences, their decision-making processes, and their interactions with both patients and the medical team (Merriam and Tisdell, 2016; Marshall et al., 2022). Furthermore, in-depth interviews can be adapted, including new questions or modifying existing ones based on the previous responses of participants. This enables a deeper exploration of specific areas of interest (Rubin and Rubin, 2005).

A single-case study can be defined as an intensive study of a single unit with an aim to generalize across a larger set of units (Gerring, 2004; Hunziker and Blankenagel, 2021). The interest in single-case studies has increased in recent years in different health fields (Stetler, 2009; Champagne, 2014; Porcheret, 2014). Single-case studies present advantages, such as they enable methodological advances, especially in the case of observational studies (Kitzmilller, 2010; Arias-Pujol et al., 2022). Additionally, the polar coordinate analysis proposed has been used in recent years in various fields, such as clinical psychology (Rodríguez-Medina et al., 2018; del Giacco et al., 2020; Arias-Pujol et al., 2022), occupational health (Portell et al., 2019), classroom activities (Belza et al., 2019), sports (Maneiro et al., 2020; Iván-Baragaño et al., 2023), and conflict mediation (Alvarado-Alvarez et al., 2021). However, the context in which this single-case study (Sandelowski et al., 2009; Anguera, 2018; Arias-Pujol et al., 2022) was developed, a hospital ED, is totally new.

Though the approach to single-case studies has generally been qualitative, it has also been heterogeneous in the literature. Our objective was to develop a case study from a mixed methods approach, thus integrating qualitative and quantitative elements. Specifically, a needs assessment (Sanduvete-Chaves et al., 2009) of work teams was carried out to evaluate the work climate. Given that the starting point

was a single interview, an intensive treatment of the information is needed.

2 Methods

Two checklists guided the methodological process: the Guidelines for Reporting Evaluations based on Observational Methodology (Portell et al., 2015) and the Methodological Quality Checklist for studies based on Observational Methodology (Chacón-Moscoso et al., 2019), derived from the Guidelines for Reporting Evaluations based on Observational Methodology, which presents adequate validity evidence based on its content (Chacón-Moscoso et al., 2018).

2.1 Design

The observational design presented is idiographic, punctual, and multidimensional (Blanco-Villaseñor et al., 2003; Anguera et al., 2021). It is idiographic because it is based on a single case (an interview). The design can be considered punctual because the information was obtained in a single session, although there was intra-session follow-up because the full interview was analyzed. Finally, it is multidimensional because the study was based on a theoretical framework and structured in four dimensions. It then materialized in the observation tool.

2.2 Participant

The person selected at random from among the staff who volunteered to be interviewed was an ED worker at a public hospital in the south of Spain. The patients at this hospital hail from a diverse demographic. The selection criteria for the participant were (a) currently working at the ED when the study was carried out, and (b) having worked in the ED for at least three years.

The worker interviewed was a 55-year-old man who participated voluntarily. He was a doctor in the ED with an indefinite contract, 25 years of experience in his profession, and 23 years working at his current workplace. One of the authors, JALL, interviewed the participant in a hospital room. The interview yielded substantial new and rich information.

2.3 Instruments

2.3.1 Observation instrument

Based on a theoretical framework that laid out the fundamental work climate factors for ED teams (Sanduvete-Chaves et al., 2018) and the unique characteristics of this service, a non-standard tool was designed in keeping with indirect observation (Portell et al., 2015; Anguera et al., 2018c; Anguera, 2021). This tool combined field format and a system of categories.

The dimensions proposed for the theoretical framework included (A) job satisfaction, referring to how workers feel about their job and work conditions; (B) productivity/achievement of aims, which refers to the workers' sense of whether they have everything they need to do their job properly and achieve their goals; (C) interpersonal

relationships, referring to the workers' feelings about their fellow team members; and (D) work performance, referred to all aspects related to how the workers do their jobs (Table 1). A system of exhaustive and mutually exclusive categories was built for each dimension.

2.3.2 Recording device

A digital audio recorder was used to record the in-depth interview. Express Scribe software (version 2.0) was used for the transcription.

2.4 Procedure

2.4.1 Quantitizing/liquefying

According to the methodological process of indirect observation, the text can be liquefied (Anguera, 2020). This is combined with the quantitizing of the text in keeping with (direct and indirect) observational methodology, from the mixed-method perspective. It is possible to operate quantitatively with codes to which the textual units are assigned, either uniquely or in co-occurrence.

The mixed methods (Creswell and Plano Clark, 2011), broadly developed in the last two decades, offers vast potential for the integration of qualitative and quantitative elements. When referring to such integration paths, connecting (Creswell and Plano Clark, 2011) was chosen to build one dataset upon the other. The connecting forms the groundwork for the quantitizing, which consolidates previous proposals that have enabled the observational methodology to be considered a mixed method on its own (Anguera and Hernández-Mendo, 2016; Anguera et al., 2017). Neither methods nor techniques are combined, as is traditional according to conventional mixed methods or in multimethod studies (Anguera et al., 2018b). Data from different sources are neither combined. The information is transformed in a different way than what is described in the literature on mixed methods (Sandelowski et al., 2009).

This work presents a proposal for quantitizing that can be adapted to all situations, enabling the observational methodology to be used as a scientific method (Anguera et al., 2018a; Chacón-Moscoso et al., 2021). Additionally, it fits with the connecting (Creswell and Plano Clark, 2011). It materializes when the macro-stages QUAL-QUAN-QUAL are alternated (Figure 1). In the first QUAL stage, the observational design is proposed, and the indirect observation instrument is built, yielding a descriptive record that is systematized until it becomes a code matrix. In the QUAN stage, the systematized record is subjected to data quality control (Chacón-Moscoso et al., 2023), using robust analytical techniques appropriate for categorical data. Finally, in the second QUAL stage, the results are interpreted. This procedure is consistent with the nature of the information obtained and the methodology applied.

The information captured during the interview is transformed into a record and this constitutes the raw material for analysis. This data collection relies on a text transcription as its first step, taking into account that "transcripts are necessarily selective in the details that are represented" (Hepburn and Bolden, 2013). In this study, only verbal behavior was considered, without taking into account any additional information that could be garnered (gesture, gaze, cadence, etc.) in studies focused on the multimodality of human behavior.

The first decision to establish was the segmentation criterion in units. The behavior flow was set in interactive units (Birdwhistell, 1970) that were then ranked based on their granularity (Schegloff,

TABLE 1 Indirect observation instrument.

Dimensions	Category systems	Code
A. Work satisfaction	We take pride in our work	A1
	We seek to understand the needs of our clients	A2
	We readily adapt to new circumstances	A3
	We strive to achieve successful outcomes	A4
	We have the experience to do our job well	A5
	Our workday provides the time we need to do our jobs	A6
	We coordinate well with the other hospital services	A7
	Each member has a role based on his/her area of expertise	A8
	Our work is important	A9
	We develop our skills and knowledge	A10
B. Productivity/achievement of aims	Our work group is known for quality work	B1
	We have a common purpose	B2
	We have the necessary infrastructure	B3
	We receive the necessary training	B4
	The characteristics of our service are appropriate	B5
	Our services are provided correctly	B6
	Our work group is known for its productivity	B7
	We feel motivated doing our work	B8
	The merit of the job we do is recognized	B9
	Our colleagues value our profession	B10
	The work we do is appreciated	B11
	Our expertise is recognized	B12
	Our expectations have been fulfilled	B13
	The type of patient we see is aligned with the services we provide	B14
	We know our patients	B15
	We coordinate with other hospital services	B16
	We are recognized for our individual contributions	B17
	We have a plan that guides our activities	B18
	We participate in the decisions of our group	B19
	We know what is expected of us on the job	B20
C. Interpersonal relationships	We have good communication within the group	C1
	Team members have a good working relationship	C2
	I feel comfortable with my work group	C3
	I have good personal relationships	C4
	The work climate is conducive to group work	C5
D. Performance at work	We understand each other's capabilities	D1
	I know my professional shortcomings	D2
	We know what tasks each member handles	D3
	The patients we see are aligned with the services we provide	D4

2000). Various levels of granularity could be formed (Schegloff and Sacks, 1973). Given the advantages and disadvantages of each unit type, we have combined syntactic and contextual criteria (Anguera, 2020).

Once the transcription was segmented into text units by means of the indirect observation instrument (Table 1), each text unit was

coded. One or more codes were obtained for each of them, depending on the corresponding dimension/s involved. If only one dimension was affected, the text unit was assigned to the corresponding category; if several dimensions were affected, the co-occurring categories were recorded, generating a systematized record (Figure 2). The key to this coding is based on the data classification widely used in both direct

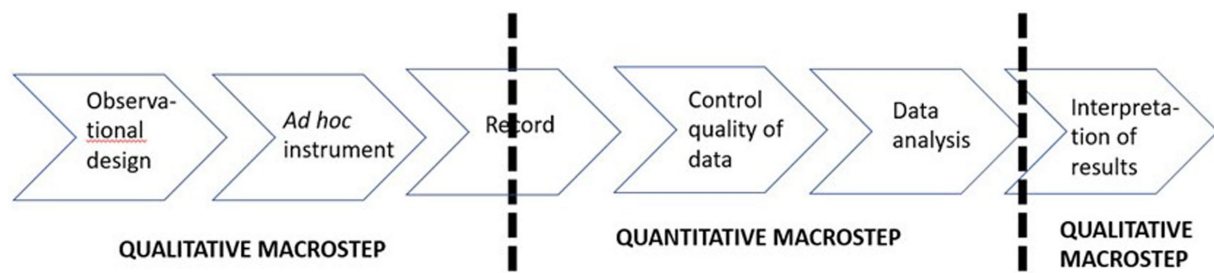


FIGURE 1
Steps of indirect observation.

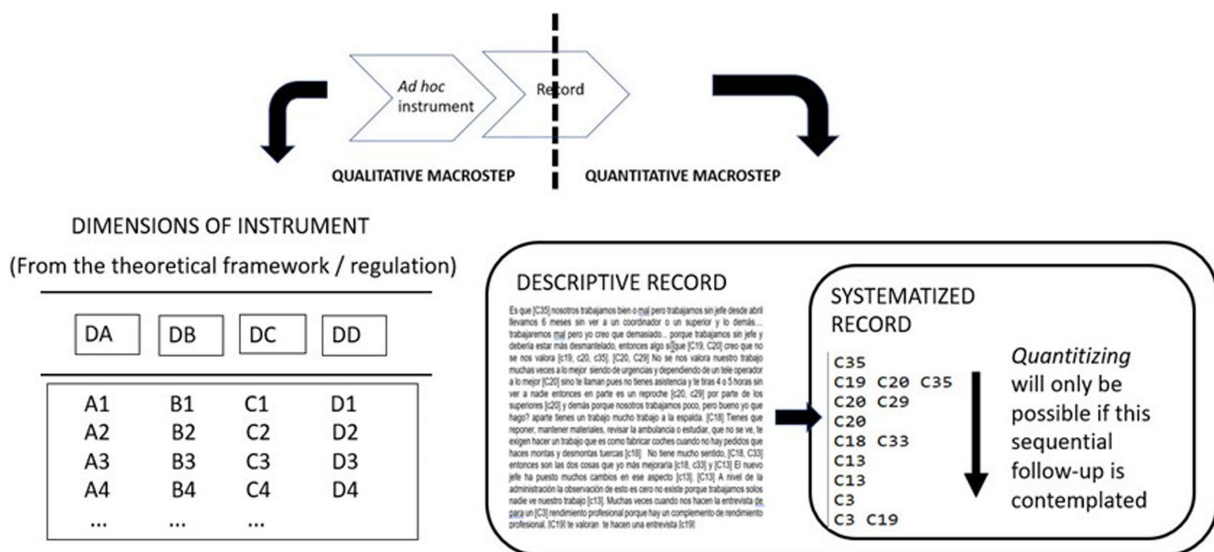


FIGURE 2
A graphic depiction of quantizing/liquefying.

and indirect observational methodology (Bakeman, 1978; Anguera et al., 2018c), from the beginning to the end of the session, obtaining a codes matrix whose columns were the four dimensions (A, B, C and D) established in the indirect observation instrument. Each row represented one of the textual units obtained when the text of the interview was segmented.

When completed, the first QUAL stage yielded a code matrix. Since data are already arranged sequentially and available for analysis, once the data went through quality control, quantizing is possible.

2.4.2 Data quality control

To control the data quality, (Holgado-Tello et al., 2016) three independent researchers (authors MTA, SCM, and SSC) coded the transcription of the interview, dividing the text into content units and assigning a code for each different content. Disagreements were resolved through consensus. The Supplementary material includes a segment of the interview with an example of a coding assignation. The kappa (κ) coefficient (Cohen, 1960) was calculated using HOISAN (v. 1.6.3.3), based on the records made by the three coders. Values over 0.7 were considered adequate.

2.4.3 Polar coordinate analysis

Polar coordinate analysis is one of the most suitable categorical data analysis techniques (Blanco-Villaseñor et al., 2003; Anguera et al., 2021), given that it allows a relations map to be drafted. This map shows the statistical relationships of association between a specific behavior of interest, the focal behavior, and others known as conditioned behaviors, i.e., behaviors that may be related to the focal behavior. For those that do relate, it is then necessary to determine the type and degree of the relationship. This quantitative relations analysis also allows these relationships to be charted as vectors, facilitating conclusions about the relationships, types, and intensities of behaviors.

The polar coordinate analysis (Sackett, 1980) constitutes a second stage of the lag sequential analysis (Bakeman, 1978). It considers the adjusted residuals obtained in the lag sequential analysis as data, once these are corrected (Allison and Liker, 1982). The analysis starts with the focal behavior and is both prospective (forward-looking) and retrospective (looking backwards). It provides insight into how the relationship between the focal behavior and the conditioned behaviors varies or evolves over time (in this case, throughout the recording of the interview). Retrospectivity from lag 0 to -1 , from lag -1 to -2 ,

TABLE 2 Interpretive guideline for vectors in polar coordinate analysis.

Quadrant in which the vector of each conditioned behavior is located	Sign of the prospective Z_{sum}	Sign of the retrospective Z_{sum}	Meaning
I	Positive	Positive	Prospective and retrospective activation
II	Negative	Positive	Prospective inhibition, retrospective activation
III	Negative	Negative	Prospective and retrospective inhibition
IV	Positive	Negative	Prospective activation, retrospective inhibition

TABLE 3 Parameters corresponding to the polar coordinate analysis, considering A2 as a focal behavior.

Category	Quadrant ^a	Prospective Z_{sum}	Retrospective Z_{sum}	Ratio	Vector length	Vector angle
A2	I	0.31	0.31	0.71	0.44	45
A3	I	0.48	3.4	0.99	3.43**	81.92
A4	II	-0.42	1.29	0.95	1.36	108.11
A5	I	0.31	0.45	0.83	0.55	55.78
A6	III	-1.34	-0.53	-0.36	1.44	201.34
A7	IV	3.02	-0.04	-0.01	3.02**	359.3
A9	II	-0.56	1.31	0.92	1.43	112.97
A10	IV	3.18	-0.56	-0.17	3.23**	350.05

All codes were considered conditioned behaviors.

^aQuadrant where the vector is located. ** $p < 0.01$.

and so on, was applied (Anguera, 1997). This analysis algorithm was included when programming the HOISAN software (Hernández-Mendo et al., 2012).

The data obtained were independent because each datum is calculated based on the corresponding lag. This enabled the use of parameter Z_{sum} or the “flag” parameter (Sackett, 1980), thus facilitating data reduction. The Z_{sum} parameter is based on the principle that the distribution of the sums of n -independent Z values is normal, with $\mu = 0$ and $\sigma = 1$. It is calculated using the formula

$$Z_{sum} = \frac{\sum Z}{\sqrt{n}}$$

where n is the number of lags. Z_{sum} is calculated for each conditioned behavior. The prospective Z_{sum} values are obtained considering the positive lags, and the retrospective Z_{sum} values are calculated considering the negative lags. The number of positive and negative lags should be the same, and a minimum of five lags is recommended, i.e., from -1 to -5 and from $+1$ to $+5$ (Sackett, 1980).

For the prospective and retrospective Z_{sum} values, the relationships between focal behavior and conditioned behaviors are vectorized (Sackett, 1980). The length or radius of each vector would be

$$\text{Length} = \sqrt{(Z_{sum \text{ prospective}})^2 + (Z_{sum \text{ retrospective}})^2}$$

and the angle

$$\varphi = \text{Arc sen} \frac{Z_{sum \text{ retrospective}}}{\text{Length}}$$

A vector is obtained for each conditioned behavior. The graphic origin of all vectors will be the focal behavior. Given that prospective and retrospective Z_{sum} values can be positive or negative, the corresponding vectors can be plotted considering that the prospective Z_{sum} are represented on the abscissa axis, and the retrospective Z_{sum} on the order axis.

The adjusted residuals, Z values, angles, and vector lengths are obtained using HOISAN (v. 1.6.3.3) [www.menpas.com] (Hernández-Mendo et al., 2012), which calculates them from sequential multi-event type II data (Bakeman, 1978). In addition, the vector graphing was optimized using the free software R (Rodríguez-Medina et al., 2022) [https://jairdmed.shinyapps.io/HOISAN_to_R_2022/].

The vectors are interpreted based on whether the prospective and retrospective Z_{sum} values obtained are positive or negative, as indicated in Table 2. The significant relationships between the focal behavior and the conditioned behaviors ($p < 0.05$) are characterized by vector lengths > 1.96 , while highly significant relationships ($p < 0.01$) are distinguished by vector lengths > 2.58 .

3 Results

Intercoder reliability was $\kappa = 0.82$, which indicated satisfactory concordance. Afterwards, a polar coordinate analysis was carried out considering each code of the indirect observation instrument as a focal behavior and all the codes that comprise the instrument as conditioned behaviors.

The results corresponding to the focal behaviors A2 *We seek to understand the needs of our clients* (Table 3 and Figure 3), and B2 *We have a common purpose* (Table 4 and Figure 4) are presented for illustrative purposes and considering all the codes of the indirect observation instrument as conditioned behaviors.

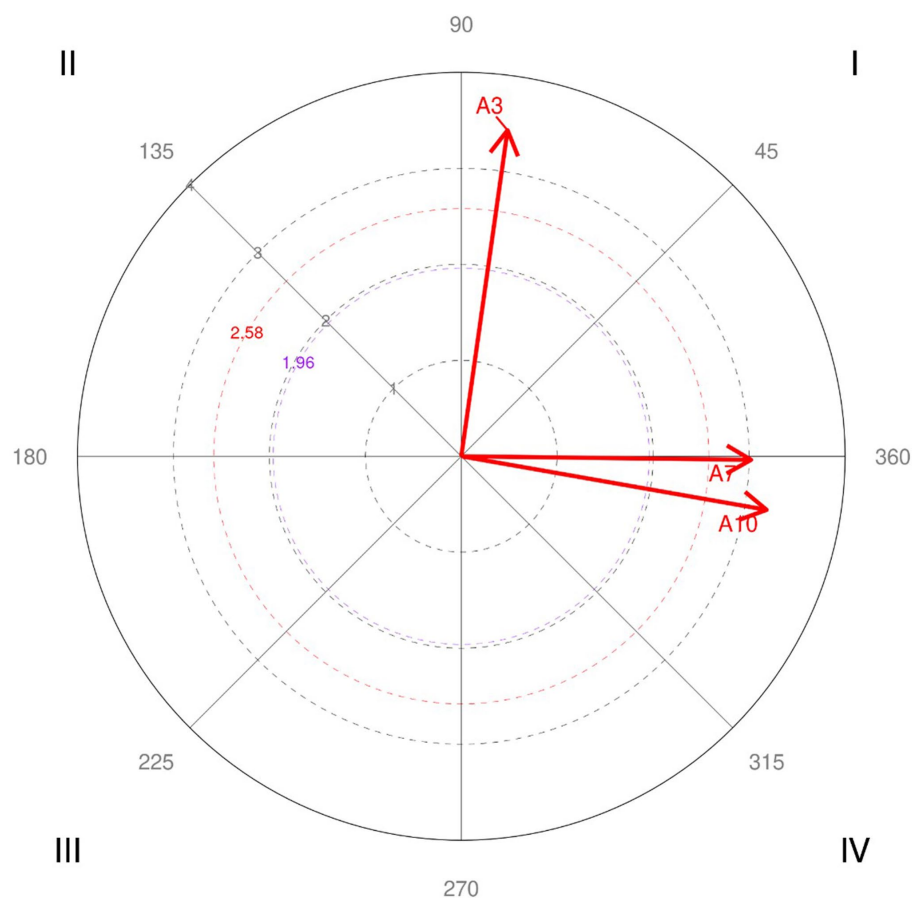


FIGURE 3

Significant vectors obtained in the polar coordinate analysis, considering A2 as a focal behavior, and all codes as conditioned behaviors.

TABLE 4 Parameters corresponding to the polar coordinate analysis, considering B2 as a focal behavior.

Category	Quadrant ^a	Prospective Z_{sum}	Retrospective Z_{sum}	Ratio	Length	Angle
B1	III	-0.3	-0.3	-0.71	0.43	225
B2	III	-0.17	-0.17	-0.71	0.25	225
B3	I	2.26	2.26	0.71	3.2**	45
B4	III	-0.65	-0.65	-0.71	0.92	225
B5	III	-0.25	-0.25	-0.71	0.35	225
B6	I	1.61	3.72	0.92	4.05**	66.57
B7	III	-0.43	-0.43	-0.71	0.61	225
B8	III	-0.25	-0.25	-0.71	0.35	225
B9	III	-0.35	-0.35	-0.71	0.5	225
B10	III	-0.17	-0.17	-0.71	0.25	225
B11	III	-0.17	-0.17	-0.71	0.25	225
B13	III	-0.17	-0.17	-0.71	0.25	225
B14	III	-0.25	-0.25	-0.71	0.35	225
B15	III	-0.43	-0.43	-0.71	0.61	225
B16	III	-0.35	-0.35	-0.71	0.5	225
B18	III	-0.47	-0.47	-0.71	0.66	225
B19	III	-0.39	-0.39	-0.71	0.56	225
B20	I	1.59	1.94	0.77	2.51*	50.66

All codes were considered conditioned behaviors.

^aQuadrant where the vector is located. * $p < 0.05$; ** $p < 0.01$.

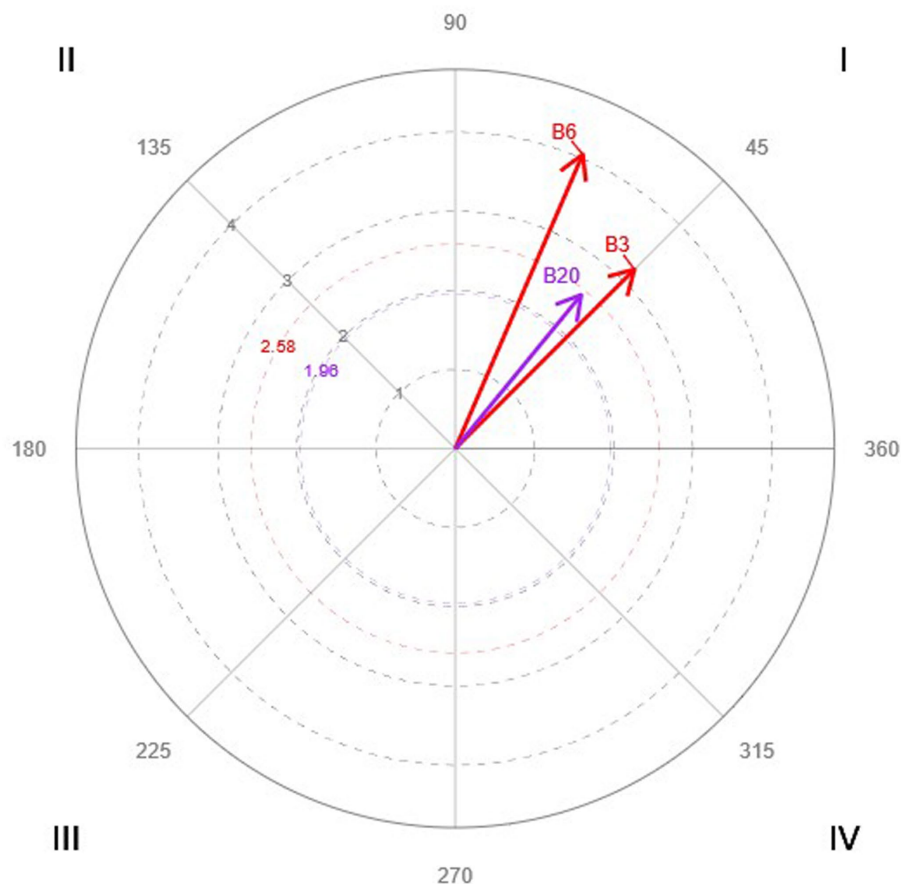


FIGURE 4
Significant vectors obtained in the polar coordinate analysis, considering B2 as a focal behavior, and all the codes as conditioned behaviors.

Tables 3, 4 present all results, regardless of whether the relationship was significant. Figures 3, 4 include only significant and highly significant vectors.

When A2, *We seek to understand the needs of our clients*, is considered the focal behavior, it is found to have a significant relationship with A3, *We readily adapt to new circumstances*. There is reciprocal activation $A2 \leftrightarrow A3$ (quadrant I), showing its functional and organizational benefits for the ED. Additionally, asymmetric relationships with A7, *We have good relations with the other services*, and A10, *We develop our skills and knowledge*, were found in quadrant IV. A2 favors both behaviors (prospective $Z_{sum} = 3.02$ and 3.18 respectively). Nevertheless, A7 and A10 present an inhibitory relationship with A2 close to zero (retrospective $Z_{sum} = -0.04$ and -0.56 respectively); i.e., they have a good relationship with the other hospital services or developing skills and knowledge does not imply that it is easy to adapt to new circumstances.

Considering B2, *We have a common purpose*, as a focal behavior, three significant reciprocal activations (located in quadrant I) are found with the following behaviors: B3, *We have the necessary infrastructure* ($B2 \leftrightarrow B3$); B6, *Our service works correctly* ($B2 \leftrightarrow B6$); and B20, *We know what is expected of us on the job* ($B2 \leftrightarrow B20$). This result

is especially relevant from the point of view of shared mission and good organization.

4 Discussion

In-depth interviews are not commonly used in the implementation of programs, given that research has not indicated any productive use of them. This paper presents an adequate method to obtain detailed and thorough information based on an in-depth interview.

The mixed method approach used herein started exclusively with qualitative data (the responses to an in-depth interview) which, after being systematized, were subject to a quantitative analysis, and finally reached a qualitative interpretation of the results. Polar coordinate analysis is commonly used in direct observation. This is the first time to our knowledge that its use is presented in indirect observation and in the context of ED.

There are some limitations to the method proposed. First, substantially more time and human resources are needed for an in-depth interview than for other tools, such as questionnaires (Cano-García et al., 2017). Nevertheless, we consider that the level of detail and usefulness of the information obtained proved worthwhile.

Additionally, the qualitative interpretation could prove difficult for an external evaluator, given that this person is unfamiliar with the context and details. For this reason, we recommend carrying out an internal evaluation within the organization or, if an external evaluation is needed, to work closely with stakeholders from the organization that is being evaluated.

All workers in the ED were asked to participate. As a result, we interviewed different ED professionals (emergency technicians, nurses, doctors, administrative staff and security personnel). Nonetheless, the aim of the present study was to show how qualitative and quantitative elements can be integrated through indirect observation, enabling a mixed-method approach to be used in an in-depth interview. In order to achieve this, a doctor's interview was chosen at random from the set of interviews conducted and analyzed as an illustrative but non-representative example (Gerring, 2006). High external validity was not the main objective in this study, which is why we do not discuss the generalization of the results. It is impossible to know whether a single doctor is not representative of the doctor subgroups unless the homogeneity of the subgroup was assessed beforehand. Additionally, other ED workers would probably have a different point of view about their group's work climate than doctors do. To obtain representativeness of the work climate in this ED, a study with multiple cases would be useful: other workers, such as nurses and orderlies, would be included, and the kappa coefficient would indicate the extent of agreement between their responses.

There are some important practical applications for implementation systems in terms of improving the functioning of organizations. Taking the case study presented herein, and considering that B2, *We have a common purpose*, and B6, *Our service works correctly*, presented significant reciprocal activation, workers should receive a clarification about the common purpose of the services their area provides if it is not deemed to be working properly (for example, if patients complain about the treatment received).

In the single-case study presented, the method proposed was illustrated in the context of an ED. Nevertheless, the method is flexible and can be adapted to contexts such as another hospital service and any other organization, as long as an informative in-depth interview can be carried out.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Scientific Ethics Committee of Universidad Autónoma de Chile. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SC-M and MTA came up with the idea for the study. SC-M, MTA, and SS-C contributed to the design. JL-L acquired the data. MTA and JL-L conducted the analysis. All authors interpreted the results, wrote the initial draft of the manuscript, revised the article and approved the final version. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1247577/full#supplementary-material>

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Metaphors of adolescence during COVID-19 pandemic: a mixed-method analysis in relation to well-being and alexithymia

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Introduction: During the pandemic, young people experienced a general increase in stress levels in their home and school environments and in their relationships with peers and family, largely due to restrictions on freedom of movement and social isolation. The ability to identify sources of stress and respond positively to them, using both personal and environmental resources, seems to be key to maintaining an acceptable level of well-being. This study investigates the association between alexithymic traits, self-perceived well-being, and self-representations in adolescents as expressed via narrative metaphors during the COVID-19 epidemic.

Methods: The sample comprised 229 Italian adolescents (51.1% females, mean age = 16.64). The research design was based on an exploratory, parallel, mixed-method approach. A semi-structured online interview was used as the major data gathering tool including both standardized quantitative questionnaire and open-ended questions. Data were analyzed by means of descriptive statistics, quantitative textual analysis and multidimensional co-word correspondence analysis.

Results: Main findings reveal a general low level of perceived well-being associated with alexithymia, affecting adolescents' lexical choices for their metaphors. Alexithymia-related low levels of well-being correspond to metaphors in which confusion and overpowering emotions predominate. Vivid pictures indicating vitality and a bright view on the future is often correlated with high levels of well-being.

Discussion: Overall, these novel findings appear to show an interactive effect of perceived well-being and alexithymia on adolescents' ability to identify and describe their own condition. Furthermore, metaphors emerge as powerful tools for investigating well-being in adolescents since closely related to inner states.

KEYWORDS

well-being, alexithymia, self-representation metaphors, adolescents, mixed-method

Introduction

The COVID-19 pandemic forced the implementation of multiple measures aimed at limiting the spread of the disease. These included closing places of public recreation and education, such as schools and universities, and restricting face-to-face interaction by means of enforced "social distancing." Adhering to social distancing has been particularly challenging for adolescents, for whom interaction with peers is especially important. Adolescence represents a period of rapid physical, social, cognitive, and emotional change with key implications for health and well-being into adulthood (Azzopardi et al., 2019). Some of the most notable changes relate to an increased focus on developing friendships and interacting with peers (Spear, 2000; Casey et al., 2010; Blakemore and Mills, 2014) and a reduction in time

spent with parents, also due to the development of greater autonomy and the changing nature of child–parent relationships (Larson et al., 1996; Laursen and Hartl, 2013).

Although adolescence can be a time filled with new and exciting experiences, it can also be a period of great difficulty and manifold social challenges. Experiences undergone during this period can greatly influence and shape an individual's future social interactions and overall psychosocial well-being. Established evidence indicates that the incidence of most mental health difficulties peaks during the transition from childhood to young adulthood, affecting up to 20% of adolescents (Bertha and Balázs, 2013). Furthermore, among under-25s, psychological and emotional difficulties account for almost one in two instances of health loss (Kessler et al., 2007; Gore et al., 2011). A recent survey on health and well-being in European adolescents (Inchley et al., 2020) yielded key findings: there is a general decline in mental well-being with increasing age, whereby older adolescents have lower levels of life satisfaction, are less likely to report excellent health, and suffer more frequent health problems. By age 15, girls report poorer mental well-being than boys. The prevalence of multiple health complaints has increased since 2014, with the most common concerning nervousness, irritability, and sleep difficulties. The key protection factors that emerged from the study were parents and good communication with parents and the peer group. A recent study by Campbell and Osborn (2021) drew on network analysis to examine the relationship between psychopathology (in terms of depression and anxiety symptoms) and psychological well-being (in terms of happiness, optimism, social support, perceived control, and gratitude) in adolescence. Emotional help and support from family and loved ones during adolescence seemed to be the key to coping with negative psychopathological symptoms, while low interest/pleasure emerged as a symptom influencing the relationship between well-being and psychopathology: the authors postulate that having low interest/pleasure in everyday things may lead adolescents to live a withdrawn life lacking the social support needed to improve positive well-being.

Pre-pandemic research has therefore shown that family and school connections are leading protective factors for the mental health of adolescents and young people. During the pandemic, young people experienced a general increase in stress levels in their home and school environments and in their relationships with peers and family, largely due to restrictions on freedom of movement and social isolation. In spring 2020, high school students did not have access to school premises and were invited to participate in various forms of distance learning. In many cases, the school closures continued into autumn/winter 2020 and spring/summer 2021, with adolescents being afforded variable forms of access to teaching (fully virtual, partially in-person, or – in a smaller proportion of cases – fully in-person). At the same time, adolescents' access to social support networks such as peers or relatives was significantly reduced. These changes in teenagers' living environments affected their mental health and well-being, with a general increase of post-traumatic stress, anxiety, depressive symptoms, insomnia, denial, anger, and fear, as well as grief-related symptoms (Duan et al., 2020; Guessoum et al., 2020) and a worsening of existing mental health problems (Golberstein et al., 2020). A number of studies have attempted to identify individual differences among adolescents in terms of how successfully they managed their well-being during the pandemic, for example, in relation to the tendency to use certain coping strategies. A recent study with Italian adolescents (Pigaiani et al., 2020) showed that one

in two adolescents experienced a significant deterioration in their perceived levels of well-being during the pandemic, with an increase in anxiety symptoms. The most interesting finding concerned the difference between adolescents who reported having more frequently adopted active coping strategies and identified positive aspects of the situation and those who displayed poorer self-regulation skills and suffered more acutely from isolation and living full-time with their families: the former group did not detect as great a decrease in their levels of well-being as did the latter. The ability to identify sources of stress and respond positively to them, using the available personal and environmental resources, seems therefore to be key to maintaining an acceptable level of well-being even in the face of stressful events.

Alexithymia in facing stressful events

Given that past research strongly suggests that adolescents' interactions with their peers, friends, and family can have a major impact on their psychological well-being – especially in the face of stressful events such as the recent pandemic – it is important to investigate the factors that may contribute to relationship difficulties during this vulnerable stage of life. Among such factors, the ability to effectively manage emotions is fundamental to healthy psychological and social development in adolescence. Furthermore, the issue of emotional regulation is particularly salient during this life stage, which is characterized by a generalized and temporary increase in the use of maladaptive strategies, linked partly to neuroendocrine maturation processes and partly to the transition from hetero-regulation (implemented by caregivers) to emotional self-regulation strategies (Zimmermann and Iwanski, 2014). With regard to the use of maladaptive emotion regulation strategies, alexithymia has been found to be a strong predictor: this personality construct (Sifneos, 1973) consists of difficulty in identifying and verbalizing emotions, impoverishment of the imagination, and poor symbolic thinking skills. These deficits are believed to cause an inability to regulate emotions and affect, predisposing individuals to psychological and somatic symptoms.

In the literature, alexithymia has been associated with lower perceived social support (Kojima et al., 2003; Karukivi et al., 2011), a range of mental health problems, including depression, anxiety and eating disorder symptoms (Karukivi et al., 2010a,b), psychological distress (Saikkonen et al., 2018), and poor quality of life (Mattila et al., 2009). Not surprisingly therefore, alexithymia is associated with difficulty in coping with stressful events and the chronicization of dysfunctional responses (Mavroveli et al., 2007; Fiorilli et al., 2020). Indeed, in line with the stress-alexithymia hypothesis proposed by Martin and Pihl (1985), alexithymic traits can negatively affect the ability to identify and cope with stressors. In turn, this difficulty can prolong exposure to stressful situations and favor the emergence of burnout symptoms (Lapa et al., 2017; Romano et al., 2019), including in high school students (Fiorilli et al., 2020; Farina et al., 2021). Adolescents with alexithymic traits may be more prone to incorrectly assessing or failing to identify emotionally stressful elements of problematic situations, which in turn may heighten and protract their perceptions of tension and difficulty, ultimately leading them to become emotionally exhausted (Hamaideh, 2018). Furthermore, teenagers who find it difficult to identify and manage their emotions generally express more anger, an emotion that is associated with engaging in aggressive behavior, whether physical or verbal (Sfeir et al., 2020; Pepe et al., 2023). Therefore, if we take the coronavirus

emergency to represent a source of multiple, intense stressors, it is plausible that presenting with alexithymic traits may be a strong risk factor for adolescents' well-being during this period. This is in line with recent findings reported in the literature: studies found that alexithymic traits predicted psychopathological symptoms triggered by the COVID-19 scenario (Tang et al., 2020; Merlo et al., 2021). Alexithymia was also found to significantly mediate the effects of attachment to mothers and attachment to peers on peritraumatic distress due to COVID-19 (Tambelli et al., 2021). Neurobiological studies had previously identified an association between alexithymia and the dysregulation of cortisol levels in response to stressful situations (Alkan Härtwig et al., 2013), which drives higher anxiety and depressive symptoms. Wang et al. (2021) reported a significantly higher incidence of alexithymia in adolescents suffering from depression during the pandemic. These outcomes suggest that the public health emergency has been a major source of stress, which has facilitated the development of alexithymia by negatively influencing the identification, expression, and regulation of emotions during everyday life events. In turn, personality traits or behaviors associated with alexithymia affect the physical and mental health of adolescents – especially the most fragile – reducing their capacity for social adjustment and increasing their risk of psychopathological outcomes.

Thus, it can be assumed that alexithymia is associated with poor capacities of identifying and describing both internal states and stressful external events and is plausibly one of the major risk factors for well-being in adolescence. Furthermore, subjective well-being in adolescence may be associated with better self-assessment and understanding of one's own state of health (Katja et al., 2002). It is therefore important to explore the relationships between alexithymia and adolescents' perceptions of themselves and their levels of well-being during the COVID-19 emergency. Metaphors have emerged as valuable tools in understanding the complex cognitive and emotional landscape of adolescents. Lakoff and Johnson (1980) argue that metaphors are not merely linguistic embellishments but fundamental mechanisms through which individuals conceptualize abstract concepts. The application of self-metaphors in adolescent research aligns with the cognitive development theories, emphasizing the role of metaphorical thinking in shaping cognitive processes during adolescence and is also widely used in narrative counseling (Larsen and Larsen, 2004). Therefore, the integration of self-metaphors in research methodologies offers a nuanced approach to capturing the intricate nuances of adolescent experiences, enriching our understanding of their cognitive and emotional development.

In this study, we set out to investigate adolescents' perception of themselves and their levels of well-being during the COVID-19 pandemic. More specifically, we firstly studied the association between alexithymic traits and self-perceived well-being. According to abovementioned literature, we hypothesized to find a negative association between these variables. Furthermore, we explored possible relations between well-being, alexithymia, and self-perceptions during adolescence as expressed by means of narrative metaphors. Besides assessing participants' levels of well-being by means of a validated and standardized instrument such as the WHO-5, we assumed that teenagers' use of words to describe themselves would be associated with and – at the same time – act as a good indicator of their ability to identify and describe their inner states as well as external stressful events, and ultimately reflect their state of well-being. We hypothesized that low alexithymia would be associated with high perceived well-being and positive, pro-active

narrative metaphors; on the contrary, we expected that high alexithymia and low well-being would be more strongly associated with “passive” and negative images of adolescence (for example, stressful difficulties and obstacles).

Method

Sample

The sample comprised 229 Italian adolescents attending classic and scientific high schools (e.g., in the Italian educational system this kind of school is called *lyceum*). The schools were located in a highly urbanized area, near the city center. The gender composition of the sample was evenly balanced, with 48.9% males ($n = 112$) and 48% females ($n = 110$); 7 participants (3.1%) did not state their gender. Age ranged from 14 to 19 years ($M = 16.64$, $SD = 1.46$). We adopted a convenience sampling approach (Emerson, 2015). Criteria for being included were: (1) attending high school, (2) being aged between 14 and 19 years, (3) accepting the terms of participation in the study. We set no exclusion criteria. We collected the data over a two-month period, from April to June 2021.

Procedure and materials

The research design was based on an exploratory, parallel, mixed-method approach (Teddlie and Tashakkori, 2006; Anguera et al., 2020). The primary data collection instrument was a student-centered, computer-assisted, and semi-structured web interview (CAWI; Kurniawan, 2018). The interview consisted of three main sections: (1) demographic background, (2) quantitative measures of wellbeing and alexithymia, (3) open-ended question on being an adolescent during the COVID-19 public health emergency. Each section included both closed questions (e.g., statements to be rated on Likert scales) and open-ended questions, with a view to triangulating the emergent data and cross-validating the results (Denzin, 2012). The data were collected anonymously, and all participants were fully briefed about the nature of the research. Participation in the study was on a voluntary basis, meaning that no monetary or financial rewards were offered to the participants. The study was approved by the Ethical Board of Milano-Bicocca University (prot. N. 0059806/21) and it was conducted according to the ethical principles defined by the Declaration of Helsinki (World Medical Association, 2001) and the American Psychological Association code of conduct (American Psychological Association, 2010). Given that the sample was composed of minors, we also obtained informed parental consent for all participants.

Measures

World Health Organization Well-Being Index

The five-item World Health Organization Well-Being Index (WHO-5, Staehr, 1998) is a brief, generic global rating scale measuring subjective well-being (Topp et al., 2015). The measure has been used in many different settings as a measure of positive well-being and a proxy for mental health (Jahoda, 1958). The questionnaire contains five items: (1) 'I have felt cheerful and in good spirits', (2) 'I have felt calm and relaxed', (3) 'I have felt active and vigorous', (4) 'I woke up

feeling fresh and rested' and (5) 'My daily life has been filled with things that interest me'. Participants must rate these statements on a Likert-type response scale ranging from 5 (all of the time) to 0 (none of the time). We computed raw WHO-5 scores by summing the scores for responses to individual items. Global scores ranged from 0 (absence of well-being) to 25 (maximum well-being) and we then conventionally translated them to a scale from 0 to 100. A generally accepted threshold for identifying reduced wellbeing and being at risk of developing symptoms of depression is a score of under 50 (Hoffman et al., 2012). In the present study, the reliability coefficient for the WHO-5 measure – as assessed via Cronbach's alpha (α ; Cronbach, 1951) – was 0.817.

Toronto Alexithymia Scale

The Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994; Italian validation by Bressi et al., 1996) consists of 20 items assessing three dimensions: difficulty identifying feelings (DIF; sample item: "I am often confused about what emotion I am feeling"), difficulty describing feelings (DDF; sample item: "It is difficult for me to reveal my innermost feelings even to close friends"), and externally-oriented thinking (EOT; sample item: "I prefer to analyze problems rather than just describe them"). Students are asked to express their level of agreement with each item by rating it on a 5-point Likert scale (from 1 = strongly disagree, to 5 = strongly agree). Both the original validation study (Bagby et al., 1994) and the validation study of the Italian version (Bressi et al., 1996) confirmed the three-dimensional structure of the TAS-20 but recorded better reliability for the global measure. For this reason, in the present study – as in numerous others in the literature (e.g., La Ferlita et al., 2007) – TAS-20 was used as a global unidimensional measure of alexithymia (Cronbach's $\alpha = 0.852$). Additionally, the adoption of a global score allowed us to use standard cut-off points for classification purposes. Specifically, following Bagby et al. (1994), we took a score of ≤ 50 to indicate "non-alexithymia," between 51 and 60 to indicate "borderline alexithymia," and over 61 to indicate "alexithymia."

Metaphors as qualitative research material

Language functions as both a subject and a medium in virtually all qualitative and mixed-method research approaches (Schmitt, 2005). Within such approaches, the use of metaphor is frequently seen as either a literary device or a distinctive characteristic of figurative language (Lakoff, 1986) given that metaphors can reveal and represent a participant's ideas and perceptions, as well as fulfilling a generative or catalytic function. For instance, during the data collection phase of a study by Henri and Hay (1997), metaphors were elicited as proxies for mental schema. The authors invited respondents to complete the phrase "a teacher-librarian is like..." and then describe what they had just written. Analyzing this data enabled Henri and Hay to identify the underlying images and understandings that their respondents were bringing to bear on their professions, which in turn shed light on structural and cultural impediments to librarians becoming teacher-librarians. Thus, metaphors may offer a valuable tool for depicting complex realities (Miles and Huberman, 1994), bring to light previously unnoticed aspects of phenomena (Lakoff and Johnson, 1980), and add depth of meaning to existing knowledge. In addition, the use of metaphors can help to apply established properties of familiar notions to less familiar occurrences, so that less familiar phenomena can be investigated and elucidated (Moss et al., 2003). Finally, by reducing concepts and highlighting some features over

others, metaphors can bring behaviors and processes into sharper focus (Lakoff and Johnson, 1980). In the present study, we surveyed adolescents' metaphors by asking the participants "If you had to describe using one phrase, image, or metaphor what it is like to be a girl/boy your age these days, what would you write?"

Data analysis strategy

We subjected the data from this mixed-method study to quantitative textual analysis (QTA; Bolden and Moscarola, 2000; Kelle, 2004). QTA is a branch of qualitative content analysis and assumes that (1) words that tend to appear together (i.e., in close proximity) in a given context may be interpreted as related to the same lexical theme or concept within the discourse under study (Brier and Hopp, 2011) and (2) traditional statistical techniques may be used to analyze narrative data (Miller and Riechert, 2001). We applied co-word analysis (CA, Greenacre and Blasius, 2006) to the adolescents' responses to the question "If you had to describe, using one phrase, image, or metaphor, what it is like to be a girl/boy your age these days, what would you write?" The value of using CA to analyze this type of material is that it enables researchers to represent the structure of their data by converting a set of proximity measures into visual distances corresponding to specific locations within a spatial (Cartesian coordinate system) configuration (Borg et al., 2013). The outputs of this analysis are word-based maps that help to identify recurrent themes, their relative importance, and how they are related to one another. In this study, we assessed lexical similarities within our narrative corpus in terms of the relative chi-square and Salton's cosine values (Hamers, 1989) along with their statistical significance levels (cut-off was set at $p < 0.05$). Salton's cosine allowed us to organize these relationships geometrically so that "they can be visualized as structural patterns of relations" (Wagner and Leydesdorff, 2005, p. 208).

In the context of the present study, we expected that the output of the CA would allow us to analyze the adolescents' metaphors by grouping together "naturally" occurring themes based on lexical similarity measures; we would then be able to examine how the prevalence of these themes was related to the participants' levels of well-being and alexithymia. All analyses were conducted using TLAB 5.0 and SPSS 21.0.

Data cleaning and general descriptive statistics for the text corpus

As with other data exploration techniques, QTA requires a pre-processing stage to prepare the data for analysis. In keeping with the literature, we applied *normalization* (removing all general function words such as articles, connection forms, and prepositions); *lemmatization* (reducing all inflected words to their root form as it would be found in the dictionary) and *synonymization* (words that may be considered equivalent from the semantic point of view – e.g., illness and sickness – are reduced to the same root form) to preserve the accuracy of the textual data while preparing a database for running algorithms to generate both occurrence and co-occurrence matrices (for further details about this process, see Li et al., 2000; Recchia and Louwerse, 2015; Veronese et al., 2016, 2021).

The resulting qualitative database was composed of 1,616 occurrences, 652 raw forms, and 439 hapaxes (i.e., words that occurred

once in the corpus). On adopting a threshold of at least four occurrences (text coverage 83%), root type/token ratio (an index of text richness) was 16.21, suggesting that the data were suitable for multiple correspondence analysis.

Results

Descriptive analysis and multiple correspondence analysis

The descriptive statistics for well-being scores by alexithymia group are summarized in Table 1.

An analysis of variance in the wellbeing scores of the three different cohorts of participants grouped as a function of their levels of alexithymia revealed a statistically significant difference [$F(2,227) = 18.45, p < 0.001$]. Given that the three group sizes were quite different, we performed Levine's test to assess the variances among groups. There was homogeneity of variances for scores, as supported by the test [Levene's test = 1.84, $p = .161$]. Bonferroni post-hoc analyses revealed that the group of participants characterized by possible alexithymia reported statistically significant different scores ($p < 0.001$) than the other two groups. Group differences in terms of wellbeing scores suggested that the group with possible alexithymia reported lower scores when compared with both the non-alexithymia group ($\Delta = 17.35$, 95% confidence interval = 10.09–24.61) and the not-defined group ($\Delta = 16.80$, 95% confidence interval = 6.96–26.65). The effect size, Cohen's d , for the three-group comparison was equal to .39. This outcome lent support to the idea that the group of adolescents with possible alexithymia symptoms experienced significantly lower wellbeing than the other two groups. See Figure 1 for the percentage of participants in each range of wellbeing scores.

The next step in our data analysis strategy was to explore the association between scores on WHO-5 and occurrences of the words used by the participants to describe their adolescence via narrative metaphors. The results are summarized in Figure 2.

Starting from the group characterized by lower wellbeing (green dots), the most frequently used words were: strong (forte), stressed (stressato), complicated (complicato), difficult (difficile), to understand (capire), people (persone). The group reporting medium wellbeing (light blue dots) typically made use of words such as: change (cambiamento), age (età), to feel (sentire), to lose (perdere), adulthood (adulto). Finally, the words most frequently used by the group with a high level of wellbeing (red dots) were: good (bello), to live (vivere), moment (momento) and ours (nostro).

Next, we conducted correspondence analyses with a view to producing an organized semantic space (see the Method section) that

summarized the numerical relationships between the metaphors and the two selected explanatory variables: well-being and alexithymia. The results of the co-word analysis of correspondence are graphically represented in Figure 3.

Overall, the correspondence analyses suggested a two-dimensional (eigenvalue_dim1 = 0.68 and eigenvalue_dim2 = 0.53) solution accounting for approximately 48.9% of total inertia (that is to say, the conceptual equivalent of explained variance in multivariate analysis). As shown in Figure 3, the semantic space is represented two relatively dense semantic attractors (more specifically, in the dynamics of non-linear systems, an attractor is a dense point in space at which movement may or may not take place; like a magnet, it can draw objects into its sphere of influence; Guastello, 2010). Toward the left pole of the X axis, the first semantic attractor was characterized by words such as: good ($t = 1.55$), moment ($t = 0.94$), to live ($t = 1.70$), to think ($t = 0.94$), to feel ($t = 0.95$) and alive ($t = 1.93$). In addition, this pole was associated with high levels of wellbeing (WHOGROUP_4, $t = 5.33, p < 0.01$) and low alexithymia (TASGROUP_1, $t = 8.78, p < 0.01$). This semantic profile may be interpreted as describing participants characterized by both high levels of wellbeing and low alexithymia, who were experiencing good feelings and emotions about being an adolescent during the COVID-19 pandemic. With regard to the second attractor, the opposite side of the "X" axis grouped words such as: be strong ($t = 1.39$), anxiety ($t = 1.27$), complicated ($t = 1.33$), to understand ($t = 0.72$) and people ($t = 0.70$). Furthermore, this pole was associated with low wellbeing (WHOGROUP_1, $t = 8.99, p < 0.01$) and high alexithymia (TASGROUP_3, $t = 11.38, p < 0.01$). This semantic profile seemed to include words used by adolescents with low wellbeing and high alexithymia to express negative emotion and general difficulty understanding others (or being understood).

The final stage of the analysis involved attributing a meaning to the two Cartesian axes so as to offer an overall description of the word profiles organizing the semantic space. This kind of analysis may be performed by first examining the geometric figures formed by the outermost points of the representation (see Greenacre, 2007): in the present case, a polygon whose vertices correspond to the positive and negative poles on the x-axis and y-axis. Next, the two dimensions were labeled based on the relative contributions of the different words to the various factors, as established by measuring the association between each of the root forms and its underlying semantic dimension. As in numerical principal component analyses, this was done by computing and comparing saturation coefficients – k –, which took the form of squared cosine values (i.e., a measure of association ranging between 0 and 1 that resembles a saturation coefficient, Benzecri, 1992). The first dimension, corresponding to the "X" axis, separated the high wellbeing/low alexithymia group on the left from the low wellbeing/high alexithymia group on the right side. The second dimension corresponded to the "Y" axis and featured an attractor describing negative personal feelings (negative y-axis) and, on the opposite side, positive internal states (positive y-axis). The words associated with the first dimension were: anxiety ($\cos = 0.52$), stress ($\cos = 0.33$), to live ($\cos = 0.41$), strong ($\cos = 0.34$) and difficult ($\cos = 0.23$). It seems that here the latent component drew together different negative emotions and feelings connected with the experience of being an adolescent during the pandemic. From this perspective, the axes may be interpreted as reflecting an overall representation of internal states that ranges from positive psychological experience (negative side of x-axis) to negative outcomes (positive

TABLE 1 Main statistical descriptives for wellbeing scores in relation to TAS-20 cutoff scores ($N = 229$).

	Non-alexithymia ($n = 107$)		Not-defined ($n = 37$)		Possible alexithymia $n = 85$	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
WHO-5 Scores	59.14	18.59	58.59	20.55	41.79	23.20

M = mean, *SD* = standard deviation. According to WHO, subjects scoring lower than 50 require screening for clinical depression.

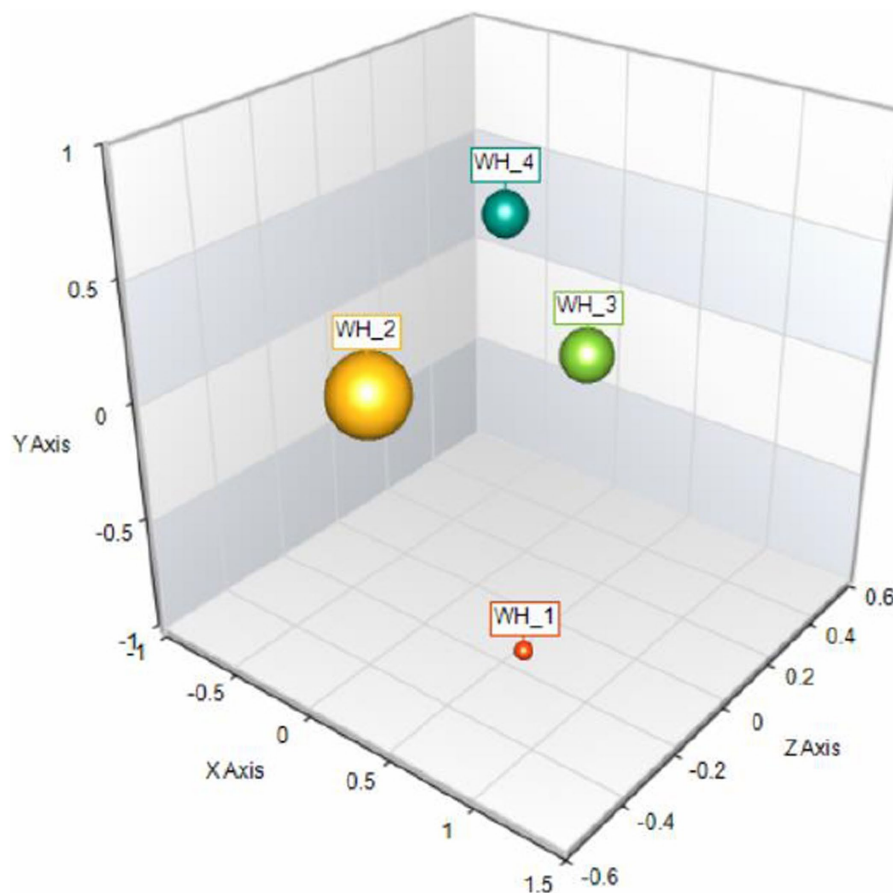


FIGURE 1

Graphical representation of percentage distribution of adolescents by WHO-5 scores: low wellbeing (red dot, < 25) 12.2%, medium-low wellbeing (yellow dot, WHO-5 between 26 and 50) = 33.6%, medium-high wellbeing (green dot, WHO-5 between 51 and 75) = 34.9% and high wellbeing (light blue dot, WHO-5 > 75) = 19.2%.

x-axis). The words associated with the second dimension were: alive ($\cos = 0.86$), freedom ($\cos = 0.84$), adolescent ($\cos = 0.75$), to feel ($\cos = 0.66$), to understand ($\cos = 0.65$) and good (0.49). A closer look at the Cartesian coordinates reveals that this second dimension divides the metaphors of those who were more “agentic” (in other words who were able to articulate a sense of control over their lives) on the positive side of Y-axis, from the words of those who were more “passive” and felt that they needed to be strong in a complicated period. Finally, in keeping with the qualitative research tradition and in order to provide a flavor of the adolescents’ words, we report representative extracts from their narrative texts in Table 2. This is a double-entry table that represents the intersections between the high vs. low well-being groups (Groups 1 and 4) and high vs. low alexithymia groups (Groups 1 and 3).

Discussion

The results of this study are generally in line with the hypotheses that we had formulated. They will be commented on below with reference to the two main objectives concerning the link between alexithymia and adolescents’ perceived well-being and the associations between these variables and their use of self-metaphors to represent themselves during the pandemic. We finally discuss on the use of

narrative metaphors as an effective method of investigating well-being in adolescents along with more standardized instruments.

Well-being and alexithymia

With regard to perceived levels of well-being among adolescents, we found that just over half of our sample reported medium-high or high levels, while 45.8% are below the cutoff score of 50 and 12.6% below the score of 25. Considering that, conventionally, scores between 30 and 50 correspond to mild depression and < 30 to moderate depression, these outcomes should make us reflect on the possible effects of the public health crisis on well-being in adolescence. This finding is in line with the existing literature, where the negative effects of the COVID-19 emergency on mental health have been extensively discussed. It is especially consistent with the results of a study in a large group of Austrian adolescents (Pieh et al., 2021), which points up, from 2018 to 2020, a decrease in the mean perceived well-being score, as measured by the WHO-5, from 43.7 to 35.8 (albeit that both of these scores invite reflection on the state of mental health in adolescence more generally). Data collected from samples of adolescents in previous years showed generally higher levels of perceived well-being (see, e.g., Strittmatter et al., 2015), suggesting that the public health crisis has likely accelerated a decline in

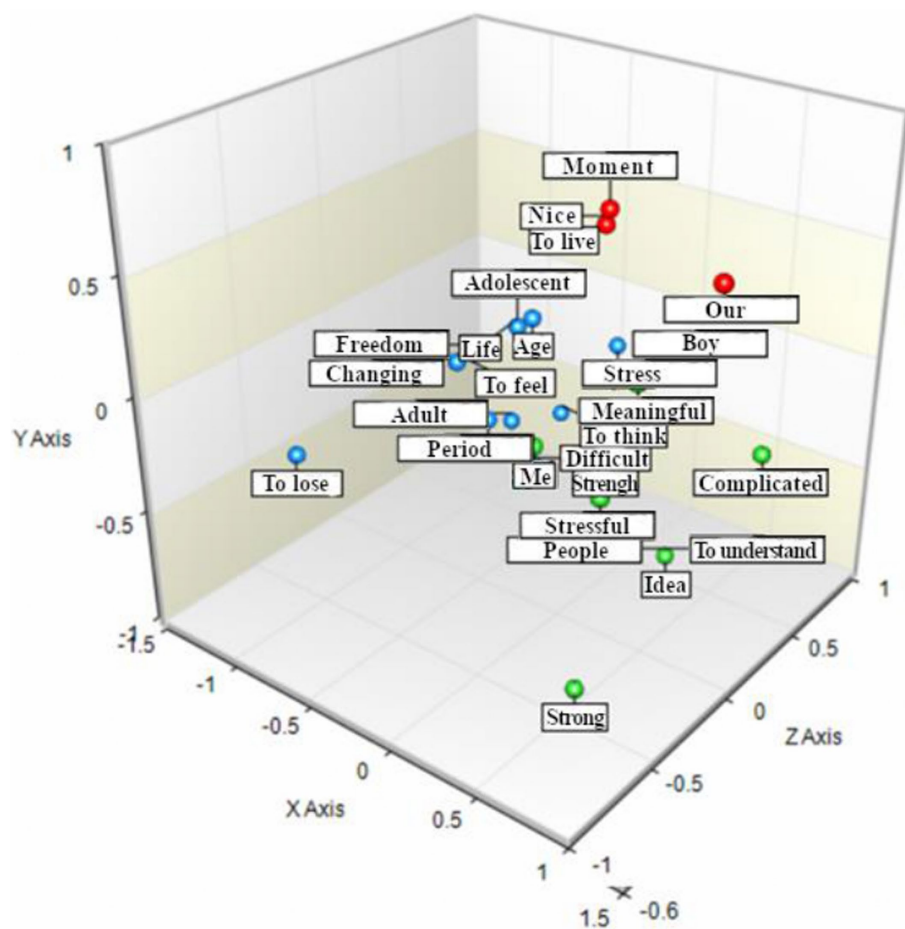


FIGURE 2
Graphical representation of the associations between words used to described adolescence and the well-being cohorts.

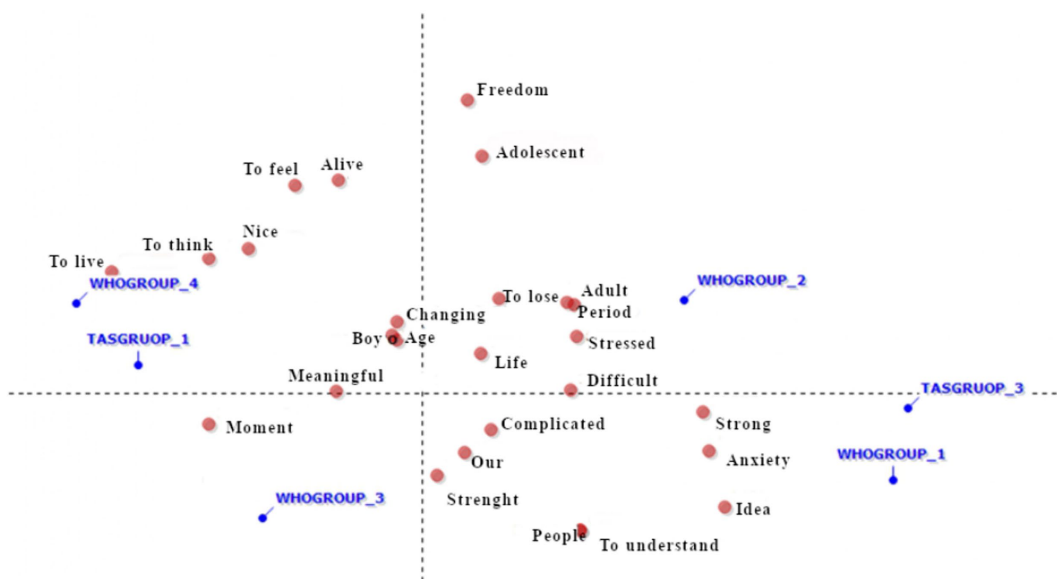


FIGURE 3
Results of multiple correspondence analysis.

TABLE 2 Selected extracts from the adolescents' texts grouped by levels of wellbeing and alexithymia.

	WHO_GROUP1	WHO_GROUP4
TAS_GROUP1	No quotes available	"life is like a tightrope, be careful jumping because it might break." (male, 14 y.o.) "an explosion of beautiful and less beautiful emotions, and a desire to return to normal life" (Female, 16 y.o.) "be the future" (Male, 17 y.o.) "a colorful explosion" (female 15 y.o.)
TAS_GROUP3	"A storm of hormones, emotions and negative thoughts in the face of uncertainty and hope for a less bleak future" (male, 16 y.o.) "To be poised on a cliff called sociality." (male, 15 y.o.) "Please help me" (female, 17 y.o.) "having the desire to experience, go out and enjoy life but at the same time the awareness that it is not always possible or not succeeding due to other causes (e.g., strict parents or lack of motivation)" (Male, 16 y.o.) "Our bodies are maturing with an emptiness inside, and that feeling will one day end with emotions inside." (Female, 17 y.o.) "It would be too complicated to explain, amongst other reasons because at this time I do not understand anything about anything anymore" (Female, 15 y.o.)	"it is not a good period" (Male, 14 y.o.), "performance anxiety mixed with fun" (Male, 17 y.o.) "there's a saying: yesterday is history, tomorrow is a mystery, but today is the present...that's why it's called the present." (Female, 16 y.o.)

WHO_GROUP4=high wellbeing, WHO_GROUP1=low wellbeing, TAS_GROUP1=no alexithymia, TAS_GROUP3=possible alexithymia. The label "no quotes available" is used because the first quadrant comprised three missing answers and two "I do not know".

adolescents' mental well-being that has been showing up in the literature for the past 7 or 8 years (Inchley et al., 2020).

Both the group of adolescents with no alexithymic traits, as assessed using TAS-20, scores and the "not defined" group (with no clear alexithymic traits) enjoyed sufficiently good levels of perceived well-being. Perceived well-being in the group of adolescents with scores above the clinical cutoff for alexithymia was significantly lower than that of the other groups, with a mean score that fell within the range that would normally require screening for depression. This result is in line with evidence that highlights the link between alexithymia and depressive symptoms (Alkan Härtwig et al., 2013; Karukivi et al., 2010a,b), a relationship that appears to have become particularly pronounced during the COVID-19 emergency (Wang et al., 2021). Moreover, this result is in line with research that emphasizes the link between alexithymia and other clinical profiles, such as eating disorders and alexithymia (Meneguzzo et al., 2022), which the covid-19 experience has further intensified, as evidenced by the increase in restrictive and compensatory behaviors during the pandemic as a dysfunctional strategy to maintain or lose weight (Meneguzzo et al., 2024). Therefore, it seems that adolescents with marked difficulty identifying and being aware of their own emotions also need to invest significant effort in attempting to identify, understand, and manage sources of stress in complex situations, such as the present pandemic scenario. In line with the stress-alexithymia hypothesis (Martin and Pihl, 1985) and with studies associating alexithymic traits with the risk of burnout (Hamaideh, 2018; Farina et al., 2021), understood as a manifestation of fatigue in alexithymic young people, so too, our results clearly showed alexithymia to be associated with low subjective well-being and the risk of developing depressive symptoms.

Metaphors of adolescence during the pandemic

The link between perceived well-being and alexithymia identified in this study is reinforced by additional insights given by the

intersection of this association with recurrent themes in narrative metaphors on adolescence, as identified via co-word analysis.

A first interesting finding concerns the association between low perceived well-being and the use of words from the semantic domain of fatigue and difficulty (e.g., "stressed," "complicated"...), while high levels of well-being are associated with terms that express qualities or positive and vital aspects of this period of life (e.g., "beautiful," "live"...). If metaphors, as proposed by Lakoff and Johnson (1980), facilitate detection of the features of a concept that people identify as most salient, our data clearly implies that high levels of perceived well-being are associated with images of adolescence that emphasize vitality, despite teenagers' peculiar life conditions at this historical moment. On the other hand, subjects whose self-perceived psychological well-being is poor, tend to emphasize the stress and difficulty associated with being adolescents. Superimposing the alexithymia cohorts on the semantic space built around the narrative metaphors suggests that subjects with alexithymic traits, together with those who display low levels of well-being, belong to a semantic area characterized by negative emotions and general passivity in coping with both these internal states and external stressors. It is plausible, again in alignment with the stress-alexithymia hypothesis, that poor emotional self-awareness and general difficulty in identifying feelings, contribute to an emphasis on fatigue, with respect to which a sense of being overwhelmed and unable to cope appears to emerge, as reflected in terms that articulate strategies of passive "resistance" to the situation ("strong," "strength") rather than an active quest for solutions. This, in turn, can understandably lead to a negative assessment of personal well-being. In contrast, the semantic space occupied by non-alexithymic adolescents with higher levels of well-being is characterized by terms that not only express positive emotions, but also greater agency ("freedom," "understand"): it is possible that a greater ability to understand emotional experience facilitates a more complex reading of the contingent situation, and the identification of both possible sources of stress and vital resources. This view could in turn enhance subjects' sense of self-efficacy in managing stressful situations,

thereby allowing satisfactory levels of personal well-being to be maintained.

Relating representative extracts from the participants' narrative metaphor texts to levels of well-being and alexithymia confirmed the above set of associations. More specifically, levels of well-being below the cutoff for screening for depression, when associated with alexithymia, seem to favor the emergence of descriptions in which confusion and the feeling of being emotionally overwhelmed prevail ("storm of hormones," "please help me"). On the other hand, when poor wellbeing is not associated with alexithymia, depressive symptoms appear to dominate: indeed, the adolescents at the intersection of these two conditions did not even answer the question or wrote that they do not know how to answer it. On the contrary, when high levels of perceived well-being are associated with alexithymic traits, the texts, although focused on the theme of difficulty, do not seem to reflect a state of being emotionally overwhelmed or particular confusion, but rather use "catch phrases" to describe the adolescent condition. Finally, strong well-being in the absence of alexithymic traits, was associated with the use of evocative images representing vitality and a positive outlook on the future.

Overall, these novel findings appear to show an interactive effect of perceived well-being and alexithymia on adolescents' ability to identify and describe their own condition. When their levels of well-being are low, adolescents seem to lack the motivation or the ability to identify an image that describes them, even if they do not display alexithymic traits: below a certain level of psychological well-being, consistently with a depression framework, the ability to identify and understand one's own feelings appears to be less important, as though feeling bad were acting to block access to resources for emotional competence. On the other hand, when low levels of well-being are associated with alexithymic traits, the emergent image of adolescence is one of feeling confused and overwhelmed by emotions that are difficult to manage. In this case, it might be plausible to assume that, on the one hand, adolescents with clear basic alexithymic traits are conditioned by them in relation to their ability to read emotional experience, leading them to emphasize fatigue. On the other hand, when depressive symptoms are present, situations of emotional stress may accentuate alexithymic traits (see Wang et al., 2021). Hence, reciprocal interdependence among these aspects appears to be reflected in the ability to provide a description of self. When perceived well-being is high, alexithymic traits appear to impact more on the ability to express and communicate one's feelings in a personalized way (as reflected in the use of catch phrases), than on the ability to identify positive and negative aspects of adolescence.

Limitations and future directions

This study, similarly to others of its kind, features several limitations that should be noted. First, the study is cross-sectional, which means that the teenagers were questioned at a point in time when the COVID-19 epidemic was still ongoing. While this was congruent with the research aims, the research design offers no information about the dynamic evolution of the phenomena under observation, either in terms of well-being or in terms of the metaphors used to characterize adolescence. A second limitation concerns the fact that the interviews were administered online. Although this approach facilitated data collection at a time when mobility constraints

and public health measures made it difficult to gather data directly in the field, it raises concerns regarding the sample's effective representativeness. The most susceptible groups of teenagers or those with educational and economic difficulties may have had restricted access to the Internet and computer technologies, affecting their ability to respond the survey. This means that caution is required in generalizing our findings to all Italian teenagers. In the future, follow-studies within this line of inquiry should be conducted with larger samples and longitudinal designs in order to gain a clearer picture of the variables studied, in terms of both the stability of the identified associations and the scope for change, especially given the fact that adolescence is a period of transition and rapid transformation in general.

Future research endeavors can explore several avenues to deepen our understanding of the interplay between the explored variables, especially in the context of ongoing societal challenges after the COVID-19 epidemic. Firstly, longitudinal studies could be employed to track changes in alexithymic traits, well-being, and metaphorical expressions over time, providing insights into the dynamic nature of these associations during the transitional period of adolescence. Additionally, investigating the impact of intervention programs aimed at enhancing emotional awareness and expression in adolescents may offer valuable insights into potential avenues for improving well-being. Furthermore, there is a critical need to extend this research to clinical populations, such as adolescents diagnosed with anxiety disorders, eating disorders, or other mental health conditions. By embracing diverse research methodologies and considering the experiences of clinical populations, future studies can contribute to the development of effective interventions that promote positive mental health outcomes in adolescents facing specific mental health challenges.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethical Committee of Milano-Bicocca University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

EF: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AP: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

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Process evaluation of PsyCovidApp, a digital tool for mobile devices aimed at protecting the mental health of healthcare professionals during the COVID-19 pandemic: a mixed method study

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Introduction: PsyCovidApp, a digital intervention aimed at safeguarding the mental health of healthcare workers during the COVID-19 pandemic, demonstrated in a randomized clinical trial to yield significant improvements solely among healthcare workers undergoing psychotherapy or receiving psychotropic medication.

Objectives: (1) To identify contextual factors and mechanisms of action that influenced the impact of PsyCovidApp during the aforementioned trial; (2) To pinpoint enhancements for optimizing its efficacy.

Materials and methods: For the first objective, a process evaluation was conducted, amalgamating quantitative techniques (surveying 216 healthcare professionals who had utilized PsyCovidApp during the trial) and qualitative methods (in-depth interviews with 16 healthcare workers). The second objective involved a panel of seven experts, utilizing the RAND-UCLA methodology.

Results: The quantitative study (response rate = 40%) revealed that 22% of respondents had not fully accessed the content of PsyCovidApp. The average usage time was 22.7 min/day, being higher ($p < 0.05$) among consumers of psychotropic medications. Contents related to relaxation and mindfulness were most highly rated. Acceptability and usefulness scores ranged between 7.3–7.5/10 points, with higher ratings ($p < 0.05$) among women and older healthcare workers. The qualitative study uncovered that the primary barriers to using PsyCovidApp were workload, lack of time, and exhaustion. Its primary mechanisms of action included emotion identification, mental health regulation (e.g., insomnia, intense emotions), and learning of techniques and skills. The expert panel reached a consensus on 29 proposals to optimize PsyCovidApp.

Conclusion: The knowledge derived from this study could inform the design and implementation of future similar digital tools.

KEYWORDS

mixed methods, COVID-19, process evaluation, digital intervention, healthcare workers, mental health

Introduction

The healthcare crisis caused by the COVID-19 pandemic that began in 2020 caused an unprecedented increase in mental health issues among the healthcare professionals tasked with handling the crisis (Li et al., 2021; Canal-Rivero et al., 2023; Cruz-Ausejo et al., 2023), with high rates of acute stress (40%), anxiety (30%), burnout (28%), depression (24%), and PTSD (13%) (Serrano-Ripoll et al., 2020; Walton et al., 2020; Chirico et al., 2021; Saragih et al., 2021). Other long-term studies have also found a worsening of mental health 1 year after the pandemic (Viejo Casas et al., 2023).

In addressing the urgent need to identify effective resources that can be given to healthcare services to combat this problem, many systematic reviews highlight the lack of scientific evidence on the effectiveness of the interventions that were available up to that time, specifically designed for this population and context (Muller et al., 2020; Serrano-Ripoll et al., 2020; Drissi et al., 2021; Viejo Casas et al., 2023).

In June 2020, a team of psychologists and psychiatrists developed a digital intervention, in the form of a mobile phone app, called PsyCovidApp, designed expressly to safeguard the mental wellbeing of healthcare professionals with respect to the COVID-19 pandemic. PsyCovidApp takes a psycho-educational approach using cognitive-behavioral psychology (with content on handling emotions, lifestyle choice, workplace stress, burnout, and social support) and mindfulness. It also includes many practical tools (Serrano-Ripoll et al., 2021).

PsyCovidApp was studied in a randomized clinical trial (RCT) that started in June 2020. In total, 482 healthcare workers participated, the majority from around Spain's Autonomous Communities (Fiol-DeRoque et al., 2021). After 2 weeks of follow-up, PsyCovidApp was not shown to significantly improve the overall mental health of participants. However, subgroup analyses do suggest significant improvements among healthcare professionals who took psychotropic medication or were receiving psychotherapy (Fiol-DeRoque et al., 2021). Upon completion of the RCT, 92% of participants (control and test groups) requested to have permanent access to PsyCovidApp, which suggests it has a high acceptance rate.

As has been suggested in previous systematic reviews (Kate et al., 2022; Delassalle and Cavaciuti, 2023), due to the scarcity of scientific evidence that exists on digital tools for handling mental wellbeing in healthcare professionals during pandemics (Witarto et al., 2022; Delassalle and Cavaciuti, 2023), we must look beyond the quantitative results of clinical trials and probe into the circumstances and mechanisms through which this kind of intervention does and does not produce its desired benefit. The objectives of the present study are as follows: first, to determine the impact of contextual factors, factors related to implementation, and the mechanisms of action that

determine the effectiveness of PsyCovidApp, and second, to identify key aspects that can be included in PsyCovidApp to optimize its potential as a psychological support tool for healthcare workers facing similar crises in the future.

Materials and methods

Framework of reference

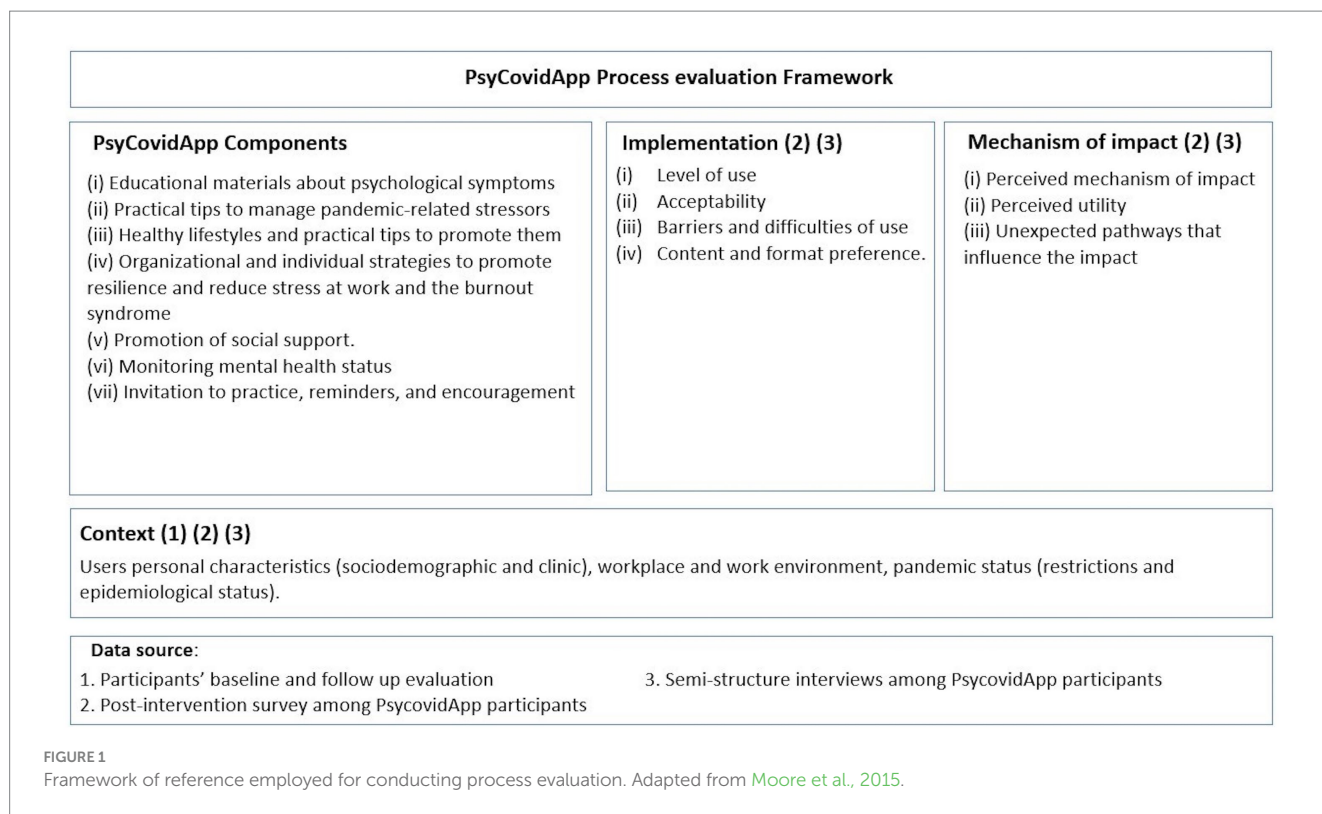
For our first objective, we carried out a process evaluation, following the guidelines of the Medical Research Council (Moore et al., 2015). This evaluation focused on three aspects: the context in which it took place, the form in which it was implemented, and the mechanisms through which the desired impacts were achieved (Figure 1). In carrying out the process evaluation, we took a mixed methods approach (Doyle et al., 2016), combining both quantitative and qualitative research techniques.

Process evaluation of PsyCovidApp with quantitative techniques

We developed an *ad hoc* questionnaire (available in Appendix A) to gather information on participants' experiences and use of PsyCovidApp during the RCT, i.e., usage of the tool over the 2 weeks of the RCT (7 items), usage of the tool after finishing the RCT (2 items), making use of the content on PsyCovidApp (15 items), and acceptability and perceived utility of PsyCovidApp (4 items). Sociodemographic, work-related, and clinical data were also gathered from participants.

All participants in the test group who authorized us to contact them regarding study updates once the RCT was finished were invited to complete an online questionnaire ($n=216/248$), but the 234 participants from the control group were not invited, as they did not have access to PsyCovidApp during the RCT. After the first invitation, two reminders were sent. Responses to the questionnaires were recorded between December 22, 2020, and January 27, 2021 (6 months after the RCT was completed).

We performed a descriptive statistical analysis, calculating the number and percentage of participants in each category for the categorical variables, as well as the average and standard deviation for continuous variables. The differences between groups were analyzed by Chi-squared test for categorical variables and a comparison of means for continuous variables. We used parametric and non-parametric tests depending on the type of data. We analyzed the differences in scores on the questionnaire as a function of



participant profile (age, sex, professional category, use of psychoactive medications, participation in psychotherapy, and changes on scales of depression, anxiety, and stress).

interviewers critically assessed their own role and the objective of the study so as to not influence the participants' responses.

Process evaluation of PsyCovidApp with qualitative techniques

We carried out a qualitative study using in-depth individual interviews to understand in detail the experiences of the professionals who used PsyCovidApp, exploring many possible barriers, suggesting improvements, and discussing the context in which it is used. We deliberately selected our sample to ensure representativeness among participants in terms of age, sex, professional category, how much they used the intervention, and whether or not they took medication and/or received psychotherapy. Interviews were performed over the telephone in January 2021, and they were recorded and transcribed. Five interviewers participated (MJS, GPM, EG, MEG, and CS); all of them have previous experience with qualitative methods. We made sure we performed the number of interviews required to answer our research question and ensure we had robust data. We created a topic guide (Box 1), which was agreed upon by the team of interviewers. The whole group met as a team and in pairs to train and standardize the interviews. Transcripts were analyzed using thematic analyses (Braun and Clarke, 2006), first individually, and then in pairs, for added rigor and to ensure that the data was seen from various perspectives. We used a topic guide as the departure point and then took an inductive approach to be able to identify emerging topics. One researcher (MJS) created an overview of the results, which was reviewed and validated by the rest of the team. The

Panels of experts for optimizing PsyCovidApp

For our second objective (to identify possible points of improvement for optimizing the impact of PsyCovidApp), we consulted a panel of experts, which was put together following the RAND-UCLA methodology (Fitch et al., 2001). A total of seven experts with multidisciplinary backgrounds were recruited, including specialists in mental health, lifestyle, digital health, and app design. Before participating on the panel, they received information on PsyCovidApp (i.e., the scientific article on the results of the RCT (Fiol-DeRoque et al., 2021), and the overview of the quantitative and qualitative process evaluation).

We performed two rounds of queries, both digital, via online questionnaires. In the first round, all possible improvements along with their rationale were presented, and the panel was asked to classify these suggestions into the preestablished categories posed by the team of researchers, though they were allowed to add additional categories if necessary. The suggestions received were then compiled, recategorized, and duplicates were eliminated. The second round involved asking the panel to individually assess the suggestions, independent of all others. The panel then considered the suggestions from two points of view: perceived usefulness (Up to what point is it likely that this suggestion will significantly improve PsyCovidApp?) and feasibility (Up to what point is it feasible to carry out this measure?). Both aspects were evaluated on a visual, analog scale from 1 to 9.

BOX 1: Topic guide used for individual qualitative interviews conducted as part of the process evaluation.

Acceptability, utility, usage, and difficulties encountered

- Overall Impression: Broadly speaking, can you tell me about your experience participating in this project?
- Scope of the Intervention: How was accessing the intervention for you (how easy or difficult did you find it)? Were you able to access the intervention via your mobile phone? Describe the process...
- Dosage (Extent of Usage): Do you recall how frequently you used it? (a lot, quite a bit, sparingly, daily, whenever possible...). Share your usage experience.
- Timing/Context: Do you remember at what times of day it was better or more favorable for you to access the App? In what context did you use the application (home, work, etc.)?
- Action Mechanisms: To what extent has this App been useful in caring for your mental health during this pandemic period? If it has been useful, how do you think the App has aided you?
- Preferences: Which contents did you like the most? Which ones are the least?
- Usability: How easy or difficult did you find the App to use?
- Utility: How useful have you found the contents?
- Level of Acquired Knowledge: How much do you think you have learned from these contents?
- Behavioral Changes: To what extent have you applied what you have learned in your day-to-day life?
- Regarding Timely Messages: What can you tell us about their frequency, relevance, content, etc.?

Barriers

- What barriers do you think people might face in using the App?

Suggestions for improvement

- Did you feel anything was missing in the contents? Is there any content you would eliminate or reinforce (e.g., audiovisual vs. text, for instance)?
- What do you think we could improve to make this App more useful?
- What do you think we could enhance to make this App more appealing?
- What do you think we could improve to make this App easier to use?
- Would you suggest any improvements for the intervention for widespread, large-scale usage?

For each suggestion for improvement, we determined its level of pertinence and appropriateness and the level of agreement reached among the experts. Pertinence and appropriateness were classified as follows: pertinent/appropriate (unanimously ranked 7–9), unclear (with a median of 4–6, or any disagreement), or not pertinent/inappropriate (unanimously ranked 1–3). We assessed agreement among the experts individually for each of the suggested improvements, considering there to be a consensus if 90% of the experts ranked the suggestion in the same range (1–3, 4–6, and 7–9) (Fitch et al., 2001).

Results

Process evaluation

Quantitative analysis

Of the 216 healthcare professionals invited to complete the online questionnaire, 87 responded (a response rate of 40.3%). This sample was representative of the participants in the RCT intervention group, with no statistically significant differences in any of the clinical or sociodemographic variables reported (Appendix B), except for age (the group of participants in the RCT was significantly younger).

Of the 87 healthcare professionals who participated, 89.7% were women ($n=78$) with an average age of 45.4 years old (SD: 10.1 years) and an average professional career of 19.2 years (SD: 8.8). By professional category, 35.6% ($n=31$) were nursing assistants, 33.3% ($n=26$) were doctors, and 29.9% ($n=26$) were registered nurses.

Regarding their clinical profiles (established during the base assessment of the RCT), 18.4% ($n=16$) of the healthcare professionals claimed to take psychoactive medications, and 9.2% ($n=8$) received psychotherapy before participating in the RCT. The average score on the DASS-21 scale was 6/21 (SD: 4.0).

Most of those interviewed (85%, $n=74$) stated that they had no technical issues when accessing PsyCovidApp, and 78% ($n=65$) claimed to have accessed all the content on the app (Table 1). The average age [SD] of the participants that accessed all the content was greater than the average age of those who left some modules unseen ($p=0.006$): 46.96 [9.45] versus 39.27 [9.97] years old, respectively.

Around half (46.7%) of the people who claimed that they had not accessed all the content gave reasons that include a lack of time, a lack of interest, and a lack of relevance (as they already had previous knowledge in the area).

Regarding the amount of time, they used PsyCovidApp during the RCT (Appendix C), 47% stated they used the app more than 4 days a week during the 2 weeks of the trial, with slightly more use during the first week, 65.5% ($n=57$), than during the second week, 49.4% ($n=43$). The time that participants dedicated to using the app was 22.7 min/day (SD: 20.6; median: 15, IQR: 10–30). Regarding total access time over the week, on average, participants spent 5.66 h/week on the app (SD: 4.85; median: 15, IQR: 10–30). Additionally, those that took psychotropic medication showed a higher average usage time ($p<0.05$) than the rest of the participants (24.4 versus 22.3 min).

About the four dimensions assessed for acceptability and perceived utility of PsyCovidApp, average scores oscillated between 7.32 and 7.49 points out of 10 (Table 2).

TABLE 1 PsyCovidApp usage by healthcare professionals assigned to the intervention group of the randomized clinical trial.

	N (total = 87)	%
Technical issues in accessing PsyCovidApp		
No	74	85.06
Yes	8	9.20
I do not know/I do not remember	5	5.75
Access to all content		
Yes	68	78.16
No	15	17.24
I do not know/I do not remember	4	4.60
Reasons for not accessing all content (N = 15)*		
Lack of time	7	46.67
Lack of interest	7	46.67
Previous knowledge on the topic	7	46.67
Content deemed irrelevant	4	26.67
Access problems with the App	1	6.67
Others	1	6.67
PsyCovidApp use first week		
1 day	4	4.60
2–3 days	19	21.84
4–6 days	34	39.08
All 7 days a week	23	26.44
Did not access at all	3	3.45
I do not know/I do not remember	4	4.60
PsyCovidApp use second week		
1 day	8	9.20
2–3 days	23	26.44
4–6 days	28	32.18
All 7 days a week	15	17.24
Did not access at all	5	5.75
I do not know/I do not remember	8	9.20
Daily use of PsyCovidApp (minutes)		
Mean (SD)	22.7 (20.6)	
Median (IQR; range)	15 (10–30; 0–120)	
0 min	2	2.30
1 to 5 min	11	12.64
6 to 15 min	33	37.93
16 to 30 min	31	35.63
31 to 60 min	3	3.45
> 60 min	7	8.05
Weekly use of PsyCovidApp (hours)		
Mean (SD)	5.66 (4.85)	
Median (IQR; range)	4 (2–8; 0–24)	
0	2	2.30
1–2	23	26.44
3–5	23	26.44
6–10	23	26.44
> 10	8	9.20
NA	8	9.20

IQR, interquartile range; N, number of participants; SD, standard deviation. *non-exclusive responses.

TABLE 2 Assessment of Acceptability and Perceived Utility of PsyCovidApp. The data represent the average score (SD) of the four scales (theoretical range between 1 and 9 points in all of them); *p* = level of statistical significance.

	Appropriate tool	Quantity of information	Utility of the tool	Likelihood to recommend PsyCovidApp
Sex	<i>p</i> = 0.190	<i>p</i> = 0.006	<i>p</i> = 0.217	<i>p</i> = 0.174
Man (<i>n</i> = 9)	6.33 (2.55)	5.78 (2.59)	6.22 (2.91)	6.44 (2.74)
Women (<i>n</i> = 78)	7.43 (2.17)	7.95 (1.88)	7.46 (2.28)	7.61 (2.34)
Age	<i>p</i> = 0.019	<i>p</i> = 0.005	<i>p</i> = 0.012	<i>p</i> = 0.008
<36 years (<i>N</i> = 17)	5.88 (2.91)	6.47 (2.45)	5.88 (3.18)	5.88 (3.20)
36–45 years (<i>N</i> = 25)	7.60 (1.96)	7.72 (2.11)	7.44 (2.18)	7.56 (2.16)
46–55 years (<i>N</i> = 29)	7.38 (1.86)	7.62 (1.88)	7.45 (1.78)	7.66 (1.84)
>55 years (<i>N</i> = 29)	8.31 (1.71)	9.06 (0.93)	8.5 (1.93)	8.81 (1.80)
Total (<i>n</i> = 87)	7.32 (2.22)	7.72 (2.06)	7.33 (2.36)	7.49 (2.39)

When analyzing the assessments made by participants broken down by profile, we see certain differences related to sex and age. Women scored the quantity of information contained on PsyCovidApp higher than men, and older participants gave higher scores on metrics concerning the appropriateness of the tool, the quantity of information, the usefulness of the tool, and the probability of recommending PsyCovidApp. No differences were noted with regard to professional category, taking psychoactive medications, participating in psychotherapy, or a change in DASS-21 score (data not shown).

Qualitative analysis

Sixteen women and three men were interviewed (six nurses, six doctors, and seven nursing assistants from different fields), aged between 29 and 61 years old. In [Box 2](#) we show selected illustrative quotes in text form.

Regarding the perceived acceptability and usefulness of PsyCovidApp, participants accepted and positively evaluated the tool, which was perceived to be useful considering the critical situation that was playing out, which itself was marked by excessive work, exhaustion, and stress. Participants highlighted the usefulness of the tool in raising awareness of their own psychological state. For some participants, PsyCovidApp served as an adjuvant to psychoactive medication or psychotherapy, while others, though not receiving treatment, found the app to be a support, helping them to sleep better, for example. A minority of users rated the tool not useful, finding the resources provided to be too basic.

The main barrier to the use of PsyCovidApp was a lack of time. PsyCovidApp was used mainly outside of the workplace, given the difficulty professionals had in using it at work (because of personal protective equipment and an excessive workload). The process of downloading and using the app was perceived to be simple. Some participants expressed that the organization of the contents into hierarchical modules and submodules made it more difficult to use.

Daily notifications were perceived to be useful for reminding participants to keep using PsyCovidApp. However, some users

suggested that being able to define the time of the notification would be helpful, as they were notified too early, and subsequently forgot to use the app, making the notification useless. The contents that were most well-received were those related to breathing, relaxation, and meditation, as well as tools to deal with sleep problems. On the other hand, contents on healthy lifestyles were less attractive, and they were found not to provide new information or practices. In general, participants felt that they acquired practical abilities (e.g., around half of the participants stated that they learned something and had made use of suggested relaxation techniques), but that they got less theoretical knowledge.

Suggestions were made to improve the tool's level of personalization and interaction. It was also suggested that the app provide some of the content in greater depth and offer final self-assessment questions. Another suggestion involved being able to receive feedback on the user's mental health or having professional assistance available at some point (e.g., via chat). Another suggestion was to improve the look and design of the app and incorporate some gamification.

Expert panel

A panel consisting of seven experts (see acknowledgments) actively participated in two rounds of identifying and prioritizing improvement proposals. In the first round (identification), a total of 57 proposals were made ([Appendix D](#)). In the second round (prioritization), 29 (51%) of these proposals were agreed upon as highly useful and feasible. These proposals are shown in [Box 3](#). Of the remaining proposals, nine (16%) were perceived as useful but not feasible, 13 (23%) as feasible but not useful, and six (11%) were considered neither useful nor feasible.

Discussion

With our process evaluation we are able to provide more in-depth knowledge on the contextual factors, implementation factors, and action mechanisms that determined the effectiveness of PsyCovidApp. Despite the app being considered a useful and

BOX 2: Examples of verbatim quotes from healthcare professionals (n=16) who participated in the qualitative interviews.**(1) General acceptance of the app**

"It seemed very interesting to me, and I found it very helpful. It really opened up for me... Many times, we have information, I do not know how to explain it, that we, as healthcare professionals, do not apply to ourselves. I mean, we know what anxiety is, we know what stress is, but sometimes, we put it aside in our minds. It was very good to remember things, to recall anxiety, to remember the symptoms of seeing them in myself and be able to act upon them. It was very beneficial for me, very beneficial." (woman, 46 years old, pediatric nurse)

(2) App utility

"Yes, it was very helpful for me. It was great for me. I do not know if maybe, at that moment, I was alone, and it helped me see things in a different way, I do not know, but it really helped me a lot... I think, to make me stronger, for example, to know how to get out of situations. A bit more like that because there are times when I say, I see people who are worse off than me. Because with everything going on, I do not even know how we are managing to cope." (woman, 40 years old, healthcare assistant in polyvalent care)

(3) App usage (dose-response)

"When I received your notifications. The app would send you a notification for one reason or another, and then I would use it. If there was no notification, I would not use it. Always in the morning, first thing." (man, 60 years old, hospital doctor)

(4) Barriers and difficulties encountered in using the app

"One would be what I told you, that we always have time for other things except for taking care of ourselves. This could be one, I mean, it's hard for us. Like I said before: 'I know what I have to do. I do not do it, but I know that...' This would be one. Yes, because, besides, you know what happens? We are under a lot of tension, we really need it, but since we are so overwhelmed, when we leave here, we dedicate a little time to the family and then to other things we have to do, and then you say, 'Well, I'll do it tomorrow.' I think this would be one thing. I could not tell you more." (woman, 61 years old, primary care doctor)

(5) Content preferences

"The ones I liked the most were the calming topics, those were about breathing, exercises... I do not remember very well what that section was called, but there were breathing exercises, concentration exercises, relaxation. Those exercises are what I liked the most." (man, 55 years old, internal medicine doctor)

(6) Level of knowledge acquired and/or applied

"Well, I've learned, I think I would say, I do not know how to explain it. I have not learned to make life different, I've learned more to live with myself. I do not know if this explains it. [...] From zero to 10, I would say I've learned? A 9. Because in that period of March, April, May, or June when this caught us by surprise, there were moments when I felt a bit lost. I did not even know how to face it but how to assimilate certain things that were new and yes, in those months, it was good." (woman, 61 years old, healthcare assistant in Internal Medicine)

(7) Temporal messages (frequency, relevance, content, etc.)

"For me, yes, because it was like forcing myself a bit. The reminder would arrive, and I'd say: 'Okay, I'll take a look.' For me, it was an important part at that moment when you had 8,500 things in your head, and it was like a really good moment in the morning because, I tell you, it coincided more or less with the time I was having breakfast, and it suited me." (woman, 41 years old, care assistant in a care center)

(8) Improvement suggestions

"No, improve? I think it's very good. There are always things, but if I were to review everything and analyze it, this yes, but right now, nothing comes to mind... It's very well expressed, the contents are very good, and all that I've worked on, I truly find it very good, it's adapted and very good." (woman, 51 years old, assistant in an Infectious Diseases Unit)

(9) Formats

"I liked the audiovisuals. In fact, I think it was part of what I also used at night. Now it's been a few days since I used them, but I remember they were like this because just listening to the voice always relaxes a lot. Yes, the fact that they were explaining it and as I did it at night, it also rested my eyes. That format, I liked it, very well." (woman, 46 years old, primary care doctor)

BOX 3: Suggested improvements for PsyCovidApp with a high level of consensus on their utility and feasibility.**Utility**

- Add a podcast format for the same written text
- Deepen the techniques and strategies aimed at protecting the mental health of healthcare professionals
- Prioritize the App's functions concerning the primary need it aims to address

Attractiveness

- Improve visual aspects. The UI (User Interface) involves neuroscience: Use more vibrant colors, rounded buttons, calls to action, enriching images, highlighted texts
- Ability to change font size
- Summary of completed sections or modules
- Add (unlock) contents based on the completion of objectives/themes
- The information is very theoretical, alter the language used. The positive aspect is that it can be applied by professionals in their routine clinical practice with other users

Easy of use

- Provide a content outline
- Enable access to modules directly from the content guide
- Modify the navigation with "BACK and NEXT" buttons to direct buttons. Add an easily accessible exit to the main menu without alarmist indications, but more user-friendly and empathetic
- Direct attention and facilitate decision-making
- Modify multimedia content or the system so that (1) the mobile device does not lock after a few seconds; (2) multimedia content (e.g., audio recordings) continues to play
- Add a reminder system or mode for the last completed module/section/theme; have a view from the index showing how many steps are yet to be seen or have been seen in each module. For example: Mark different modules already consulted with a different color/tonality
- Reduce the amount of information and redesign UI (User Interface) pages to make functionality more user-friendly and to better connect with users

Widespread large scale use

- Adapt content to a "non-COVID" context
- Specify where individuals can seek help (mental health/physical activity/nutrition)
- Resilience is explained in one of the modules but appears in the module introduction as if it were a well-known concept

Adding contents

- Offer different difficulty levels: create modules on the same topic but with more advanced content
- Include some simpler content, especially in emotional regulation
- Possibility to include some scales (anxiety, Maslach Burnout Inventory...)
- Add self-assessment forms or systems
- Add explanations or clarification for some technical terms used. For example: verborhea
- In modules like possible stress reactions, it might be interesting for the user to mark the identified reactions as a self-awareness process
- Add a module on pain
- Add notifications at specific times of the day

Removing contents

- Modules M2.1 and M2.2 seem somewhat redundant, perhaps consolidating them into one
- Remove and update invalid links (e.g., the link from the Ministry of Health, Consumption, and Social Welfare in module 2.2 of section 11/13 in "Practical ideas for physical exercise")

Feedback

- Automatic (and if possible, personalized) feedback

acceptable tool, its level of use varied, and was higher among healthcare professionals who were already taking psychotropic medications or receiving psychotherapy. The main obstacles to implementation were based on the individual and the context, e.g., being overworked, lacking time, or being exhausted. The main action mechanisms that contributed to improving mental health were related to aiding a participant in identifying his/her own emotions, regulating different aspects of mental health (specifically insomnia and having intense emotions), and promoting the learning of abilities and techniques (e.g., relaxation and mindfulness). The panel of experts identified 29 suggestions about which a high level of consensus on their feasibility and usefulness in optimizing the beneficial effects of PsyCovidApp.

Strengths and limitations

The main strength of this study is its use of mixed methods, which has allowed us to obtain data from various sources and analyze them using a variety of methodologies. An important strength of the qualitative study is that it complies with all the main criteria of methodological rigor: credibility, reliability, transferability, and confirmability (Steinke, 2004).

Our study is not free from limitations. First, although we invited all the participants of the test group from the RCT to complete the quantitative questionnaire, the response rate was 40%. Although we do not see any significant differences in the clinical or sociodemographic characteristics of participants and non-participants, it is possible that those who participated were specifically those who had a more favorable experience with or opinion of PsyCovidApp. This possible participation bias could mean that we are overcounting the high ratings we found for perceived appropriateness and usefulness. Secondly, information on the use of the application and the contents that were consulted was gathered 6 months after the RCT was completed. Although most (92%) participants requested to have PsyCovidApp reactivated so that they could continue to use it after the RCT, we cannot discard the possibility that recall bias may have affected their answers. Finally, it is worth noting that our evaluation of the implementation of PsyCovidApp is limited by the fact that it was not possible to collect actual usage data from the application during the RCT. Thus, usage data is based on self-referenced information provided by the participants themselves.

Our results compared to previous literature

As suggested in a recent systematic review, the scientific evidence on digital interventions aimed at protecting the mental health of healthcare professionals that were on the front lines of the COVID-19 pandemic is scarce, due largely to the scant number of studies that have been carried out (Drissi et al., 2021). There is a greater amount of evidence on digital interventions aimed at improving mental health for the general population during the COVID-19 pandemic (Witarto et al., 2022; Ye et al., 2022). Findings from these studies suggest that such interventions could potentially be effective at improving symptoms of anxiety, depression, stress, and insomnia during a pandemic. Although there is evidence available to suggest that interventions like PsyCovidApp-based on cognitive-behavioral therapy and mindfulness—are effective, adherence and level of use tend

to be lower in digital interventions than interventions led by a professional, which conditions the overall effectiveness of these kinds of interventions.

The quantitative assessment of our process evaluation revealed a greater level of use of PsyCovidApp among participants who were taking psychoactive medications, while the RCT showed mental health improvements in the subgroup of those taking such medications or those receiving psychotherapy (Fiol-DeRoque et al., 2021). This could be indicative of a dose–response effect. However, it might also suggest a greater effectiveness of the app among people with more serious mental health problems, which would be in line with the results of a recent meta-analysis (Serrano-Ripoll et al., 2022) suggesting that mental health apps are more effective in patients with more serious conditions.

Our results are consistent with those presented in a recent systematic review, which identified four factors that determine the continued use of digital tools for dealing with mental health: app personalization, the use of reminders, a “friendly” design and being technically stable (making them easier to use), and complementary support from a person (Jakob et al., 2022). These four factors were identified both in the results of our qualitative study as well as by the panel of experts.

Being able to combine PsyCovidApp with personal psychological support was identified as beneficial both in the qualitative interviews and by the panel of experts. To this end, similar support can be found in a recent systematic review, which concludes that including the support of a mental health professional improves the effectiveness of and adherence to mobile phone apps designed to improve mental health (Szinay et al., 2020).

With regard to daily notifications, previous studies have provided evidence that these reminders can have a negative effect if they are received at times or places where the use of such apps would be inappropriate, as they deal with sensitive or stigmatized topics, i.e., mental health (Szinay et al., 2020). Being able to personalize the notifications by defining a timetable and frequency could help improve the level of use of PsyCovidApp by healthcare professionals.

Relevance of the results to clinical practice and research

The results of our study provide valuable information for the design, development, and implementation of future applications destined to provide mental health support to healthcare professionals facing crises, in addition to applications destined to provide general mental health support and support for other chronic diseases.

Our results reveal the need for healthcare professionals to have time to access the resources offered to them to improve their mental health. Simply offering the tools is not enough. Rather, there must be a workplace environment that allows them to make use of the tools as part of their job.

Conclusion

Our study of a process evaluation has allowed us to create information on the acceptability, level of use, mechanisms of impact, and context of the PsyCovidApp intervention. The results obtained,

along with the 29 suggestions identified by the panel of experts, represent new scientific evidence upon which to base future efforts aimed at optimizing the implementation and effectiveness of PsyCovidApp, and upon which to structure the design and development of new tools.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Research Ethics Committee of the Balearic Islands (IB 4216/20). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MF-R: Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. MS-R: Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. SM-M: Formal analysis, Methodology, Writing – original draft, Writing – review & editing. GP-M: Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. CS: Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. MG-B: Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. EG: Formal analysis, Validation, Writing – original draft, Writing – review & editing. MG-T: Funding acquisition, Resources, Visualization, Writing – original draft, Writing – review & editing. RZ-C: Project administration, Validation, Writing – original draft, Writing – review & editing. IR-C: Conceptualization, Funding acquisition, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Application of indirect observation within mixed methods to contrast the results obtained through direct observation: a discussion with observed Pikler educators

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Introduction: This work arises from a previous research, “Pikler educators early in the morning” carried out in the Emmi Pikler Nursery School in Budapest through Systematic Observation. In it, Piklerian choreographies were found in observed educators’ behavior during the studied three daily activities: feeding breakfast, dressing to go to the garden and free play accompanying. All of them share certain Piklerian principles, which are synthesized in three central keys: the stability of the educator’s behavior, her strategic and intentional positioning, and an active emotional control.

Objectives: This study aims to contrast this synthesis of results by means of an in-depth interview with the two observed educators, and to apply the methodological approach of indirect observation within mixed methods for its analysis. The objective is to confirm whether the three central keys are recognized as their own and to look for new theoretical-practical elements within the studied educational approach.

Materials and methods: We applied an in-depth interview and analyzed it following the guidelines of indirect observation. The participants were the two educators previously observed, a translator from the Pikler team, and the three observers, authors of this work. An *ad hoc* observation instrument was elaborated, and the three macro-stages QUAL-QUAL-QUAL proposed within mixed methods were rigorously followed.

Results: Lag sequential analysis was used to conduct data analyses. We deepened in prospective lags and obtained the response pattern underlying the interview. Then, we performed a concurrence analysis to investigate the relationship between the central keys obtained in our original research and Piklerian ideas.

Conclusion: In-depth interview within mixed methods has been a novel and generous tool leading us to substantial and methodological contributions, despite the simplicity of performed analyses. Interviewed educators’ response pattern is a faithful reflection of the Piklerian *modus operandi*. The study of concurrences shows that Piklerian education is something natural, integrated in its professionals, with the exception of emotional control, which still requires permanent reflection.

KEYWORDS

early education, mixed methods, indirect observation, in-depth interview, Pikler-Lóczy educational approach

1 Introduction

The baseline of the present paper are the results obtained in the research “Pikler educators early in the morning” (Belza, 2020; Belasko, 2023; Sagastui, 2023) in which Observational Methodology (OM) (Anguera, 1979) was applied to study daily interactive routines at the Emmi Pikler Nursery School in Budapest. Specifically, the aforementioned research focused on everything that happened in the studied educational center during the morning, so educators’ four distinct activities were identified and investigated: feeding breakfast, changing diapers, dressing children to play outside and accompanying their free play. The study of educators’ behavior both in body cares (Belza, 2020; Belasko, 2023) and while they accompanied children’s autonomous activity and free play (Sagastui, 2023) led to valuable conclusions about quality early education. This was possible thanks to the perfect fit between the studied educational approach and the characteristics of OM (Anguera, 2003), a methodology within mixed methods. Now, we intend to go one step further and reaffirm the obtained results, in this case, by using indirect observation; more specifically, by conducting an in-depth interview with the experienced educators observed in the original research.

Pikler-Lóczy education is an early and quality educational approach that emerged in Budapest in 1946, when pediatrician Emmi Pikler and her team took over a foster home in Lóczy street, from which it took its former name: Lóczy Institute or Lóczy foster home (Falk, 2018c). Since then and up to the present day, this center has changed its name multiple times —Methodological and Pedagogical Institute for the Care of Babies and Young Children, Emmi Pikler National Institute of Pedagogical Methodology of Foster Homes—, and has become a European reference in quality early childhood education, continuous professional training in this educational stage, and rigorous scientific research, a transcendent endorsement of its particular way of doing things (Herrán, 2013; Herrán, 2014). In 2006 the original center —the foster home— closed and Emmi Pikler Nursery School opened its doors in the same location.

The founder’s previous training as a pediatrician was key in her subsequent professional journey. In fact, she learnt almost every principle that marked her as a doctor during her studies in medicine, which she first applied in her own family and then professionally, as a family pediatrician: to observe the child’s body in its natural environment; to conceive physical and psychological development as inseparable and intimately conditioned by the physical and human conditions of the context (Wallon, 1980, 1985); to understand prevention as the establishment of healthy living and developing conditions; to respect the child’s characteristics; to promote children’s activity and, to that end, to create *ad hoc* play spaces and provide children with clothing that would not restrict their movement; to seek children’s cooperation all the time, even in medical check-ups; to safeguard children’s autonomous motor development as the basis for healthy, progressive and safe movements, which were not observed among children who were taught to move; and a long *etcetera*. After

verifying the model’s viability, the challenge was to find the precise conditions for a healthy and balanced education in an institutional, collective context as Lóczy foster home (Pikler, 1969; Herrán, 2013; Falk, 2018c).

This was certainly an ambitious and accurate model since it aimed to generalize family upbringing to the collective context of the foster home. To this end, the conditions surrounding babies and young children were closely reflected on; the goal was to establish a comprehensive early education system, focused on babies’ and young children’s characteristics, and to investigate their particular *modus operandi*, mainly through longitudinal observations of child development and its conditions. The result was a complete success (Pikler, 1968, 1969). The guiding principles of this approach are (David and Appell, 1986, 2010; Falk, 2008): the importance of a privileged affective professional bond, differentiated from the family bond, since the relationships between babies and their caregivers at the foster home were not familiar; the value of young children’s autonomous activity, so that the resulting motor development is harmonious and can lay the foundations for a promising intellectual development; the convenience of promoting children’s awareness, both of themselves and of their environment; and the importance of a good state of health, origin and result of the correct application of the previous principles.

It is worth adding that, within this educational approach, some central issues can be highlighted, such as the areas of early development (Belza et al., 2019, 2020) or the intervention modalities that accompany them (Sagastui et al., 2022). Among the areas of early development, on the one hand, central and some other punctual body cares can be distinguished: from diaper changing (Falk and Vincze, 2018) or feeding (Vincze, 2018), to wiping the nose, or adjusting the child’s clothes (Hevesi, 2018). On the other hand, there is autonomous activity: from movement itself and the postural development associated with it (Pikler, 1969), to manipulation with one’s hand and, with it, infant play (Kálló and Balog, 2013; Tardos, 2014). Within these, there are some activities in which the infant needs direct adult intervention and some others that he or she can perform on his or her own either with indirect help or without it, but always with the adult’s presence or supervision (David and Appell, 1986, 2010; Falk, 2018d; Tardos, 2008, 2014; Szöke, 2016). Overall, every activity pursues the same goal: the voluntary and happy progression of children’s autonomous behavior.

In order to consolidate this educational approach, meticulous self-research was essential. In fact, the model was developed through the application of their own modality of systematic perception, known as Piklerian observation (Mózes, 2016; Tardos, 2018b). This comprehensive research enabled the team to deepen in their knowledge on early development and about their intervention or educator-child interaction and, at the same time, to improve their professional practice. To achieve this goal, they had to put a large number of factors under control, both of form and substance (Mózes, 2016). In relation to the former, the observation they conduct to study

their very educational approach is direct, focuses on everyday situations of the natural context, and both the recording and the treatment of data are rigorous, contrasted, discussed and reworked at three levels: interpretative, explanatory and propositional (Mózes, 2016; Tardos, 2018b). In relation to the latter, it is important to highlight that, in seeking to describe the manifestations and behavior of children as well as the most appropriate conditions for intervention as concretely and rigorously as possible, they have developed a common terminology throughout their history. It is a system of well-defined and shared concepts and vocabulary that not only objectifies what is observed, but also gives it a greater degree of temporal and spatial stability, standardization of the framework and certainty in the framing, which makes it possible to conduct better comparisons and analyses than other observational modalities (Mózes, 2016; Tardos, 2018b).

Thus, beyond organizational issues (David and Appell, 1986, 2010; Tardos and David, 2018), such as having a small number of children per classroom, distributed among the three educators of the group—so that each one is responsible for a small number of children, three or four at most, in order to be able to take care of them in good conditions (Falk, 2018a)—, or a precise agenda—regular but adaptable to the circumstances of everyday life with all its vicissitudes—, the educational activity as a whole requires a careful preparation of its human and material conditions (Wallon, 1978). Pikler educators conduct each and every body care in such a way that the infant is the protagonist, the center of their action. So everything the educator does or proposes to the infant is done in practically the same order each and every time (Herrán, 2013; Falk, 2018b), and at the pace that this infant requires, while simultaneously and permanently taking into account and attending to the infant's varied gestures, actions, responses, comments, etc., encouraging his or her participation (Hevesi, 2018), awareness and, with them, their autonomy (Falk, 2018d). Novel educators receive specific initial training in addition to monitoring by their experienced colleagues, so that they progressively internalize the Piklerian *modus operandi* (Kelemen, 2016). All educators share what they observe on a daily basis, so that they have a deep knowledge of each of the babies or children in the group (Mózes, 2016; Tardos, 2018b). The spaces, materials, objects and toys both in the classroom and in the garden, where they spend most of their time, are thoughtfully selected and organized, responding to infants' current interests, preferences and capabilities (Kálló and Balog, 2013; Tardos, 2014, 2018a).

Regarding body cares, this preparation permits the educator to be able to fully focus on the care itself, and on each child, his or her pace, ability and interest. All of them are developed following a precise choreography, which all educators share (Herrán, 2013; Falk, 2018b). This choreography is the way to homogenize all the interventions with each child, thereby emulating the family environment. On the other hand, autonomous activity has a great place in infants' life; at the beginning, free movement and play take place simultaneously, and these immediately differentiate from each other, so that their conditions do too (Kálló and Balog, 2013; Tardos, 2014; Tardos and Szanto-Feder, 2018). That is why, in addition to having two square meters per child in the classroom—so they can move freely as they conquer the vertical posture—, one of the structures that favors motor skills invented by Emmi Pikler herself is incorporated in the center of the classroom, such as the Pikler labyrinth, the Pikler triangle with its ramp, or platforms of various sizes (Pikler, 1968; Falk, 2018d). In

relation to free play, the material they offer is varied and always appropriate to children's developmental level, preferences and interests: from a dotted cotton cloth with bright and contrasting colors that is given from the moment the baby is able to differentiate his or her own hand, to books or more complex didactic games (Kálló and Balog, 2013; Tardos, 2014; Szöke, 2016).

The Emmi Pikler Nursery School is the faithful heir of all the knowledge accumulated during the 65 years of the Lóczy foster home's history, and it is where the original research referred to in this article—initiated by Herrán in 2013 (Herrán, 2013; Belza et al., 2023b)—was carried out. Unlike the usual Piklerian research, which mainly observed child development, and basically due to temporal issues, its object of study was the activity of the Pikler educator or choreography. Thus, the objective was to empirically demonstrate the Piklerian choreographies deployed in each area of early development and, secondarily, to unravel their educational potential (Belasko et al., 2019; Belza et al., 2019; Sagastui et al., 2020). The systematic observation of two experienced educators early in the morning while they attended to and accompanied the children in their respective groups over a period of 3 months allowed a comprehensive study of the updated Pikler-Lóczy educational approach. Thus, OM (Anguera, 1979, 2003) turned out to be the ideal methodological option for the proposed objective, as it allows to capture spontaneous behavior in its natural context, deconstruct it and analyze it to obtain a pattern that, in this case, was expected to fit with the studied Piklerian choreographies, nuanced and previously demonstrated by the Pikler team itself.

OM provides guidelines and valuable procedural resources to combine qualitative and quantitative perspectives along the same research process, which led it to be considered a mixed method itself (Anguera et al., 2018a; Hitchcock and Onwuegbuzie, 2022).

In this sense, the proposal made from OM is based on the ordered succession of QUAL-QUAN-QUAL stages (Anguera and Izquierdo, 2006; Sánchez-Algarra and Anguera, 2013). The first, qualitative, corresponds to the development of the observational instrument (Anguera et al., 2007) and, with it, the systematic recording of all the units extracted from the reality to analyze (Anguera and Blanco-Villaseñor, 2003). The sample collected in the original research referred to in this study reports on three types of body care—changing diapers, feeding breakfast and dressing children to go out to the garden—and on free play accompanying (Belza, 2020; Belasko, 2023; Sagastui, 2023). The *ad hoc* observational instruments used in these investigations incorporate a common part, related to the shared Piklerian *modus operandi*, and a specific part, associated with the daily moment studied in each case and its conditions.

Precisely, the systematic recording conducted through the observation instrument makes it possible to systematize the initially descriptive recording in a code matrix that can be analyzed through specific quantitative techniques for categorical data (Anguera et al., 2021). Thus, OM relies on the *connect* option—proposed by Creswell and Plano Clark (2011) as one of the three possible ways to carry out mixing within mixed methods research: merge, connect, embed—, since this option allows to conduct the *quantitizing* (Sandelowski et al., 2009), which, in this case, is carried out with the obtained observational data. In other words, the second stage of the research process, aimed at ensuring the rigor of the recording through the quality data analysis (Blanco-Villaseñor and Anguera, 2003) and analyzing of the collected observational data itself (Blanco-Villaseñor et al., 2003), is characterized by being predominantly quantitative.

Considering the general objective, the demonstration of the choreographies displayed by Pikler educators, and the specific ones—which included obtaining the behavioral patterns of each body care or moment, the study of their different parts and intervention modalities, the comparison between both educators in search of a shared *modus operandi*, etc.—data analysis techniques were different in each research. The proposal made through OM does not combine methods or techniques, nor data from different sources, but transforms the collected qualitative information into data susceptible to analysis with appropriate quantitative techniques (Anguera et al., 2020). Specifically, three techniques were used in the original research: lag sequential analysis (Bakeman, 1978; Bakeman and Quera, 2011), polar coordinate analysis (Sackett, 1980; Anguera, 1997) and T-Pattern detection and analysis (Magnusson, 1996, 2000, 2020). These techniques are based on the primary parameters of order and duration, which include frequency too. According to several authors, this makes the integration more robust than most empirical publications on mixed methods that only apply conventional analytical techniques based on frequency (Anguera et al., 2020). Moreover, it is worth mentioning that a number of studies within the educational field have started to use this methodological approach (e.g., Bonilla et al., 2020; Escolano-Pérez et al., 2020; Navarro-Adelantado and Pic, 2021; Pic et al., 2021).

The third and final stage, qualitative, corresponds to the interpretation of the results in relation to the objectives of the study and, in this case, Piklerian theory (Anguera et al., 2018b). Thus, the studies conducted on giving breakfast (Belza et al., 2019, 2020, 2023a,b; Belza, 2020), dressing to go out to the garden (Belasko et al., 2019, 2022, 2023; Belasko, 2023) and free play accompanying (Sagastui et al., 2020, 2022, 2023, 2024; Sagastui, 2023) bring together some basic Piklerian ideas that, indeed, emerge from the analyzed daily educational practice, intimately related to each other. These are, among others, the methodical empathic adoption of the child's perspective; a certain perspective taking or emotional distance, which allows an important degree of objectification when analyzing habitual situations; placing personal aspects under control, based on the internalization of a shared paidocentric or child-centered educational culture; the coherence and support of the educational team, which reflects together, periodically and systematically; the importance of daily observations and their analysis and elaboration, in view of the individual adjustments to each child; the heritage of the foster home, partly evident in the organization and functioning of the nursery school, and also latent in subtle educational attitudes that optimize the way of educating, ensuring its quality.

Among the results obtained in the original research, three central keys arose. Namely, the *stability* of Pikler educators' behavior, always adaptable to the human and physical circumstances of each moment; their *strategic and intentional positioning*, which allows the optimal focus of attention and the ergonomics of the intervention; and an active and fluid *emotional control*, associated to professional empathy, to the children's protagonism in their own education, as well as to the awareness of being a permanent role model. At this point, beyond being able to go deeper into each daily activity, it was deemed necessary to return to Lóczy in order to contrast the obtained results, and check if they really reflect the perspective of the studied educators.

This line of research has provided new and enlightening knowledge about Pikler-Lóczy education thanks to the use of OM, as a mixed method; since, in the third stage of the process, the behavior

of the observed educators was not only described, but also explained. This task has been exceptionally simple because of the complementarity between observational methodology and the Pikler-Lóczy educational approach, since this very model is defined by its own, characteristic and original observational tradition. In fact, Piklerian observation supported the development of the choreographies of daily educational tasks and permitted to qualify, clarify and model them observation by observation, child by child, care by care, definition by definition, until they were constituted, thanks to the quality and rigorousness of their continuous work and effort.

Now, the aim is to go one step further and discuss the interpretations of the behavioral patterns found in the original research, "Pikler educators early in the morning" together with the observed experienced educators. Thus, we used indirect observation (Anguera et al., 2018c; Del Giacco et al., 2019, 2020) to meet this goal, specifically, an in-depth interview (Anguera, 2021). So, after several face-to-face and formal meetings with the educational team in Lóczy to present them the results of the original research, a virtual meeting was arranged between the researchers and the educators, supported by a translator, aiming to exchange opinions on the obtained results. This way, we close the research with this third stage of OM, as we go back to the observed educators, so that they can confirm or refuse the conclusions about their own practice, validating, if necessary, the conducted research.

Therefore, the general objective was to contrast certain central results obtained in the original research, "Pikler educators early in the morning" by conducting an in-depth interview, a modality of indirect observation within mixed methods, to the two educators observed in it, and in doing so, to clarify three key ideas. This general objective unfolded two specific objectives. The first was to confirm whether, in the expert opinion of the observed educators, the three central keys found in the original research exist in their daily practice and in their shared reflection, and if so, whether they recognize them as their own. The second was, based on this potential recognition, to trace new theoretical-practical elements that may qualify, broaden or enrich the Piklerian educational discourse.

2 Materials and methods

This work was developed using Observational Methodology (OM). OM represents the appropriate methodological approach to study and evaluate spontaneous behavior in its habitual context (Anguera, 1979, 2003), and it is a field that has gone through great advances at a procedural, technological and also conceptual level. So much so that it is now being used as a suitable approach for the analysis of in-depth interviews.

Following the three macro-stages QUAL-QUAN-QUAL proposed by mixed methods (Anguera, 2021), the transcription of the in-depth interview (QUAL stage) was the starting point for quantizing. Based on the corresponding theoretical framework and a certain empirical expertise, an observation instrument was constructed with a defined structure. This instrument made it possible to systematize the transcription until it took the form of a code matrix, which depicts information that was still qualitative although already highly systematized. These data could be later subjected to quantitative analyses appropriate for categorical data (QUAL stage). Through this procedure it was possible to detect the underlying structure of the

in-depth interview, as well as to ascertain the map of relationships between codes/sub-dimensions revealed by the results of the analysis and interpreted by returning to the theoretical framework (QUAL stage).

2.1 Participants

The interview was conducted with two expert educators of the Emmi Pikler Nursery School, currently active and with more than 30 years of experience in this institution. It is worth mentioning that the team of professionals of this educational center includes different profiles, from pedagogues to pediatricians, educators, psychologists, etc. However, as the object of study of our original research was the behavior of these educators in their own classroom, educators were considered the most suitable professionals to achieve the objective of this work, which was to analyze the discourse about their own practice.

In this sense, in this nursery school there are a total of three groups of children, and three educators for each of them, a total of nine. The criteria for selecting the educators to be interviewed were: (1) having completed their professional training in Lóczy's own nursery school under the direction of pediatrician Emmi Pikler; (2) having actively participated in the continued professional development programs planned by the institution; (3) being familiar with the results of our original research about their own educational practice as a result of having attended the research feedback sessions held in September 2023 in Lóczy.

After applying the aforementioned criteria, two educators were selected, in addition to a translator from the institution itself and therefore also an expert on the object of study. A 47-minute in-depth interview was conducted. In addition to the two educators and the translator, the three authors of this paper participated in the interview. One of them was the interviewer, while a second one supported her and the third one acted as a listener.

2.2 Instruments

An observation instrument was developed *ad hoc* to analyze the in-depth interview. Precisely, we created a field format because it is more flexible and allows the study of several levels of response simultaneously (Anguera et al., 2007). The dimensions to include within the observational instrument were proposed based on the content of the in-depth interview questions and were supported by the theoretical framework, which despite not being required for a field format development, it is advisable (Anguera et al., 2018a). In this case, the instrument includes four dimensions, in addition to the dimension that serves to identify the speaker of each recorded textual unit. The first dimension refers to the sections of the interview, mainly divided into the three central keys found in the original research and previously presented. The second dimension specifies the communicative intention of the interlocutor in each textual unit, so it is divided into two sub-dimensions, one referring to the interviewer, and the other to the interviewees. The third dimension details the content of the interview, specifically, the ideas that the educators express in their discourse or about their own practice. Finally, the fourth dimension groups together paralinguistic behaviors, considered

relevant given the frequent use of gestures and non-linguistic cues by participant educators.

Once the dimensions to examine are proposed, the development of an *ad hoc* instrument requires repeated exchanges between the theoretical framework and the obtained responses, aiming to establish a catalog of codes or diverse behaviors in each dimension, which must be mutually exclusive (Anguera et al., 2018a).

Table 1 lists the dimensions, sub-dimensions and codes included in the field format.

2.3 Procedure

In line with the three macro-stages QUAL-QUAN-QUAL proposed by OM within the mixed methods approach, this study follows the proposal developed by Anguera (2021) to analyze in-depth interviews through indirect observation.

First of all, and once the purpose of this work was formulated, a plan was designed to obtain the required information. We decided to conduct a single interview with the selected participants, with whom training sessions had previously been held and, therefore, were already aware of the results of the original research, "Pikler educators early in the morning." The interview was carried out following an open script or outline as a general guideline. First of all, the interview was divided into three sections. Each of them referred to one of the central keys found in the original research, which we aimed to discuss with the interviewed educators. As presented in the introduction, these keys are: 1) the stability found in the habitual behavior of the educator; 2) the educator's focus of attention depending on her aim to intervene or not; 3) the educator's emotional control during her interventions.

Once the themes of the interview had been established, several questions were asked about each of them with the aim of clarifying, defining and agreeing on their meaning. Thus, these questions were not designed to be formulated literally during the interview, but rather as a resource in case it was necessary to clarify the topic. For example, the first central key was posed as follows: "*previous research has resulted in behavioral patterns that report that educator's behavior is very stable, because there is a sequence of actions she systematically repeats.*" Next, questions were made: "*do you agree with this characteristic we found within your daily work? Do you have a choreography or protocol that you systematically follow in each activity or body care? Do you always try to do it the same way?*"

The interview was conducted and transcribed, and then this transcription was transferred into Excel, once relevant decisions about how to code the interview had been made. In this sense, the first decision concerned the segmentation of the transcript into textual units. There are several criteria that can be applied: orthographic, syntactic, contextual, interlocutory, etc. This decision is closely related to the pursued degree of molecularity. Specifically, in this work, two of the above-mentioned criteria were adopted and combined: first, the interlocutory, understood as the turns of speech throughout the interview and, second, the orthographic, so each sentence was established as a textual unit. The last step of this qualitative stage involved the systematization of the recording, carried out by assigning each unit of analysis a code or codes within the observation instrument. Given their mutual exclusivity, each unit was assigned as many codes as

TABLE 1 Field format.

Dimension	Sub-Dimension	Code
Participant	Interviewer 1	E
	Interviewer 2	HB
	Translator	EM
	Interviewee 1	JK
	Interviewee 2	JH
	The three of them together	LT
Section of the interview	Other: previous moments, greetings, etc.	A0
	(1) Stability/adaptability	A1
	(2) Focus of attention, strategic positioning	A2
	(3) Emotional control, acting as a role model	A3
	End of interview and giving thanks	A4
Communicative intention	Others: idiomatic, technical, etc.	I0
Interviewer	Asks	I11
	Explains, raises point	I12
	Reformulates to clarify idea	I13
	Reformulates to confirm she has understood	I14
	Confirms	I15
	Asks translation	I16
	Denies	I17
Interviewee	Confirms	I21
	Adds new information	I22
	Exemplifies	I23
	Reformulates in the same sense	I24
	Reformulates in another sense	I25
	Denies, nuances	I26
	Answers	I27
	Asks for clarification	I29
Content	Child's perspective	C1
	Perspective taking, analysis of situation	C2
	Culture, personality, interiorization	C3
	Function of observations	C4
	Previous training, foster home	C5
	Teamwork and reflection	C6
	Original research, researchers' perspective	C7
Paralinguistic	Vocalization to confirm: <i>Ajam, igan</i>	P1
	Laughs	P2
	Coughs	P3
	Laughs + vocalization to confirm	P4

Dimensions, sub-dimensions and their corresponding codes.

co-occurrences between the different dimensions included in the instrument were detected.

The second stage, which is predominantly quantitative in nature, started with the development of the systematized recording. This is the step in which *quantitizing* occurs, an important step in research within mixed methods. It is, precisely, the process where the primary parameters of the recording proposed by Bakeman (1978) are obtained: frequency, order and duration. The proposal developed within OM is fundamentally based on order or sequence (Anguera et al., 2017, 2021), that is, the code matrices are formed by successive cooccurrences of codes —the rows of the matrices— which allows the application of various quantitative techniques of analysis appropriate for diachronic data. Before analyzing the data from these code matrices, they must be subjected to quality control, as this methodology undoubtedly requires an effort to detect

biases in the recording, as well as mismatches between observers. Therefore, in this case, the three researchers systematically recorded the whole interview, obtaining three different code matrices. There are numerous coefficients to quantitatively verify the quality of data, but in this case, canonical concordance coefficient (Krippendorff, 2013) was chosen, since it permitted to calculate the concordance between the three recordings. This coefficient was calculated using HOISAN and obtained a satisfactory result of 71.99%.

Once the quality of data had been checked, data analyses were carried out. In this case we opted to use a technique particularly suitable to detect structures within relationships between codes: lag sequential analysis (Bakeman, 1978; Bakeman and Quera, 2011).

This technique is used to identify regularities between observed behaviors and, therefore, discover associations between them, specifically, through the calculation of observed and expected probabilities (Bakeman and Quera, 2011). Starting from a certain behavior, known as criterion behavior and selected based on the study objectives, this analysis shows what other behaviors —conditioned behaviors— precede and follow it, through retrospective (lags −1, −2, −3, etc.) and prospective (lags +1, +2, +3, etc.) lag sequential analyses. The results obtained are called adjusted residuals and show the likelihood of appearing of each conditioned behavior in each lag that is studied. Depending on the value of obtained adjusted residuals, it can be concluded if a behavior’s likelihood of appearing in a specific lag is higher than the effects of chance, with a significance level of $p < 0.05$ (adjusted residual > 1.96). When the obtained adjusted residual is negative, it shows that the relationship between criterion and conditioned behaviors is inhibitory. Concurrence of behaviors can also be studied, considering adjusted residuals in lag 0. The data used for this analysis were type II: event based and concurrent (Bakeman, 1978), and data analyses were performed in SDIS-GSEQ v. 5.1 (Bakeman and Quera, 2011).

In order to satisfy objective 1, we performed a lag sequential analysis to check for a potential communicative pattern within participants’ discourse when answering to the proposed questions. For this analysis, we used the recording of the researcher who had the leading role in this study. When it comes to analyses responding to objective 2, we explored concurrences between behaviors and, in this case, we performed the same analyses with the recordings made by the three researchers, aiming to reach more conclusive results.

After the quantitative results are obtained, these have to be interpreted. The return to a qualitative phase in the study of the in-depth interview closes the circle of the connect option (Creswell and Plano Clark, 2011), situated within mixed methods.

3 Results

The first objective of this research was to detect if the interviewed educators, who count with a long experience working under the principles of Pikler-Lóczy education, confirmed the existence of the three central keys found in our original research and if, in addition, they recognized them as their own.

In order to achieve this objective, a lag sequential analysis was carried out. Among the behaviors included within the communicative intention dimension of the field format, “interviewer asks” (I11) was introduced as a given behavior and all those related to the interviewees’ communicative intention were selected as target behaviors: confirms (I21), adds new information (I22), exemplifies (I23), reformulates in the same sense (I24), reformulates in another sense (I25), denies/nuances (I26), answers (I27) and asks for clarification (I29).

Positive lags, that is, those belonging to the prospective perspective of lag sequential analysis, were analyzed. Significant adjusted residuals found in each lag are included in Table 2 and result in a pattern shown in Figure 1.

Specifically, when the interviewer asks educators a question, they initially respond with another question (I29) that seeks to clarify the discussed topic. Then, the interviewee answers (I27) directly to that question. After this, she reformulates in another sense (I25) in two consecutive lags, which would add nuance to her argument. In the fifth prospective lag, no significant behaviors were found, potentially indicating that the interviewer adds another question or intervenes to clarify something that is being discussed. This idea is reinforced by the behaviors observed in the following two lags: in both of them the interviewee adds new information about the topic they are talking about (I22). As no significant behaviors are found in the next two lags, this would constitute the end of the behavioral pattern.

The second objective of this work was oriented to reveal new theoretical-practical elements that could broaden or enrich,

TABLE 2 Lag sequential analysis of communicative intention.

	Lag +1	Lag +2	Lag +3	Lag +4	Lag +5	Lag +6	Lag +7	Lag +8	Lag +9	Lag +10
I21 – Confirms										
I22 – Adds new information						2,336	3,107			
I23 – Exemplifies										
I24 – Reformulates in the same sense										
I25 – Reformulates in another sense			2,024	2,016						1,97
I26 – Denies/nuances										
I27 – Answers		2,609								3,684
I29 – Asks for clarification	3,573									

I11 (interviewer asks) as given and interviewees’ communicative intention behaviors as target. Significant adjusted residuals on positive lags. Bold values significant adjusted residuals in each of the studied lags.

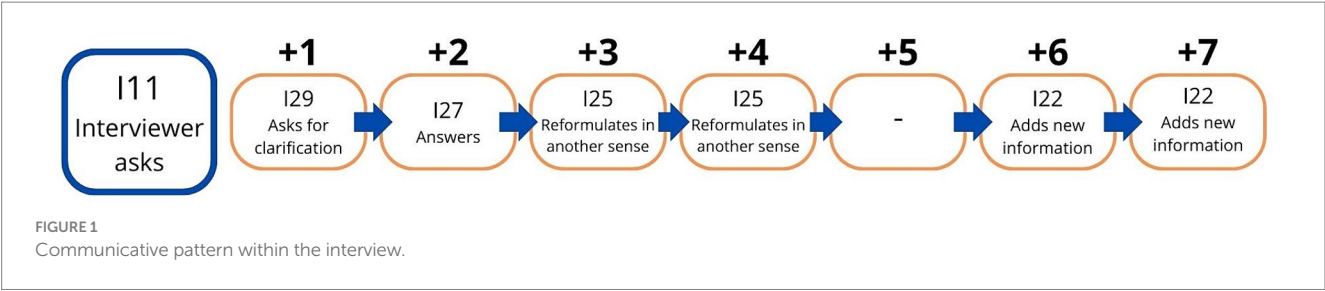


TABLE 3 Comparison of adjusted residuals obtained by analyzing the systematic recording of each of the three observers.

	A1			A2			A3		
	OBS1	OBS2	OBS3	OBS1	OBS2	OBS3	OBS1	OBS2	OBS3
C1		3,02	2,53	4,37	3,58		-3,61	-3,31	3,42
C2					4,45			-6,35	
C3		-2,74	-2,36	-2,93	-4,6		3,84	6,29	
C4						4,23			-3,35
C5					-2,19			3,25	2,75
C6					-2,32	-3,02	1,99	3,17	4,16
C7	4,26	4,85	5,87			-2,33		-2,11	-2,04

Significant concurrences between the three central keys and the seven aspects of the interview content.

broaden or enrich the interpretation of the Piklerian educational practice. In this case, we applied the same technique, lag sequential analysis, but just to analyze concurrences. Specifically, we studied concurrences between the three central keys found in our original research —stability (A1), focus of attention and strategic positioning (A2), emotional control (A3)— and the aspects related to the content of the interview that were found when developing the indirect observation instrument: child’s perspective (C1); perspective taking/analysis of the situation (C2); culture, personality, internalization (C3); role of observation (C4); previous training in the foster home (C5); teamwork and reflection (C6); original research and researchers’ perspective (C7).

Given that the three observers performed a systematic recording, the same analysis was conducted with the three samples. Obtained results are presented in Table 3. Regarding to stability (A1), concurrences were found with the child’s perspective (C1, obs 3), with the analysis of the situation (C2, obs 2) and with aspects related to our original research (C7, obs 1, 2 and 3). In addition to these concurrences, we found a significant negative adjusted residual in one case: culture (C3, obs 2 and 3).

As for strategic positioning (A2), we found concurrences with the following content aspects: child’s perspective (C1, obs 1 and 2), analysis of the situation analysis of the situation (C2, obs 2) and function of observations (C4, obs 3). Significant negative adjusted residuals were also found with culture (C3, obs 1 and 2), previous training in the foster home (C5, obs 2) and teamwork (C6, obs 2 and 3).

Finally, when analyzing emotional control (A3), concurrences were found with culture (C3, obs 1 and 2), previous training in the foster home (C5, obs 2 and 3) and teamwork (C6, obs 1, 2 and 3). Significant negative adjusted residuals were also found: child’s perspective (C1, obs 1, 2 and 3), function of observations (C4, obs 3) and original research (C7, obs 2 and 3).

4 Discussion

The general objective of this study has been met since it was possible to contrast the central results obtained in the original research “Pikler educators early in the morning” by means of an in-depth interview (Anguera, 2021) —a modality of indirect observation within mixed methods— with the two educators observed. The results of the original research were demonstrated as central keys of the Pikler-Lóczy educational approach. In the first place, we found the always adaptable stability of the educator’s behavior to the human and physical circumstances of each moment or educational situation. Thus, depending on the child or children she is intervening with and the classroom space she is in, the educator’s behavior is extremely stable, almost choreographic and performative, so that she emanates a fundamental security for an optimal child development. Secondly, the educator always shows an interested positioning. It is never casual, but instead, very conscious and intentional. If she is not present or nearby, she observes attentively or seeks information verbally or using gestures. This positioning is strategic, so the educator’s focus of attention is always optimal; this is especially beneficial as attention in a collective environment is necessarily varied, and it also contributes to an ergonomic educational management. Third, there is an active and fluid emotional control, typical of conscious professional empathy, so the educator is known to be a permanent role model, who yields the protagonism of their education to babies and young children themselves. This aspect makes the studied educational approach truly *paidocentric*.

The first specific objective was confirmed as we obtained a defined communicative pattern. The three central keys discussed throughout the interview were not denied —there is no denial (I26) in the pattern—, so they would be confirmed; however, they were not confirmed as initially presented by the interviewer. Instead, interviewed educators reworked those ideas their own way, as shown

in the obtained behavioral pattern. Educators do so through questions to clarify (I29) the presented idea, some punctual answers (I27), reiterated reformulations (I25) and the contribution of new information (I22) because they evidently know the details of their own activity better than the interviewers. In other words, they use the typical Piklerian model of shared reflection, always dialectical and open to nuance, which has developed since the very origin of the educational model, and which has made the educators the professionals they are. Evidently, while doing so they seek to ensure that the terminology is common and that the concepts and vocabulary used are well defined and shared by both interviewees and interviewers. This makes it possible to establish better comparisons and analyses and optimizes both their observational modality and their educational model.

The second objective, on the other hand, was refuted. Despite recognizing the three central keys as their own, albeit with nuances, the obtained results do not point to new Piklerian theoretical-practical elements to contribute. They limit themselves to confirming certain central issues of the model. Thus, stability (A1) takes into account the child's perspective (C1), as well as the situation (C2) in which the activity takes place, and is also related to the research findings (C7) explained to them. At the same time, this central key of Piklerian education seems to be something structural or part of the model itself and not the result of internalization or acquired culture about children (C3). Indeed, the ability to give stability to each moment and, with it, the adaptability to children flows in their daily lives, it is not an idea or a concept that is reached, but a permanent educational exercise with specific children in the concrete situation in which he/she finds him/herself, which was precisely the object of the original research that was being contrasted in the interview. Something similar happens with strategic positioning (A2). It is again related to the child's perspective (C1), to the analysis of the specific situation (C2), as well as to the observation of the context (C4). This means that the educator's positioning is never a result of chance, but she focuses on the child she is intervening with and the context. Culture (C3), previous training in the foster home (C5) and the educational team's continuous reflections (C6) are absent when analyzing their relationship with strategic positioning (A2). Finally, when it comes to emotional control (A3) there is a certain inversion compared to the previous aspects, since it does seem to be associated with culture (C3), previous training in the foster home (C5) and the educational team's continuous reflections (C6). In other words, it seems that emotionality would be a factor that requires permanent personal reflection among educators, which the two previous keys —stability (A1) and strategic positioning (A2)— do not require, since they would flow without any effort in educators' usual intervention. Moreover, it would be an intrinsic and generalized emotional control, not associated to the specific child (C1), nor to the specific situation (C2) in which he/she finds him/herself, nor to the observation of the context (C4). Neither is it related to the original research (C7), although it should, since it is one of its vertebral results. All in all, it seems that the perspective of the interviewed educators is that “they are able to do Piklerian style”, which would be understandable after so much training, professional experience and shared reflection.

The presented methodological proposal can be considered a novel approach to mixed methods, since the possibilities offered by indirect observation to analyze the conducted in-depth interview are evident.

The potential of this study lies, precisely, in the simplicity of the equipment used, since an austere 47 minute in-depth interview and the application of an exclusive analysis technique —lag sequential analysis— led to generous results and conclusions. Thanks to lag sequential analysis in its positive perspective, a stable response pattern from the interviewed educators has been obtained, a faithful reflection of the Piklerian *modus operandi* guided by the fact that “knowing the child” is a necessary condition to be able to help him/her. It is not always enough, but the team always goes back to the question —and does it as many times as necessary— until a satisfactory and adjusted answer is found. Regarding the analysis of concurrences, it unraveled certain relationships between previously obtained results, although it basically confirmed that the Piklerian intervention style, once internalized, is not understood as such, but is part of the educator herself, with the exception of emotions, which must be kept under control on a daily basis.

In summary, this work demonstrates the perfect fit between observational methodology and Pikler-Lóczy education once again. Moreover, it has allowed us to confirm some of the results obtained through direct observation in our original research. This supports the convenience of the application and conceptualization of mixed methods, while opening the door to a more exhaustive investigation to contrast other results obtained in our original research.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Ethics Committee of the University of the Basque Country (UPV/EHU). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

HB: Data curation, Formal analysis, Methodology, Writing – original draft. JS: Conceptualization, Investigation, Writing – original draft. EH: Conceptualization, Supervision, Writing – original draft.

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Emotional regulation in the classroom: detection of multiple cases from systematic observation

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Introduction: Emotional education is learned by living with others. This study analyzes how different actors participate in the classroom, influencing students' emotional regulation.

Methods: Using a mixed methods approach [structured in macro-stages QUAL-QUAN-QUAL], 9 classes in three Chilean schools with children aged 10 to 12 are systematically observed. The audio-recorded sessions are transcribed (qualitative data) for coding from the observation instrument, and then, once the data quality is verified, they are analyzed quantitatively (quantitizing). A lag sequential analysis is performed to detect regularities and existing sequences, and a polar coordinate analysis is performed to observe the relationships among the categories in each class.

Results: Once the results of the analyses have been obtained, similarities are sought to detect the presence of multiple cases based on the two analysis techniques. The multiple cases detected are presented, detailing how interactions between teachers and students contribute to the emotional regulation and climate in the daily life of the classroom.

Discussion: The interpretation of the results makes it possible to revisit the qualitative aspect of the mixed methods and to discuss the need to problematize the role of teachers in students' development and autonomy.

KEYWORDS

emotional education, school coexistence, emotional regulation, mixed methods, quantitizing, multiple cases

1 Introduction

As part of our daily life, emotions help us to respond quickly to changes in the environment and to relate to other people, being functional and adaptive. They play a social role from the first months of life, allowing us to interact with others and learn from our surroundings. They produce the feeling of belonging, being loved, and wanting while also serving to elicit emotion in others. This allows us to develop meaning through emotional experiences, creating socio-emotional baggage we will carry throughout our lives (Quintanilla, 2018).

The ability to control and regulate one's emotions has been considered one of the most critical dimensions for establishing positive social relationships and favoring the learning and knowledge of others' emotions, observing that empathy is the primary support for prosocial behaviors (Marchesi, 2017).

In the school setting, it has been observed that children who are taught to manage their emotions better can ask for help assertively, proving to be more protected against possible situations of bullying or cyberbullying (Romera et al., 2016; Larrañaga et al., 2018), providing social integration, which implies that each person is a self-reflective subject who submits their relationships with others and civic participation in social spaces to constant criticism.

In this sense, Quintanilla (2018) emphasizes that emotions are shaped and configured by context, noting that the more individualistic a culture is, the less individuals take the interests of others into account. In addition, Bisquerra et al. (2012) emphasize the importance of education and emotional development processes, including values and ethical principles.

Thus, considering that emotional competencies are continually developing, children around 11–12 years old may cognitively have the skills needed to put themselves in the other person's place and understand the consequences of their actions (Ordóñez et al., 2016). It has become clear that processes of emotional self-regulation that enable the construction of spaces for coexistence based on shared reflections through development opportunities provided by adults need to be promoted (Alarcón-Espinoza et al., 2023a).

Thus, according to García Amilburu and García Gutiérrez (2017), educational processes should plan to disseminate the most valuable elements contributing to a person's total development within a particular community. The teacher's intentionality in the educational relationship is also considered since their motivations and beliefs will be crucial in fostering the student's development of autonomy and cognitive and emotional self-regulation.

Therefore, it is not possible to establish a separation between content and method. Students develop as moral beings to the extent that the principles inherent to the procedures are also part of the content that is being conveyed, with the attitude and example of the teachers being highly relevant (García Amilburu and García Gutiérrez, 2017); in addition, the richness of the observation of emotional regulation behaviors in daily life is highlighted (Alarcón-Espinoza et al., 2022).

Likewise, students' cooperation and participation in a joint learning action becomes a powerful instrument to construct knowledge since to advance in the appropriation of knowledge and progress from the interpersonal to the intrapersonal relationship, internalizing cultural instruments, the student must share meanings, exchange points of view, and establish rules that facilitate the shared activity. This interaction can be a source of self-esteem and confidence, while it also favors interactions and the feeling of belonging to a group (Marchesi, 2017).

Thus, assuming that emotional development and the achievement of self-regulation in children are modeled and influenced by the contexts in which their daily lives unfold and where the school has significant influence, a macro study was conducted to answer the question, "How is the development of emotional self-regulation in children from 10 to 12 years old promoted in the school environment?" This has made it possible to determine the forms of expression and emotional regulation in classrooms and discuss their effects on students' mental health (Alarcón-Espinoza et al., 2023a) as well as the behaviors that affect how students focus on the task (Alarcón-Espinoza et al., 2023b), recognizing the importance of viewing the classroom as a complex system in which, even when dealing with classes with different characteristics and located in different territories,

discernible patterns are perceived in the behavior of the various actors who participate daily. For the above reasons, this study aims to analyze, from a mixed methods approach and through the detection of multiple cases, how the different actors participate in the classroom to promote emotional self-regulation in the school setting.

2 Method

2.1 Observational design

The observational methodology is used, considered a mixed method in itself (Anguera et al., 2017), which integrates qualitative and quantitative elements using the *connect* pathway proposed by Creswell and Plano Clark (2011), following the quantizing approach of Anguera et al. (2020), and from the macro-stages QUAL-QUAN-QUAL. The observation method was used because it is a scientific method characterized by its objectivity and because it facilitates the spontaneous study of behavior in the context in which it occurs. Systematic observation is indirect (Anguera et al., 2018), collecting the data through audio recordings of observed classes (Anguera et al., 2021), which were subsequently transcribed. The observational design (Anguera et al., 2001) used is (a) Nomothetic: 9 cases (classes); (b) Follow-up: each class is observed once a week for 5 consecutive weeks (intersessional follow-up) and is observed from beginning to end (intrasessional follow-up); (c) Multidimensional: Four main dimensions are proposed, which will be taken as a basis for the observation instrument.

2.2 Participants

The 9 classes observed are three Chilean schools in the Araucanía region, located in the regional capital, a town, and a fishing village. Classes with children between 10 and 12 were observed in each school. The classes comprised girls and boys and had between 15 and 40 students. The classes observed corresponded to tutorials, class councils, arts, or language. This sample was used for this study and for others that have been part of the macro study that has aimed to examine how the development of emotional self-regulation is encouraged in children between 10 and 12 years of age in the school environment.

2.3 Instruments

The observation instrument "Guideline for the Observation of Communication and Emotional Self-Regulation" (OCAE in Spanish) was used (Alarcón-Espinoza, 2021). It was designed *ad hoc* and comprises 4 macrodimensions, 14 dimensions, 30 sub-dimensions, and 63 categories. It is based on the theoretical framework and the observed context.

The recording instrument was Excel. The software tools for data analysis were the free programs GSEQ¹ (Bakeman and Quera, 2011)

1 <https://www.mangold-international.com/en/products/software/gseq.html>

for data quality control and lag sequential analysis and HOISAN v. 1.6.3.3.4² (Hernández-Mendo et al., 2012) for the polar coordinate analysis.

2.4 Procedure

Once the school principals authorized the study, the adults and students involved were asked to sign an informed consent form, as the research was approved by the bioethics committee of the University of Barcelona through the Institutional Review Board (IRBC)0003099. In all cases, students were observed in a classroom setting with two teachers. The observed sessions were audio-recorded and transcribed into Excel files. Subsequently, the text was segmented into observation units, applying interlocutory (speaker) and syntactic (grammatical sentence) criteria (Anguera, 2021), prioritizing the former. The units obtained from the segmentation were then coded from the observation instrument.

Type II data were obtained in the recording (Bakeman, 1978) and, consequently, were concurrent and event-based.

The data quality control was guaranteed by coding 15% of the total record at three different times (separated by at least one week) and calculating Cohen's kappa coefficient (Cohen, 1968). This was done using the free GSEQ program until the required degree of agreement was achieved (value greater than 0.60).

2.5 Data analysis

To meet the study objective, once the data quality was guaranteed, the quantitative techniques of lag sequential analysis and polar coordinate analysis were applied to detect the presence of multiple cases. The analyses have been performed considering each actor or speaker as the criterion behavior (marked with the code E) and the other categories of the observational instrument as conditioned behaviors.

The lag sequential analysis proposed by Bakeman (1978) is used to detect the existence of regularities (sequential behavioral patterns) in data of a categorical nature (Anguera and Hernández-Mendo, 2015). It is necessary to start sequentially ordered from the code matrices of the record - in our case, multi-event (Bakeman, 1978). A criterion behavior is proposed, which will be the starting point for potential behavioral patterns, and some conditioned behaviors may form part of the detected behavioral patterns. To carry out the lag sequential analysis, the transition frequencies are obtained from each criterion behavior, and the number of positive (prospective), zero, or negative (retrospective) lags is determined for each of the conditioned behaviors included. Then, the unconditioned or expected probabilities are found, marking the "ceiling" corresponding to the random effect and the conditioned probabilities generated by the record. Once obtained, the unconditioned and conditioned probabilities are contrasted using the binomial test, applying the correction proposed by Allison and Liker (1982), which allows the residuals adjusted between the criterion behavior and the conditioned behaviors to

be obtained as findings that may or may not be of statistical significance. Behavioral patterns are formed from these adjusted residuals. In this study, we are particularly interested in lag 0 patterns (R0) to study only the concurrences of the criterion behavior and the conditioned behaviors. In each of these patterns, activating ($> +1.96$) and inhibiting (< -1.96) conditioned behaviors associated with the criterion behavior were obtained.

Subsequently, to ascertain the relationship among the behaviors observed with the greatest significance in the lag sequential analysis, a polar coordinate analysis, proposed by Sackett (1980), was performed to vectorize the behavior. By presenting in this study the behaviors that emerged as the most significant in the lag sequential analysis and taking into consideration as conditioned behaviors a selection of categories that appeared in the sequential patterns of behaviors, the polar coordinate analysis seeks to identify the intra-relationship between a focal behavior and conditioned behaviors.

The polar coordinate analysis is a data reduction technique that starts from the results of adjusted residuals obtained in the lag sequential analysis. Based on the proposal by Cochran (1954), the prospective and retrospective Zsum parameters are calculated for each conditioned behavior, which finds the length and angle values of each vector, bearing in mind that each conditioned behavior will be represented graphically by a vector. Vectors are interpreted in terms of their length and angle. The length is considered significant when its value is greater than 1.96 - for a significance level of 0.05 -, and the angle of the vector indicates the nature of the relationship it establishes with the focal behavior in terms of the quadrant in which it is located, with the following associative relationships becoming clear: (a) Quadrant I: The focal behavior and conditioned behavior are mutually activated, both prospectively and retrospectively; (b) Quadrant II: The focal behavior inhibits the conditioned behavior, and the conditioned behavior activates the focal behavior; (c) Quadrant III: The focal behavior and conditioned behavior are mutually inhibited, both prospectively and retrospectively; (d) Quadrant IV: The focal behavior activates the conditioned behavior, and the conditioned behavior inhibits the focal behavior.

Once both analyses were completed, similarities were sought among the results of the different cases (classes) to determine the extent to which multiple cases emerged (Stake, 2006; Yin, 2014; Anguera, 2018). Given that a conventional criterion must be established to argue the presence of multiple cases, the results matching three or more conditioned behaviors concerning the criterion behaviors (in the lag sequential analysis) and with respect to the focal behaviors (in the polar coordinate analysis) were considered.

3 Results

According to the mixed methods approach, we are in the QUAN phase and present the results obtained in the lag sequential and polar coordinate analyses.

In relation to the lag sequential analysis, to analyze how the different actors participate in the classroom, influencing students' emotional regulation, the following categories emerge, giving rise to behavior patterns when each actor (criterion behavior) engages in the classroom.

Thus, in Table 1, we can see that when the head teacher (E1) participates, they re-emphasize (B13), contribute (B11), and/or change

² www.menpas.com

TABLE 1 Conditioned behaviors associated with the participation of the following speakers considered criterion behavior: Head teacher (E1), Assistant teacher (E2), Female student (E3), Male student (E4), Several students expressing the same idea at the same time (E5), and another adult or student in a higher class (E7).

R-3	R-2	R-1	R0	R + 1	R + 2	R + 3	R + 4
	S2	A12	E1	C2142			
		C21112	B13	S1			
		S1	B11	S2			
		S2	B12	A41			
		C2142	A41	B11			
		C2141	A31	B13			
		B11	A12				
		B12	B14				
		B13					
		S2	E2	S2			
			B12				
S2	B13	A41	E3	A41		S1	
		B11	A11	B11			
		B13	B11	B13			
		S1		C2142			
		S2		S1			
				S2			
		B11	E4	B11	B13		
		B12	A12	B13			
		B13	B14	C2142			
		A12	C21115	S1			
		S1	B12	S2			
		S2	B13				
S1	S1	A11	E5	B11	S2		
S2	S2	B11	A12	B12	B11		
	B11	S1	S1	S1			
		S2	S2	S2			
		C2142	B11				
			B12				
		B12	E7		B12		B12
			B12				S1

Table shows significant results of the lag sequential analysis. Conditioned behaviors (categories) in Roman print represent an activating relationship, and those in italics represent an inhibiting relationship. The table shows the behaviors that occur before and after each of these actors participate in the school classroom.

(B12) the topic of conversation; they relate other people’s behaviors to their emotional states (A41) and/or show awareness of the emotional reactions of others (A31), they inhibit the confusing expression of emotions (A12) and the possibility of being distracted from the topic (B14). Before the head teacher (E1) starts speaking, in R-1, emotions will have been expressed in a confusing manner (A12), an extremely low tone of voice will have been heard (C21112), murmuring (S1), parallel conversations (S2) or a pause of silence more (C2142) or less (C2141) than 1 sec will have occurred, inhibiting the possibilities of contributing to (B11) or re-emphasizing (B13) the topic of conversation, or definitively changing it (B12); and in R-2 parallel conversations will have been inhibited (S2). After the teacher’s participation (E1), in R + 1, a silent pause of more than 1 sec will

be observed (C2142), or there will be murmuring (S1), parallel conversations (S2), inhibiting the possibilities of re-emphasizing (B13) or contributing (B11) to the topic of conversation, and/or of relating other people’s behaviors to their emotional states (A41).

When the assistant teacher (E2) participates, they usually change the topic of conversation (B12). Before the assistant teacher (E2) starts speaking, in R-1, parallel conversations (S2) will have been heard, which will also be heard after they participate in R + 1.

When a female student (E3) participates, they contribute to the topic of conversation (B11), expressing emotions clearly (A11). Before a female student (E3) starts speaking, in R-1, the student will have re-emphasized (B13) or contributed (B11) to the topic of conversation, a person’s behaviors will have been related to their emotions (A41),

inhibiting parallel conversations (S2) and murmuring (S1); in R-2 the possibility of re-emphasizing (B13) the same topic of conversation will have been inhibited; and in R-3 parallel conversations (S2) will have been inhibited. After the participation of a female student (E3), in R + 1, she will contribute to (B11) or re-emphasize (B13) the topic of conversation, and/or other people's behaviors will be related to her emotions (A41), inhibiting parallel conversations (S2), murmuring (S1), and/or a silent pause of more than 1 sec (C2142); and in R + 3 murmuring will be inhibited again (S1).

When a male student (E4) starts speaking, they tend to distract from the topic (B14), showing emotions in a confusing manner (A12), with a regular tone of voice (C21115), inhibiting the possibility of re-emphasizing (B13) or changing (B12) the topic. Before the participation of a male student (E4), in R-1, the topic of conversation will have been contributed to (B11), re-emphasized (B13) or changed (B12), inhibiting parallel conversations (S2), mumbling (S1) and confused expression of emotions (A12). After the participation of a male student (E4), in R + 1, the topic of conversation will be re-emphasized (B13) or contributed to (B11), inhibiting parallel conversations (S2), murmuring (S1) and/or a silent pause of more than 1 sec (C2142), and in R + 2 the possibility of affecting the same topic will be re-emphasized (B13).

When several students express the same idea at the same time (E5), they express emotions in a confused way (A12), with murmuring (S1) and/or parallel conversations (S2), inhibiting contributions to the topic (B11) and/or the possibility of changing the topic of conversation (B12). When several students express the same idea at the same time (E5), in R-1, the topic of conversation will be contributed to (B11), emotions will have been clearly expressed (A11), while inhibiting parallel conversations (S2), murmuring (S1) and/or the presence of a silent pause of more than 1 sec (C2142); in R-2, parallel conversations (S2), and/or murmuring (S1) will be present, inhibiting the possibilities of contributing to the topic (B11). In R-3, parallel conversations (S2), and/or murmuring (S1) will be inhibited. After several students express the same idea at the same time (E5), in R + 1, they will contribute to the topic of conversation (B11) and/or change the topic (B12), inhibiting both murmuring (S1)(3/9) and parallel conversations (S2); and in R + 2 parallel conversations (S2) will be observed again, inhibiting contributions to the topic of conversation (B11).

When a non-teaching adult or student from a higher grade (E7) participates, the topic of conversation (B12) usually changes. Before the participation of a non-teaching adult or student from a higher grade (E7), in R-1, the topic of conversation (B12) will have changed, and after their participation, the topic of conversation (B12) will change again. In R + 2 and R + 4, murmuring is also observed in this lag (S1).

Next, a polar coordinate analysis is carried out to determine the interrelationships among the actors present in the classroom that were most significant in the lag sequential analysis, and where each of these speakers is considered focal behavior and all dimensions are conditioned behaviors.

The participation of the head teacher (E1) (Table 2) is mutually activated by the participation of a female student (E3), a male student (E4), and/or the presence of a silent pause of more than 1 sec (C2142); by the participation of several students expressing the same idea at the same time (E5), and by the presence of a silent pause of less than 1 sec (C2141). Likewise, the teacher's participation is mutually activated by

the confusing expression of emotions (A12), inhibition when addressing a problem (D33), and/or the presence of murmuring (S1). The participation of the head teacher (E1) is mutually inhibited by the use of directive language (C13), the identification of a problem (D1), and/or the presence of parallel conversations (S2), with the participation of the assistant teacher (E2), and/or the action of encouraging student participation (B21), and with the behaviors of changing the topic of conversation (B12), regulating the participation of specific individuals (B24) and/or proposing solutions to a problem (CD21). Likewise, the participation of the head teacher (E1) is mutually inhibited by the participation of a non-teaching adult or student from a higher grade (E7), the actions of contributing to the topic of conversation (B11), limiting the participation of others (B22), encouraging students to self-regulate their participation (B23) and/or showing calmness when addressing a problem (D31), and using informative language (C11) and/or showing aggression when addressing a problem (D34).

The participation of the assistant teacher (E2) (Table 3) is mutually activated by the use of informative language (C11) and the presence of parallel conversations (S2), and by the participation of several students expressing the same idea at the same time (E5), the use of expressive language (C12), and/or the actions of contributing to (B11) or distracting from (B14) the topic of conversation. The participation of the assistant teacher (E2) is mutually inhibited by the participation of the head teacher (E1), with behaviors of relating other people's behaviors to their emotions (A41), encouraging students to self-regulate their participation (B23), identifying a problem (D1) and/or addressing it by proposing a solution (D21), with the actions of showing awareness of others' emotional reactions (A31), limiting the participation/expression of others (B22), addressing a problem calmly (D31) and/or murmuring (S1), and with the participation of a female student (E3), changing the topic of conversation (B12), and/or the use of directive language (C13).

The participation of a female student (E3) (Table 4) is mutually activated by the participation of the head teacher (E1) and the invitation for other people to express themselves (B21) through the use of informative language (C11), and the behavior of contributing to the topic (B11) and/or relating other people's behaviors to their emotional states (A41), and through the identification of a problem (D1). The participation of a female student (E3) is mutually inhibited by the participation of a male student (E4), with the participation of several students expressing the same idea at the same time (E5), and/or the presence of parallel conversations (S2) and with the presence of murmuring (S1). In addition, the participation of a female student (E3) is mutually inhibited by the use of directive language (C13), the action of regulating the participation of specific individuals (B24), and the participation of the assistant teacher (E2), an administrator (E6), and/or a non-teaching adult or student from a higher grade (E7), and/or the behaviors of changing the topic of conversation (B12), encouraging students to self-regulate their participation (B23), and/or proposing a solution to a problem (D21).

The participation of a male student (E4) (Table 5) is mutually activated by the participation of the head teacher (E1) and the invitation for other people to express themselves (B21) through the behavior of contributing to the topic (B11), through the use of informative language (C11), as well as the actions of re-emphasizing the topic of conversation (B13) and/or relating other people's behaviors to their emotional states (A41), and through the identification of a problem (D1). When a male

TABLE 2 Multiple cases: participation of the head teacher (E1) as a focal behavior with category selection as conditioned behaviors.

CLASS	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
1	C2142, E3, E4		A11, A12, A41, B12, B21, B22, B23, B24 , C12, C13, D1, D21, D24, D31, D33, E7	B14
2	C2142, D33, E3, E4		A31, B11, B12, B21, B22, B24, C13, D1, D21, D24, D31, D34, E2, E7, S2	
3	A12, C2142, E3, E4, E5, S2		B11, B12, B13, C13, D1, D21, E6	
4	A12, C12, C2142, E3, E4, E5, S1		B11, B12, B13, B21, B23, B24, C11, C13, D1, D21, D31, D32, D35, E2, E6, E7, S2	
5	A41, C2141, C2142, E3, E4, S1		A11, B22, B21, C13, D1, D21, D31, D34, E2, S2	
6	A21, C11, D24, D33, D35, E3, E4, E5	B12	B23, B24, C13, D1, D34, E2, S2	
7	C2141, C2142, E5	D35	A51, B14, B21, B22, B24, C11, C12, D1, D22, D32, E3, E7, S1, S2	
8	A21, B11, E3, E4, E5, C11, C2141		B23, B24, C13, E2, S1, S2	
9	A11, A12, A31, C12, C2141, C2142, D1, D24, D31, D33, D35, E6, E7, S1		B11, B12, B21, B22, C11, D23, E2, E5, S2	

Categories repeated in the same quadrant more than 3 times are in italics, and those categories present more than four times in the same quadrant are highlighted in bold.

TABLE 3 Multiple cases: participation of the assistant teacher (E2) as a focal behavior with category selection as conditioned behaviors.

CLASS	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
1	A12, B13, B24, C12, E5, E7		B21, B22, C11, E3	
2	B11, C13, D1, D21, D22, D24, D31, D34, D35, E4		A41, B12, B22, B23, E1, E3, E7, S1, S2	C12
3	D1	E4, S2		B12, E5
4	B12, B14, C11, S2	E7	A41, B22, B23, C12, D1, D21, E1, E6, S1	
5	A11, C11, C12, D34, E5, S2		A31, A41, B12, B13, B23, B24, C13, C2142, D1, D21, D31, D32, E1, E3, E4, S1	
6	B11, B14, B22, C11, C12, C2141, C2142, E3		A31, A41, B13, B23, C13, D1, D21, D24, D31, E1, S2	
7		E5		S2
8	B14, B23, C13, S2		A11, A21, A31, A41, B11, B21, B22, C11, C2141, D1, D21, D22, D31, D35, E1, E5	
9	B11, B21, C11, D23, E4, E5, S2		A31, B12, B13, B14, B23, B24, C13, C2141, C2142, D1, D21, D22, D24, D31, D32, D33, D34, E1, E6, E7, S1	

Categories repeated in the same quadrant more than 3 times are in italics, and those categories present more than four times in the same quadrant are highlighted in bold.

student (E4) participates, the possibility of identifying a problem (D1) is inhibited, and the identification of a problem (D1) activates the participation of a male student (E4). The participation of a male student (E4) is mutually inhibited by the participation of a female student (E3) and/or the presence of parallel conversations (S2) and murmuring. Similarly, the participation of a male student (E4) is mutually inhibited by the participation of a non-teaching adult or student from a higher grade (E7) and/or the presence of a silent pause of more than 1 sec (C2142), and by the participation of several students expressing the same idea at the same time (E5), the use of directive language (C13), the behaviors of distracting from the topic of conversation (B14) and/or encouraging participants to self-regulate their participation in the classroom (B23). The behavior of identifying a problem (D1) is present in both quadrants I and II, which indicates that identifying a problem (D1) always activates the participation of a male student (E4), while the participation of a male student (E4) sometimes activates the identification of a problem (D1) and sometimes inhibits such a possibility.

The participation of several students expressing the same idea at the same time (E5) (Table 6) is mutually activated by the action of contributing to the topic (B11), the use of informative language (C11), the participation of the head teacher (E1), the use of expressive language (C12), the behavior of inviting or encouraging the self-regulation of students in their participation in the classroom (B23), the use of directive language (C13), and/or the action of favoring the expression/participation of others (B21). The participation of several students expressing the same idea at the same time (E5) is mutually inhibited by the participation of a female student (E3) and/or the presence of parallel conversations (S2), the presence of murmuring (S1) in five of the nine classes, and the participation of a male student (E4), the use of directive language (C13), and/or the presence of a pause of silence of more than 1 sec (C2142). The use of directive language both activates and inhibits the participation of several students expressing the same idea simultaneously (E5), depending on the different episodes that occur in the classroom and/or the variability between the classes.

TABLE 4 Multiple cases: participation of a female student (E3) as a focal behavior with category selection as conditioned behaviors.

CLASS	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
1	A41, B11, B21, C11, D32, E1	S1	B13, B14, B23, B24 , C12, C13 , <i>D21</i> , D34, <i>E2</i> , E4, E5, E7, S2	
2	A41 , A51, B11, B21, C11 , C12, C13, <i>D1</i> , D22, D24, D31, D33, D35, E1		B14, B22, B23, B24 , C2142, D23, <i>E2</i> , E4, E5, S1, S2	D34
3	B11, B21, C11, E1		<i>B12</i> , B24, C13 , C2142, D1, D32, <i>E4, E6, S1, S2</i>	D35
4	B11, B21, C11, D1 , D31, E1, E7	D21, D23, C2142	<i>B12</i> , C12, C13, E4, E5, E6, S1, S2	
5	B13, B21 , D32, E1	A41	<i>E2, E4, E7, S2</i>	C12
6	A41 , E1, E2		A11, A12, C2142, <i>D21</i> , D33, E4, E5, S1	S2
7	A41, B21 , B24, C11 , S1, S2	B12	B13, B23, C13, D21 , E1, E5	A11
8	A21, A41 , A51, B11, C11, D1 , D23, D35, E1	A11, B21	<i>B12, B24, E4, E5, E7, S1, S2</i>	A12
9	B13, B21 , D24, D33, D34	B24, C13	A12, D23, E4, E5, E6, S2	C11, C2141

Categories repeated in the same quadrant more than 3 times are in italics, and those categories present more than four times in the same quadrant are highlighted in bold.

The participation of a school administrator (E6) (Table 7) is mutually activated by the action of encouraging/inviting students to self-regulate their participation in the classroom (B23) and mutually inhibited by the participation of a female student (E3) and/or the use of informative language (C11).

The participation of a non-teaching adult or student from a higher grade (E7) (Table 8) is mutually activated by the use of informative language (C11) and/or the change in the topic of conversation, by the use of expressive language (C12), the confused expression of emotions (A12), addressing a problem without proposing solutions (D24) and/or the presence of murmuring (S1). When a non-teaching adult or student from a higher grade (E7) participates, the possibility of being distracted (B14) from the topic of conversation is inhibited. When distraction from the topic of conversation (B14) occurs, the participation of a non-teaching adult or student from a higher grade (E7) is activated. The participation of a non-teaching adult or student from a higher grade (E7) is mutually inhibited by the presence of parallel conversations (S2), the participation of the head teacher (E1), and the participation of a male student (E4), the use of directive language (C13) and/or distraction from the topic of conversation (B14), and by the behaviors of favoring/inviting self-regulation in the students' participation (B23), the regulation of certain individuals (B24), and/or the presence of murmuring (S1).

Distracting from the topic of conversation (B14) is present in both quadrants II and III, which indicates that the participation of a non-teaching adult or student from a higher grade (E7) in the classroom always inhibits the possibility of distracting from the topic of conversation (B14). In comparison, a distraction from the topic of conversation (B14) sometimes activates the participation of a non-teaching adult or student from a higher grade (E7) and, at other times, inhibits their participation.

4 Discussion

This study has analyzed how the different actors participate in the classroom to promote emotional self-regulation in a natural setting, like school. Mixed methods were chosen to access qualitative data through systematic observations that make it possible to detect the daily interactions that influence, intentionally or not, the socialization processes that schools perform, then analyze the data quantitatively and finally interpret them qualitatively. In this sense, it is essential to

emphasize that the mixed methods approach has proven to be fundamental to integrating qualitative and quantitative elements, obtaining robust results from the information collected through audio recordings.

Since detecting multiple cases was the objective, it was possible to confirm the similarities in the analysis of classes that might be regarded as distinct because they are in schools in different territories and have varying student populations. Their actors might have displayed different modes of interaction and methods of emotional regulation.

Thus, a review of the multiple cases detected reveals, when the data are analyzed quantitatively, the low participation of the students, highlighting in each case the prominent role played by the head teacher as the axis of emotional, academic, and conflict management processes. Therefore, neither the assistant teacher nor the students have substantial involvement in the classroom, which implies fewer opportunities to play autonomous roles. In this regard, a dynamic is noted in which the students respond to the adults (especially the head teacher), establishing relationships that do little to promote autonomy. In addition, we also observe dynamics where, when students speak, the thread of the topic of conversation is diverted, and the teacher seeks to exercise again the role of driving force of the process, apparently assuming that the students by themselves could hardly achieve the class objectives. Therefore, it is recommended that these practices be critically examined with the teaching staff to encourage gradual changes that enable the transfer of control over the teaching-learning process to the students.

Not doing so implies difficulties in developing skills that would enable them to face conflict situations and exhibit more socially adapted behaviors. Samper (2014) identified these processes as necessary for successful emotional self-regulation, allowing them to best manage stressors and psychosocial risks. They can also practice and develop various techniques for regulating their emotions and different approaches to negotiating with others in this regard, developing metacognitive skills by observing themselves in the process of emotional regulation (Rieffe, 2016).

In this light, it becomes necessary to highlight the role of educators and educational community members in generating spaces for expression and effective emotional regulation (Alarcón-Espinoza et al., 2023a), where there are spaces for daily dialogue and joint learning through exposure to different points of view that can be expressed among classmates (Alarcón-Espinoza et al., 2023b).

TABLE 5 Multiple cases: participation of a male student (E4) as a focal behavior with category selection as conditioned behaviors.

CLASS	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
1	B11, B21, C11, E1	S1	A11, B23, C13, C2142 , D1, D24, D32, D34, E5, E7, E3, S2	B24
2	A41, B11, B21, C11 , C2141, D1, D23, D24, D31, D34, E1, E2		B12, B14, B22, B23, C12, C13, D22, D35, E3, E5, S1, S2	
3	A11, B12, B13, B21 , B24, D1, D21, D24, D32, D33, D34, E1		E3, E5, E6, S1, S2	E2
4	B11, B13, B24, C11 , C13, D1, D22, E1, E7		C2142 , E3, S1, S2	A12, B14, D23, C12, D24, E5
5	A31, A41, B11, B13, B21, C11, E1	B12, D1	B22, C2142 , D24, D32, E2, E3, S1, S2	
6	C2142, D33, E1, S1	B24, D1	E3, E7, S2	
7	B21, C11 , E5, S2		S1	A31, B22
8	A31, B11, B21, C11, E1	A41, C2141, D1, D22,	B14, E3, E7, S1, S2	
9	A41, B11, B13, B21, C11 , E2		B12, B14, B23, C13, C2141, C2142 , D1, D21, D22, D31, E3, E6, E7, S1, S2	A21, D23, D35

Categories repeated in the same quadrant more than 3 times are in italics, and those categories present more than four times in the same quadrant are highlighted in bold.

TABLE 6 Multiple cases: participation of various students expressing the same idea at the same time (E5) as a focal behavior with category selection as conditioned behaviors.

CLASS	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
1	A11, B23 , C13, E2, S2	B11, C11	B21, C2142, D32, D34, E3, E4	B13, B24, D21
2	A12, B22, B23, C12 , C13, E7, S1	B14	B11, C11, D1, D24, D31, E3, E4, S2	
3	B11, C11 , D32, E1	A31, C2142, D22, E2, E6	E4, S1, S2	A51
4	A12, B11 , B12, B14, B23, C12 , C13, D1, D21, D31, E1, E6	B21, C11, E4	C2142, E3, E7, S2	S1
5	B11, B21 , C11, E2	C2142	B13, B24, C13, D21, E7, S1, S2	A21, C12
6	A31, A41, B11 , B21, B22, C11, D1, D21, D24, D31, E1, S1	D23, D34	E3, S2	A21, D35
7	A11, B11, B23, C12 , E1, E4	A31, A41, B21, D1	E3, S1, S2	D35, E2
8	B11, C11 , E1		A21, B24, D35, C13, E2, E3, S1, S2	B22, D23
9	A21, A31, A41, B11, B21 , C11, C12, D23, D35, E2		B12, B14, B24, C13, C2141 C2142, D1, D21, D22, D32, D34, E1, E3, S1	B13, B22, S2

Categories repeated in the same quadrant more than 3 times are in italics, and those categories present more than four times in the same quadrant are highlighted in bold.

In the meantime, a student is likely to contribute to or distract from the subject matter, usually mediated by a comment from the head teacher. However, the behavior of several students expressing the same idea at the same time, associated with the confusing expression of emotions, in conjunction with murmuring, parallel conversations, and the inhibition of contributions to the topic, is highly recurrent and raises questions as to what is understood by student participation, observing that it is often a favored or little inhibited behavior, where the teacher asks a question and the children “participate” by answering the same idea at the same time. As observed, far from allowing a deeper understanding of the subject, this tends to discourage dialogue and individual contributions from the students, which are important to maintain to promote the co-construction of learning processes. This holds true especially when dealing with pre-adolescents who should have an emotional awareness that allows them to put themselves in the place of others, accepting the possibility of experiencing different emotions simultaneously (Stegge and Meerun Terwogt, 2007),

“reading the minds of others” (Villanueva and Góriz, 2016), understanding their emotions by differentiating between the emotional states of themselves and others (Marchesi, 2017) and thus favoring processes of cognitive reappraisal of emotions (Montoya et al., 2018), adaptation and resilience (Morales et al., 2021).

Concerning the observation of classroom interactions, it is important to note that the instrument used (OCAE) was designed *ad hoc* for this research. While it can be used as a reference for future studies, it should be carefully reviewed and adapted to each context.

In this light, future studies must review the meaning of the interactions in the classroom, both those that occur between students and those observed between teachers and students, since, as stated in Zhu and Shuai (2023), the quality of these interpersonal relationships is associated with the quality of the learning, noting that, as indicated by Sankalaite et al. (2023), teacher-student relationships play an important role in students’ academic and cognitive development.

TABLE 7 Multiple cases: participation of a school administrator (E6) as a focal behavior with category selection as conditioned behaviors.

CLASS	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
1				
2	B14, S2		B11, C11	B23
3	B14, B23, C13, D24, D31, S1	B12	B11, D32, E1, E3, E4, C11	A11, A21, A41, C12, D33, E5
4	B11, B23, C12, E5, E7	D21	A12, A41, B13, B14, B21, D1, D31, E1, E2, E3, S1	
5				
6				
7				
8				
9	A12, B23, C13, C2141, D1, D22, D24, D31, D32, E1, S1	B12, B22	B21, C11, C2142, E2, E3, E4, S2	

Categories repeated in the same quadrant more than 3 times are in italics.

TABLE 8 Multiple cases: participation of a non-teaching adult or a student from a higher grade (E7) as a focal behavior with category selection as conditioned behaviors.

CLASS	Quadrant 1	Quadrant 2	Quadrant 3	Quadrant 4
1	A11, A12, A21, A31, A41, B11, B12 , B22, B23, B24, C12, C13, D1, D21, D23, D24, D31, D33, E2	B14	B21, C11, C2142, E1 , E3, E4, S2	D35
2	A11, A12, A31, B11, B21, E5, C11 , C12		B12, B14 , B22, B24, D22, D23, D34, D35, C13 , C2142, E1 , E2, S1, S2	B13
3	B12 , C11	B14, C2142	B23, D1, D21, D31, S2	
4	B12 , B21, D1, D21, D23, D24, D31, D32, D35, E3, E4, E6, S2		B14 , B23, C13 , E1 , E5, S1	E2
5	B12 , S1	B24	A12, B11, B14 , E3, E5, S2	D35
6	B12 , B13, B22, C11 , S1		A11, B14 , B24, C12, E4, S2	
7	C11 , S1	A12, B14	B23, C13 , D21, D31, E1 , S2	
8	A12, A21, B23, C11 , C12, C2141, C2142, D24, D35	B21	B22, B24, C13 , E3, E4, S1, S2	A41, A51
9	B14, C13, C2141, D34, E1		B11, B21, E2, E4	

Categories repeated in the same quadrant more than 3 times are in italics, and those categories present more than four times in the same quadrant are highlighted in bold.

Therefore, the role of teachers in students’ comprehensive training (not just in content delivery) needs to be examined, considering both the contexts of each school and the institutional and/or governmental guidelines to which they must respond. As [García Amilburu and García Gutiérrez \(2017\)](#) indicate, it is impossible to establish a separation between the content and the method used to deliver that content, and the teachers’ attitude is very relevant as it may or may not facilitate learning opportunities and the development of students’ emotional regulation.

In this regard, and according to [Halberstadt et al. \(2020\)](#), there is a need to study the different beliefs of teachers about the emotions at the core of socialization processes in general and those that develop in the classroom in particular, highlighting the relevance of the educational intentionality of teachers and the school in general ([Carrasco et al., 2015](#)) to educate emotionally to prevent school bullying ([Rueda et al., 2021](#)) and influence everyday practices and communications ([Gutiérrez-Pérez and Del Barrio, 2012](#)). This will lead students through the process of creating life projects that, with the teachers’ help, will always be present as one of the most significant markers of this educational relationship’s

success, which will be seen when, after it has served its purpose, this relationship is deemed no longer necessary ([García Amilburu and García Gutiérrez, 2017](#)).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Bioethics committee of the University of Barcelona through the Institutional Review Board (IRBC)0003099. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants’ legal guardians/next of kin.

Author contributions

MA-E: Writing – original draft, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. PS: Writing – review & editing, Supervision, Conceptualization. MTA: Writing – review & editing, Validation, Supervision, Methodology, Investigation, Formal analysis.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1330941/full#supplementary-material>

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Q methodology as an integrative approach: bridging quantitative and qualitative insights in a mixed methods study on mathematics teachers' beliefs

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Introduction: This study explores the beliefs of pre-service mathematics teachers regarding the teaching and learning of mathematics.

Methods: We employed a mixed methods approach, combining quantitative Likert-scale surveys and Q methodology, an integrative quantitative and qualitative approach. A sample of 33 pre-service teachers participated in the study. Initially, Likert-scale surveys were used to ascertain general trends in belief orientations. Subsequently, the same participants engaged in a Q sort exercise, which allowed for a nuanced exploration of individual belief systems by prioritizing the same survey statements within a forced-choice grid. Qualitative interviews further enriched these findings.

Results: Q methodology analysis identified distinct belief profiles, characterized by their prioritization of specific educational practices and the contextual and subjective interpretations that underpin these preferences. The qualitative interviews provided deeper insight into the reasoning behind participants' choices in the Q sort, illustrating the complex, sometimes contradictory nature of personally held beliefs that traditional Likert-scale approaches may obscure.

Discussion: Our results underscore the utility of combining Q methodology with conventional teacher belief survey techniques to achieve a more holistic understanding of pre-service teachers' beliefs. This approach reveals the complexity within individual belief systems and highlights the potential for mixed methods research to refine the measurement and interpretation of psychological constructs in educational settings.

KEYWORDS

Q methodology, Q sort, Likert, beliefs, pre-service teachers, mathematics, mixed methods

1 Introduction

Teacher beliefs about the teaching and learning of mathematics play a central role for mathematics teachers' instructional actions in the classroom. They represent an affective component of mathematics teacher competence and are, thus, assumed to have an influence on their interaction with the world, i.e., also in their classroom (Philipp, 2007). Typically, in empirical psychological studies in mathematics education, beliefs are understood as personality traits and are methodically investigated quantitatively via Likert scale-based surveys. In these, items are formulated in statements and the degree of individual agreement

to items is measured (e.g., Laschke and Blömeke, 2013; Voss et al., 2013). Correspondingly, researchers utilize primarily quantitative data evaluation techniques such as exploratory and confirmatory factor analyses to unveil belief-dimensions as hidden patterns in the items influencing respondents' beliefs. One notable application of this approach was for example in the international TEDS-M study and its follow-up studies that analyzed (future) mathematics teachers' professional competence, and also surveyed teacher beliefs on the nature of mathematics and the teaching and learning of mathematics (Tatto et al., 2008; Wang and Hsieh, 2014; Yang et al., 2020).

However, there is criticism with respect to the application of Likert-scale surveys in the study of teachers' beliefs. Among other criticisms, it is commonly noted that items can be answered independently of each other (Carifo and Perla, 2007) and that the situation-specific context of teaching is usually not included in the formulation of items (Seifried, 2009). This may then obscure teachers' differentiated interpretation of the items (Safrudiannur and Rott, 2019, 2020, 2021). Thus, when answering, it is hardly possible for the teachers to express their subjective and individual interpretation of the items, which is related to their actual classroom experience. This then may affect the validity of the results that are obtained by the use of respective instruments (Aeschbacher and Wagner, 2016; Biedermann et al., 2016). However, these context-specific interpretations of items are especially relevant for the study of mathematics teachers' beliefs when it comes to the question how they are related to teachers' expertise and their actual teaching practice, as this relationship is of high complexity and still not clear. For example, when examining pre-service teachers who are still in teacher training, it can be assumed that they perceive or interpret the wording of a Likert item such as "Students learn mathematics best by attending to the teacher's explanations" differently than participants with a long professional experience and a lot of teaching practice. While the latter may be able to weigh up the meaning of different items situationally and are able to also cognitively process contradictory beliefs (Furinghetti and Pehkonen, 2002), the former may tend to make absolute assessments because each item has to be answered largely independently of their experience (Seifried, 2009; Buehl and Beck, 2015). Hence, in response to the criticism concerning measuring teacher beliefs, innovative research methods (and instruments) are needed in mathematics education research in which Likert-items can be discussed and related to each other so that the examination of teachers' subjective beliefs in more detail is possible and the complexity of the research object can be adequately addressed.

In this study, we therefore use a methodological approach that addresses this issue. Q methodology offers a nuanced mixed methods research technique that integrates both quantitative and qualitative approaches that can be used to measure teachers' beliefs more subjectively and allows researchers to identify and explore different patterns of thought within a group (Stephenson, 1953; Brown, 1980; Stenner and Stainton-Rogers, 2004; Newman and Ramlo, 2010; Ramlo, 2016). In our study, which is part of a Special Issue in Frontiers on Best Practice Approaches for Mixed Methods Research in Psychological Science, we show how we used Q-methodology to elicit the subjective beliefs of 33 prospective mathematics teachers (M. Ed.) on existing Likert-scale items that measure beliefs about the teaching and learning of mathematics. We chose an integrated mixed methods approach and analyzed the participants' patterns of thought both quantitatively and qualitatively. The aim of the study is to be able to make more precise statements about the belief patterns of pre-service teachers than would

have been possible using only a quantitative Likert-scale evaluation. To this end, we specifically highlight the strengths of our approach and the extent to which the mixed method approach provides added value to the survey of mathematics pre-service teachers' beliefs.

2 Theoretical background

2.1 Teacher beliefs

Teacher beliefs are one of the central affective components of teachers' professional competence (Shulman, 1986; Bromme, 1997; Seifried, 2009). As Dohrmann (2021) states, Pajares (1992) has aptly stated that whenever we speak of "teachers' beliefs" in general, we are always referring to teachers' beliefs about school, teaching, learning and students. Pajares (1992) wrote his well-known essay, in which he spoke about teachers' beliefs as a "messy construct" over 30 years ago. However, up to date, the various sub-disciplines of psychological and educational science, that deal with teachers each use their own terms for teachers' beliefs. Dohrmann (2021) describes that the terms used to describe teachers' beliefs range from "views" (Seifried, 2009) to "conceptions" in subject-didactical research (Hartinger et al., 2006). In studies on teachers, terms such as "subjective theories" (Martínez et al., 2017) or "educational beliefs" (Pajares, 1992; König, 2012) are used. "Teachers' beliefs," on the other hand, appear in research on teachers (Turner et al., 2009; Fives et al., 2015) as well as in subject didactical research (Thompson, 1992; Philipp, 2007).

This plethora of terms makes it obvious that despite extensive research on teachers' beliefs, especially in the context of pedagogical-psychological oriented approaches, a precise and universally accepted definition of beliefs remains elusive, underscoring the complexity of this concept within the educational field (Törner, 2002; Leder, 2019). Philipp (2007) defines beliefs as "the lenses through which one looks when interpreting the world" (p. 258). Richardson (1996) proposes a domain-unspecific definition of beliefs that is based on a broader understanding. She understands beliefs to be "psychologically held understandings, premises, or propositions about the world that are felt to be true" (Richardson, 1996, p. 103). This refers to a person's epistemological stands towards an object—its worldviews—, which includes affective attitudes and the readiness to act (Grigutsch and Törner, 1998) and which, in contrast to knowledge, are dependent on the degree of individual agreement (Beswick, 2005, 2007). These definitions suggest that beliefs encompass both cognitive and affective dimensions, influencing how individuals perceive and interact with their environment (Furinghetti and Pehkonen, 2002). Unlike professional knowledge, which is consensual, beliefs can vary significantly among individuals (Beswick, 2005; Philipp, 2007).

2.2 The fluidity and yet possible fixed nature of teacher beliefs and how they influence teaching practice

Teacher beliefs contain both conscious and unconscious elements, hypotheses and expectations. These beliefs are interconnected and influence each other. Some beliefs are more central and more firmly anchored than others (Furinghetti and Pehkonen, 2002). Centralized beliefs are considered to be relatively fixed in nature and to be only

changeable in the longer term within the scope of training processes, cumulative experiences or through radical changes based on key experiences (Beijaard and De Vries, 1997; Reusser et al., 2011), although it is not yet sufficiently clear which factors influence their changes in the development of expertise (Biedermann et al., 2015) and research yielded contradictory results so far (Dohrmann, 2021). So, with regard to the long-term development of beliefs, it is assumed that they are relatively stable with respect to restructuring, and to a certain extent can act as psychological filters and/or barriers (Reusser et al., 2011; Fives and Buehl, 2012). On the other hand, more peripheral beliefs are easier to adapt to new information and are closely linked to the development of expertise (Beijaard and De Vries, 1997; De Vries et al., 2014). So, beliefs can change in teachers' professional development (Swars et al., 2009; Eichler and Erens, 2015) or can be influenced by the abilities of students that are taught (Zohar et al., 2001; Beswick, 2018; Safrudiannur and Rott, 2019).

It is also assumed that beliefs are organized into an individual's belief systems, which are grouped around an object in the sense of an overarching affect, and in which different and even contradicting beliefs can coexist (Furinghetti and Pehkonen, 2002; Leder et al., 2002; Philipp, 2007). For example, a teacher may simultaneously believe that understanding mathematical concepts is more important than memorizing them, but still use many routine exercises in the classroom (Furinghetti and Pehkonen, 2002). This relativistic form, and especially the possibility of the coexistence of conflicting beliefs, make beliefs as an intrapsychic construct, with varying degrees of affective and cognitive components, particularly important when they become relevant in the complex context of teaching. This variability suggests that teachers may hold different beliefs depending on the situational context (Safrudiannur and Rott, 2019), challenging the notion of a direct and straightforward link between beliefs and behavior, such as in the enactment of teaching practices (Dohrmann, 2021).

Research on teacher action assumes a significant link between a teacher's actions in situational contexts and corresponding subjective beliefs (Thompson, 1992; Calderhead, 1996; Schoenfeld, 1998; Felbrich et al., 2010; Schmotz et al., 2010). It is proposed that beliefs orient and guide action, highlighting their fundamental role in teaching practices. This assumption is known as the consistency assumption (Grigutsch and Törner, 1998). Yet, the current state of research with respect to the relationship between teachers' beliefs and their teaching practices is not clear either: Some researchers have shown consistent beliefs and practices (e.g., Staub and Stern, 2002; Safrudiannur and Rott, 2017) whereas others have shown inconsistencies (e.g., Furinghetti and Pehkonen, 2002; Li and Yu, 2010; Cross Francis, 2015). One possible interpretation of these inconsistencies is that teachers may hold varying beliefs depending on the situation or context in question (Safrudiannur and Rott, 2020, 2021) or a different emotional involvement of teachers in action situations (Seifried, 2009). A lack of experience or external factors, such as support from school management or educational policy guidelines, can also lead to inconsistencies between teachers' beliefs and actions (Buehl and Beck, 2015).

2.3 Teachers' beliefs with regard to the teaching and learning of mathematics

Despite the complex nature of teacher beliefs and how they may or may not affect teachers' actions, there is agreement that beliefs can

be domain-specific (Törner, 2002; Eichler and Erens, 2015) or even situation-specific (Schoenfeld, 2010; Kuntze, 2011). For mathematics teachers, there is a broad consensus in the literature on the differentiation of profession-related beliefs. Ernest (1989, p. 250) proposes three views of mathematics: the relatively static instrumentalist view (mathematics is seen as an accumulation of facts, rules, and skills to be used in pursuit of some external end), the also rather static Platonist view (mathematics is seen as a static but unified body of certain knowledge), and the more dynamic problem-solving view (mathematics is seen as a process of inquiry and knowledge, not a finished product, for its results remain open to revision). Ernest (1989) also identifies these views with beliefs about teaching and learning mathematics. The instrumentalist view sees the teacher as an instructor who helps students master mathematical skills correctly, the Platonist view sees the teacher as an explainer who helps students understand mathematical concepts, and the problem-solving view sees the teacher as a facilitator who helps students construct knowledge. Other studies also identify these beliefs about the acquisition of mathematical knowledge or the teaching and learning of mathematics as a significant dimension of mathematics teachers' epistemological beliefs (Furinghetti and Pehkonen, 2002; Staub and Stern, 2002; Handal, 2003; Kuntze, 2011). In different studies from research on teachers' professional competence, transmission-oriented beliefs, in which students are viewed as passive recipients of knowledge (e.g., "Students learn mathematics best by attending to the teacher's explanations."), are distinguished from constructivist-influenced beliefs that endorse the principles of constructive learning (e.g., "Teachers should encourage students to find their own solutions to mathematical problems even if they are inefficient.") (Peterson et al., 1989; Staub and Stern, 2002; Laschke and Blömeke, 2013; Voss et al., 2013). Although the question of how teacher beliefs influence student achievement is far from conclusive, it is proposed that dynamic beliefs about mathematics and constructivist teaching-learning approaches are more strongly related to an emphasis on procedural, iterative mathematics in instructional settings (Reusser et al., 2011).

2.4 Studies on the relationship between mathematics teachers' beliefs and expertise

Studies on pre-service teachers in mathematics educational research consistently show that pre-service teachers usually already have initial beliefs about teaching and learning of mathematics at the beginning of their studies, which also influences the acquisition of their professional knowledge. In several studies, mathematics pre-service teachers therefore exhibit a strong tendency towards constructivist teaching-learning beliefs and a strong rejection of transmission-oriented beliefs (Schmeisser et al., 2013; Buchholtz and Kaiser, 2017). These beliefs are usually shaped by their own school experience as a learner of mathematics and the experiences of the university entry phase (Blömeke et al., 2014; Buchholtz and Kaiser, 2017). Constructivist beliefs about the teaching and learning of mathematics then increase throughout the entire teacher training while transmission-oriented beliefs stagnate even more. Prospective teachers within the TEDS-M study also showed strong constructivist beliefs (Felbrich et al., 2010). Pre-service teachers usually lack own teaching experiences at the beginning of their

studies, but gain first teaching experiences during their years of studies, for example in internships, which can challenge their beliefs and lead to changes in their belief systems (König et al., 2022).

Studies described by Safrudiannur and Rott (2019) emphasize this impact of teaching experiences on the beliefs and practices of teachers. Page and Clark (2010) illustrate that a teacher's experiences, both in teaching mathematics and as a mathematics learner, significantly influence their beliefs and instructional practices. Similarly, research by Huang et al. (2010) shows a distinct contrast between novice and experienced teachers in China, where novices prioritize effective teacher guidance, while experienced teachers focus on fostering students' mathematical and higher-order thinking skills. Conversely, larger-scale studies present conflicting results. For instance, Safrudiannur and Rott (2020) highlight that teaching experience, typically quantified by years, may not impact teachers' beliefs and practices as previously thought. Nisbet and Warren (2000) found no significant link between the duration of teaching and teachers' beliefs about mathematics instruction. Drageset (2010) observed that the number of teaching years does not correlate with beliefs regarding the importance of rules, correct answers, reasoning, or justification in teaching mathematics. Additionally, Wilkins (2008) reported that while teaching years have no direct effect on didactic beliefs and practices, there is an indirect negative effect. Similarly, Ren and Smith (2018) identified no association between years of teaching and either student-centered or teacher-centered beliefs. Beswick (2005) also noted a negative correlation between years of teaching experience and teachers' beliefs in a smaller study.

If we look on how teacher beliefs influence teaching practice, the focus of studies is more on in-service teachers. Empirical evidence from the German COACTIV study with in-service teachers has revealed a significant relation between constructivist-influenced beliefs about teaching and learning mathematics and the quality of teaching as well as student learning outcomes (Voss et al., 2013). However, these findings complement older findings that found stronger transmission-oriented beliefs among practicing teachers, whereby teachers with transmissive learning beliefs designed lessons in a less challenging and activating way, rather avoiding mistakes (Dubberke et al., 2008). Overall, the findings on beliefs among practicing teachers therefore do not seem clear (Reusser et al., 2011). Although Voss et al. (2013) found a strong negative correlation between them, there does not seem to be a fundamental contradiction between constructivist-influenced and transmission-oriented beliefs. Instead, the results of the COACTIV-study point to a crucial functional balance between different beliefs of teachers in varying teaching-learning contexts (Voss et al., 2013). It may therefore be advantageous under certain conditions or for specific groups of students if, on the basis of a constructivist orientation, transmissive beliefs are nevertheless accepted to a certain extent (Voss et al., 2013). Depending on the teaching situation, different beliefs may be relevant to teachers' professional actions, and beliefs therefore depend heavily on subjective judgements of the situation. Jaschke's (2018) findings in a study, that based on Q methodology, support the assumption of subjective situation-specific beliefs. In his study with mathematics pre-service teachers, he finds two types of teachers, one of which shows a rather dichotomous orientation towards a constructivist-influenced belief and rejects transmissive-oriented beliefs, while the second shows

agreement on both beliefs and shows a more mixed profile that integrates both constructivist-influenced and transmissive-oriented beliefs.

2.5 Different methods to investigate beliefs

If one looks at previous approaches to the empirical survey of beliefs in the field of teacher competence research from a methodological perspective (even beyond these studies), beliefs are primarily collected quantitatively using item rating procedures. One widely used method is the statistical evaluation of Likert scale surveys using exploratory and/or confirmatory factor analyses. These methods are generally used in studies with larger sample sizes to investigate the professional competencies of teachers, such as TEDS-M (Laschke and Blömeke, 2013) and COACTIV (Kunter et al., 2011), but also by Carter and Norwood (1997). This approach facilitates the comparison of individuals in relation to well-defined constructs and proves to be effective for the study of long-lasting beliefs or perspectives. In general, this approach to surveying teachers' beliefs offers the possibility of collecting large amounts of data with little effort and subsequently evaluating it quantitatively.

However, the survey method can conceal context- and subject-related forms of expression of beliefs, when surveying teachers in different expertise groups. For example, in traditional Likert scale surveys, teachers with different levels of expertise may rate the items differently (Safrudiannur and Rott, 2019). They found that teachers that teach in classes with many low-achieving students prioritize items differently than those teaching in classes with many high-achieving students, the former prioritizing more instrumental beliefs and the latter prioritizing more dynamic beliefs. Furthermore, there is evidence that context-independent Likert-based assessment procedures favor socially desirable responses in terms of prioritizing constructivist beliefs (Di Martino and Sabena, 2010; Aeschbacher and Wagner, 2016; Safrudiannur and Rott, 2020, 2021). In addition, Likert scale surveys often present items independently of context, so that the individual statements do not have to be related to each other (Carifo and Perla, 2007; Seifried, 2009). From the point of view of researching beliefs in different expertise groups (e.g., pre-service teachers vs. in-service teachers) or with reference to different contexts, the question therefore arises of context- and subject-related survey methods of beliefs that go beyond previous approaches aimed at persistent constructs.

On the other hand, purely qualitative methodological approaches also exist in more educational research on the beliefs of (mathematics) teachers. They can represent an alternative to the application of Likert-scale surveys as they can take much greater account of the subjectivity of the interviewees. Generally, teachers are interviewed about their beliefs (e.g., Gräsel et al., 2006; Harteis et al., 2006; Hirsch and Buchholtz, 2023), which are then usually reconstructed qualitatively. However, the methodological disadvantage here is that the questions with which the interviewees are asked to articulate their beliefs are usually quite open, which can lead to difficulties in the comparability of reconstructed beliefs or difficulties to relate the obtained results to previous research findings. In addition, the reconstructions can also be highly dependent on the interpretation of the researcher. This also poses challenges for the trustworthiness of the results obtained with regard to the methodological instrument of data collection.

From a methodological perspective, both strengths and weaknesses can be identified in the investigation of mathematics teachers' beliefs in both quantitative and qualitative approaches. Due to their subjectivity, beliefs are also highly complex and extremely difficult to measure methodologically. It therefore seems promising to pursue integrative approaches within the framework of mixed methods research designs and to develop innovative instruments that integrate quantitative and qualitative measures (Johnson and Onwuegbuzie, 2004; Gläser-Zikuda et al., 2012).

2.6 Q methodology as a mixed methodology and its utility in measuring teacher beliefs

One such mixed method measurement approach that has already been used to investigate mathematics teacher beliefs (Jaschke, 2017, 2018; Lim-Ratnam et al., 2022) is Q methodology (Müller and Kals, 2004; Newman and Ramlo, 2010; Coogan and Herrington, 2011). Q methodology, already introduced by Stephenson (1953) and further elaborated by Brown (1980), is a less frequently used methodology in mathematics educational and psychological research, but is particularly useful when studying beliefs as it studies human subjectivity. Researchers can explore different 'points of view' on a particular issue among groups of people (Coogan and Herrington, 2011), as Q studies investigate correlations between individuals, rather than items. This methodology does not impose predetermined meanings on participants. Instead, participants determine what holds meaning and significance from their own perspectives through a process called Q sorting, where they rank belief statements on a range. The data collected from multiple individuals is then subjected to a quantitative inverse factorial analysis in order to identify shared belief systems or perspectives (i.e., different types of sorts based on persons, not items), revealing groups of people who have ranked statements in a similar order. This yields a set of factors represented by all the presented statements configured in distinct and characteristic ways, rather than different subsets of the statements. The interpretation and significance of these configurations are attributed *a posteriori* through analysis, rather than predetermined assumptions. Different participants may interpret a statement differently, for instance, one person may perceive a transmission-oriented statement as negative, while another may interpret it as a positive statement, especially in contexts like teaching students with learning difficulties (Coogan and Herrington, 2011).

The main aim of Q methodology is therefore to form types of subjective views of a certain subject area that reveal similarities and differences in subjective construction (cf. Müller and Kals, 2004). While traditional Likert-scale questionnaires require large samples for statistical significance, Q methodology can yield meaningful insights with a small, targeted sample (Ernest, 2011; Ho, 2017). Typically, Q methodology works with 10 to 50 participants (Brown, 1980). In addition to Q sort data, individual comments and explanations provided during the Q sort process give context and depth to these shared perspectives when analyzed qualitatively, offering a richer and even more nuanced understanding of participants' beliefs (Brown, 1980; McKeown and Thomas, 1988). While traditional surveys often aggregate data to find common trends, Q methodology focuses on the subjective experiences and interpretations of individuals, making it a

valuable tool in educational and psychological research. Q methodology has been successfully applied in empirical studies on teachers' beliefs (Rimm-Kaufman et al., 2006; Ernest, 2011; Jaschke, 2017, 2018; Lundberg, 2019; Lim-Ratnam et al., 2022).

This integration of quantitative analysis and qualitative insights (Johnson and Gray, 2010) offers a comprehensive view of the complex interplay of beliefs within a certain group. This combination makes Q methodology as a mixed methodology particularly powerful, as it bridges the gap between numerical data and human narrative, ensuring that the subjectivity of personal considerations of participants and the context sensitivity of beliefs are preserved in the quantitative analysis (Stenner and Stainton-Rogers, 2004; Ridenour and Newman, 2008; Ramlo and Newman, 2011). This integrative mixed methods approach to studying teacher beliefs combines the specific strengths of individual methodologies and compensates for their methodological weaknesses (Johnson and Onwuegbuzie, 2004; Johnson and Christensen, 2017; Schoonenboom and Johnson, 2017).

3 Research design and methodology

3.1 Research questions

Accordingly, in this study, we follow the approach of Jaschke (2017, 2018) and consider how mathematics pre-service teachers' beliefs about mathematics teaching and learning can be analyzed using Q methodology. In an integrated approach, we combined a quantitative standardized Likert scale questionnaire survey on beliefs with a Q sort of the same items and interviewed the participants after their Q sort about the perceived similarities and differences between the two quantitative approaches and their subjective perception of the statements, thus also enabling qualitative aspects of Q methodology. Both quantitative and qualitative data collection were integrated into a quantitatively driven concurrent-sequential (quan + QUAN) → qual mixed methods research design (Morse, 1991; Schoonenboom and Johnson, 2017). The rationale for this design is twofold: first, to clarify the importance of Q methodology in the study of beliefs and to explore its advantages over Likert scale methods (which is why these quantitative findings are prioritized – which in mixed methods designs is indicated with the “quan” in capitals); and second, to highlight the subjective nature of pre-service teachers' beliefs by complementing quantitative findings with qualitative findings (Greene et al., 1989; Kelle and Buchholtz, 2015). We sought to answer the following research questions:

RQ1 (quan): What types of beliefs about the teaching and learning of mathematics are found among pre-service teachers using the Likert scales, and how can they be characterized?

RQ2 (QUAN): What types of beliefs about the teaching and learning of mathematics are found among pre-service teachers using the Q-method, and how can they be characterized?

RQ3 (QUAN → qual): What insights on the types of beliefs from the Q-sort can be drawn from the different prioritization of items in the Q-sorts with respect to the subjective evaluation of the items?

RQ4 ((quan + QUAN) → qual): What insights on the preferences of the methods to survey beliefs (Likert scales vs. Q-method) that can be drawn from the interviews?

3.2 Sample and methods of data collection

In our study, we examined a convenient sample of $N=33$ mathematics pre-service teachers at the end of their studies (M. Ed. Mathematics for Primary or Secondary School) at the Universities of Bremen (29 pre-service teachers) and Hamburg (4 pre-service teachers), two urban universities in Northern Germany. In this survey, the group of pre-service teachers shows a diverse study background: the majority (26 pre-service teachers) were studying teaching mathematics for upper secondary level, 6 pre-service teachers were studying mathematics for primary level. One participant studied for a teaching degree for special education with subject mathematics and a profile for upper secondary level. All of the pre-service teachers had several months of practical teaching experience at school in internships, so that they were able to relate the statements in the items to concrete teaching experiences in the classroom.

Each participant of the study was surveyed individually, resulting in 33 sessions that were planned as lasting about 45 min each. The data were collected in a three-step process: first, the participants completed the Likert scale questionnaires (5–10 min), second, right after this, the Q sorts were created using the Q sort technique (free in time), and third, an immediate interview of about 10–20 min was conducted on the Q sorts and questionnaires.

At step one, the pre-service teachers were completing the questionnaire containing 14 statements on beliefs about teaching and learning mathematics from the TEDS-M study, where all statements are visible at the same time but are answered independently (Peterson et al., 1989; Laschke and Blömeke, 2013). The instrument has already been tested in previous national and international empirical studies with larger samples of pre-service and in-service teachers (Tatto et al., 2008; Wang and Hsieh, 2014; Blömeke et al., 2015), and several studies identified two scales within the set of statements by exploratory and confirmatory factor analyses (Buchholtz et al., 2013; Buchholtz and Kaiser, 2017; Yang et al., 2020). On the one hand, a transmission-oriented scale on learning mathematics through teacher instruction (eight statements) and, on the other hand, a constructivist-influenced scale on learning mathematics through active learning (six statements). The statements were to be answered on a 6-point Likert scale (1 = “strongly disagree” to 6 = “strongly agree”). Table 1 shows the statements used along with their enumeration based on the TEDS-M instrument (Laschke and Blömeke, 2013). The enumeration was used to refer to specific items later in the data collection.

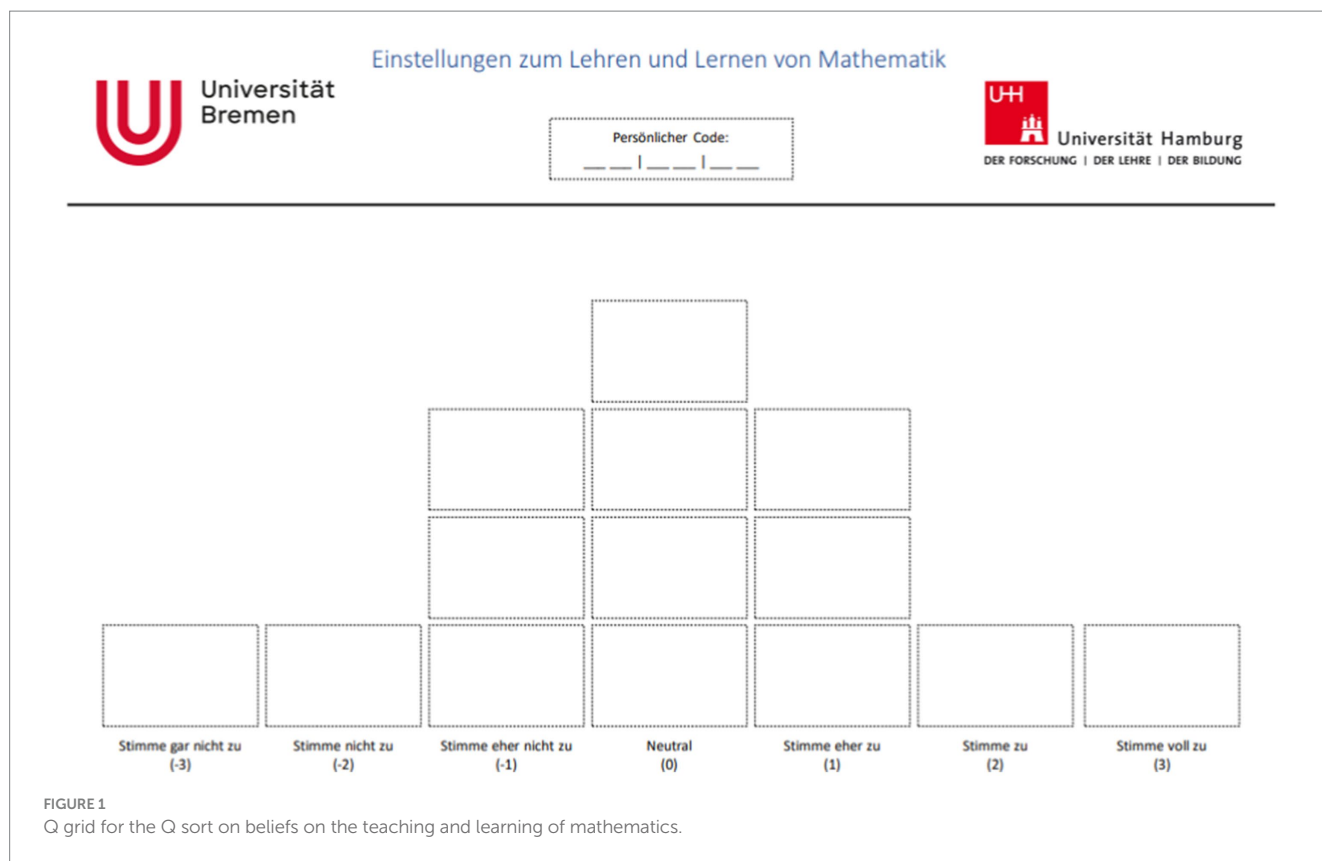
The second step of data collection took place immediately after the pre-service teachers had completed the questionnaires. They were presented with an unsorted Q set containing the same statements and the corresponding Q grid on a poster (see Figure 1). Traditionally in a study applying Q methodology, participants sort a set of statements that are specifically selected and culled for the Q study (McKeown and Thomas, 2013). In this study, to allow a comparison between the research approaches the 14 statements from the TEDS-M were used as Q set. The cards were numbered in the same way as in the questionnaire. The pre-service teachers were instructed to place the

TABLE 1 Transmission-oriented and constructivist-influenced scales to assess beliefs on the teaching and learning of mathematics (Laschke and Blömeke, 2013).

Transmission-oriented scale	Constructivist-influenced scale
1. The best way to do well in mathematics is to memorize all the formulas.	7. In addition to getting a right answer in mathematics, it is important to understand why the answer is correct.
2. Pupils need to be taught exact procedures for solving mathematical problems.	8. Teachers should allow pupils to figure out their own ways to solve mathematical problems.
3. It does not really matter if you understand a mathematical problem, if you can get the right answer.	11. Time used to investigate why a solution to a mathematical problem works is time well spent.
4. To be good in mathematics you must be able to solve problems quickly.	12. Pupils can figure out a way to solve mathematical problems without a teacher's help.
5. Pupils learn mathematics best by attending to the teacher's explanations.	13. Teachers should encourage pupils to find their own solutions to mathematical problems even if they are inefficient.
6. When pupils are working on mathematical problems, more emphasis should be put on getting the correct answer than on the process followed.	14. It is helpful for pupils to discuss different ways to solve particular problems.
9. Non-standard procedures should be discouraged because they can interfere with learning the correct procedure.	
10. Hands-on mathematics experiences aren't worth the time and expense.	

statements on the forced Q grid along the scale from (−3) to (3) according to their personal prioritization. There was only room for one statement at position −3 being assigned the lowest level of agreement (“strongly disagree”) and for one statement at position 3 being assigned the highest level of agreement (“strongly agree”) (see Figure 1). The distribution of cards roughly follows a normal distribution, but generally can also take any other non-bizarre symmetrical form (Brown, 1980; Watts and Stenner, 2012). As this was a forced Q sort, only one card could be placed in each cell, and the cards could be swapped and repositioned in between. Due to the limited number of free spaces for each level of agreement—a distinction between forced and so-called unforced Q sorts, where any number of cards can be placed at any level of agreement—the participants had to engage intensively with their own beliefs in order to judge their (dis) agreement with the statements in relation to the other statements (Fisseler, 2023).

Collecting additional qualitative data can help in the interpretation of the final results of Q sorts (Müller and Kals, 2004; Watts and Stenner, 2012; Ho, 2017). Thus, in step three of the data collection, an interview was conducted with each participant following the Q sort. Questions were asked about the individual placements, the context, and the two approaches (Likert questionnaire vs. Q sort). Examples of



questions from the interview guide that address individual placements are “Why does card X on the Q grid differ from the questionnaire, here you chose x as the level of agreement?” or “You agreed more/less with card X on the questionnaire than with card Y, with the Q grid it is the other way around—can you explain why?” Questions were also used to determine the context in which participants agreed or disagreed with the statements. The focus here was on whether individual students or whole learning groups were used as a reference when responding. At the end of the interview, questions were asked on a meta-level about the two approaches themselves. “Did you notice any differences when answering the questions using the two different methods?” or “Which method did you use to better express your beliefs?” are examples of questions from the interview guide.

Steps two and three of the data collection process were videotaped so that the interviews could be transcribed and supplemented with notes on gestures (e.g., pointing to a card). To ensure pseudonymization of the data, personal codes were assigned to each participant to be able to relate questionnaire, Q sort, and interview later on.

3.3 Data evaluation

The theoretical two-dimensional structure of scales of beliefs on the teaching and learning of mathematics was already known from other studies such as TEDS-M or COACTIV (Fennema et al., 1990; Blömeke and Kaiser, 2010; Voss et al., 2013). Furthermore, the TEDS-M items in Table 1 have been used in other studies with pre-service teachers and the two-dimensional structure with the transmission-oriented scale on “learning mathematics through teacher direction” and the constructivist-influenced scale on “learning

mathematics through active learning” (Laschke and Blömeke, 2013), has been confirmed on the basis of larger and comparable samples (Tatto et al., 2008; Buchholtz et al., 2013; Buchholtz and Kaiser, 2017; Yang et al., 2020). For this reason, it made sense to examine the factor structure in our study using a confirmatory factor analysis (CFA), which, however, did not yield results due to the small sample size and lack of prerequisites (Field et al., 2012). For this reason, only descriptive statistics were used to analyze the data set collected with the Likert-scale questionnaire, where mean scores of agreements with the items of the two scales proposed by the previous studies were calculated for each participant and correlated to obtain a measure of agreement with both scales.

The Q sorts of all participants were then statistically analyzed to detect different types of sorts. The evaluation of the Q sorts was done with the software KADE v1.2.1 (Banasick, 2019). In a first step, a Q correlation matrix was computed, representing the relationships between the Q sorts of participants. When applying Q methodology, researchers can use various factor analysis techniques, such as principal component analysis and varimax rotation, which aids in achieving more distinct and interpretable factors, making it easier to identify and describe the main viewpoints, or centroid factor analysis without rotation (which is less mathematically complex and aligns well with Stephenson’s original conception of Q methodology). The choice of method can, of course, influence the interpretation of factors. In this study, we used principal component analysis and varimax rotation in order to reduce the dimensionality of the data while retaining as much variability as possible and ensuring that each item loads strongly on one factor while remaining minimally associated with others. The selection of the number of factors was determined by applying the Kaiser criterion and looking at the

Scree-test (Field et al., 2012; Moosbrugger and Kelava, 2012). The analysis yielded to three factors, as the eigenvalues showed a noticeable drop after the first and another smaller drop after the third factor. Finding three factors is common in Q methodology and reflects the method's capacity to identify distinct yet interpretable viewpoints among participants (Lundberg et al., 2020). In the final steps of the analysis, the factor loadings were used to identify representative Q sortings of the participants for each factor (Banasick, 2019; Rahma et al., 2020). With the help of the software, the correlations of the factors were determined and the number of people with the respective prototypical sorting was estimated. In order to be able to make comparisons across factors, the weighted total score for each statement was standardized and converted into a Z-score (Watts and Stenner, 2012). The value indicates "how characterizing the statement is for the factor" (Sandhu and Hildebrand, 2022, p. 215). The Z-scores (in Q methodology also called factor scores) of the individual statements were used to create the prototypical sorting for each factor, which was then visualized by placing the items according to their Z-scores into the grid. Thus, each prototypical sorting shows a single Q sorting, which is also a very specific arrangement of statements that represents the perspective of the factor and is ideal-typical for it (Watts and Stenner, 2012). In this way, similarities and differences between the participants could be determined and individual types could be formed (Müller and Kals, 2004). On the basis of the calculated factor scores, statements were identified that were rated and placed very similarly (consensus statements) or very differently (distinguishing statements) by the participants (Sandhu and Hildebrand, 2022; Fisseler, 2023). Based on these statements, similarities and differences between the factors or types can be shown.

To enable the qualitative analysis, the 33 interviews were transcribed. The transcripts were analyzed using qualitative content analysis according to Mayring (2014, 2015), whose central element of analysis is a category system that abstracts the text structure on the basis of assigned codes. The software QCAmap (Fenzl and Mayring, 2017) was used to analyze and assign the codes. The categories were formed inductively from the material used but following the line of research questions RQ3 and RQ4. The following categories were used for the analysis

- Statements of reasoning on decisions to the positioning of statements in the Q sort (RQ3).
- General statements about the context of thought when deciding about where to put a statement in the Q sort (RQ3)
- Statements on the limitations or possibilities of the different approaches to capture or represent attitudes (RQ4)
- Statements about the preferences of either Q sort or Likert questionnaire (RQ4)

Instead of a quantitative count of the codes assigned, the analysis focused on a detailed consideration and interpretation of significant

statements and patterns that emerged from the interviews. The "point of integration" in our study (Schoonenboom and Johnson, 2017) lies in the quantitatively driven qualitative evaluation of the interview data. Following our mixed methods approach, the qualitative data evaluation of the categories was guided by the explanation of the quantitative results of the Q sort analysis and was carried out descriptively on the basis of selected text passages that were representative of the previously identified distinguishing and most extreme statements of the prototypical Q sorts within the data material. Particular emphasis was placed on the depth of content and the specific perspectives of those participants of the sample that could be assigned the identified factors based on high factor loadings in order to ensure a nuanced understanding of the thematic diversity and complexity of the statements collected to each prototypical Q sort.

4 Results

In the following, we present the findings of our study along the lines of research questions RQ1 to RQ4.

4.1 RQ1: results from the Likert scale survey

The first research question (quan) focusses on the types of beliefs about the teaching and learning of mathematics that can be found among pre-service teachers using the Likert scales, and how they can be characterized. The results of the evaluation of the Likert questionnaire showed that our prospective teachers primarily have strong constructivist beliefs on average and the whole sample tended to disagree with the transmission-oriented items (see Table 2). However, possibly due to the small sample size, no significant manifest correlations were found between the two scales, so the results must be interpreted with caution. The results are in line with findings on comparable groups of students at other German universities (Buchholtz et al., 2013; Buchholtz and Kaiser, 2017).

4.2 RQ2: results from the Q sort analysis

The second research question (QUAN) looks at the types of beliefs about the teaching and learning of mathematics that are found among pre-service teachers using the Q method, and how they can be characterized. The analysis of the Q sort revealed three different factors, i.e., typical sorts of a certain group of pre-service teachers. The factors explained 78% of variance in the sorts ($p < 0.05$). Of the 33 participants, 26 could be clearly assigned to one type. Nine people in the sample loaded on Factor 1, seven persons on Factor 2 and ten persons on factor 3. Seven people had strong secondary loadings and could therefore not be clearly identified. As Table 3 shows, the factors were strongly correlated, which indicates that the identified types

TABLE 2 Sample means and range of participants' agreement to Likert scale items.

Scale	Items	Mean	Min.	Max.	SD
Transmission-oriented beliefs	8	2.11	1.25	2.75	0.39
Constructivist-oriented beliefs	6	5.20	3.83	6.00	0.47

TABLE 3 Correlation of the identified factors.

	No. of defining variables	Composite reliability	S.E. of factor Z-scores	Factor 1	Factor 2	Factor 3
Factor 1	9	0.973	0.164	1	0.7386	0.7497
Factor 2	7	0.966	0.184	0.7386	1	0.7242
Factor 3	10	0.976	0.155	0.7497	0.7242	1

differ only in nuances and the pre-service teacher present a rather homogeneous group concerning beliefs. Overall, there is a clear prioritization of constructivist statements and rejection of transmission-oriented statements in all factors.

Figure 2 shows the prototypical Q sorts calculated in KADE. The statements are sorted in ascending order of their Z-Scores into the slots of an empty Q sort from -3 to $+3$. The statements that are significantly higher or lower in the individual factors than in the other factors, as well as the distinguishing statements that allow the interpretation of the respective factor, are marked in each case. In addition, we have colored the transmission-oriented (blue) and constructivist statements (yellow) for easier orientation; the consensus statements that did not allow any significant conclusions to be drawn about sorting patterns are colored lighter.

The following description of the three types is solely based on the prototypical Q sorts. The interviews were not taken into consideration at this point of time. Based on the sort-pattern, we were able to identify Type 1 *a posteriori* as an “understanding-oriented constructivist.” Having a more content-related view on the results we see in Figure 2 (top) that people of this type prioritize statement 8 “Teachers should allow pupils to figure out their own ways to solve mathematical problems” in the highest position followed by the statement 7 “In addition to getting a right answer in mathematics, it is important to understand why the answer is correct.” These statements are followed by various constructivist-influenced statements emphasizing the importance of giving students enough time in class to develop and explore their own solutions without a teacher’s help. However, this factor is distinguished by the neutral position of statement 14 “It is helpful for pupils to discuss different ways to solve particular problems.” A rejection of the avoidance of hands-on mathematics experiences due to time and expense (statement 10: “Hands-on mathematics experiences aren’t worth the time and expense”) is least important to these people. Statement 10 is the negation of a constructivist opinion. Thus, locating this statement in position -3 shows a strong denial of this negation and, thus, a strong acceptance of the underlying constructivist statement. This is followed by a strong disagreement on a one-sided focus on memorizing formulae.

We call Type 2 *a posteriori* “time-conscious co-constructivist” (see Figure 2, center). Like people in Factor 1, people of this type (tend to) agree with all constructivist-oriented statements, while they (tend to) disagree with all transmission-oriented statements. A more substantive examination of the results shows that people of this type also prefer statement 8 “Teachers should allow pupils to figure out their own ways to solve mathematical problems” like those of Type 1. People of Type 2, on the other hand, position statement 14 “It is helpful when students discuss different solutions to certain problems” in second place in terms of their agreement. They prioritize finding and discussing of own

solutions even over getting the correct answer (statement 7). However, they emphasize nevertheless that it is important to understand why a mathematical statement is correct and that the time required for this is well invested. Statement 4 “To be good at math, you must be able to solve problems quickly” and statement 3 “It does not really matter if you understand a mathematical problem if you get the right answer” receive the lowest level of agreement. This also shows a rejection of the focus on speed and correctness over understanding. Also noteworthy here is the neutral attitude towards memorizing formulas (statement 1), which are needed, for example, when finding your own solutions. This type emphasizes the awareness of the meaningful use of time in learning and teaching mathematics. People of this type believe that it is important to encourage students to develop their own solutions while discussing different approaches. At the same time, they emphasize that understanding different solutions and intensive engagement with mathematical tasks are more important than quick results.

We identified Type 3 *a posteriori* as “balanced process-product navigator” (see Figure 2, bottom). People of this type seem to value the exploration of different solutions and understand the importance of the process over simply arriving at the correct answer. Like Type 1, they show the (relatively) strongest agreement with statement 7 “In addition to getting a right answer in mathematics, it is important to understand why the answer is correct” but even more the (relatively) strongest disagreement with statement 6 “When pupils are working on mathematical problems, more emphasis should be put on getting the correct answer than on the process followed.” They also recognize the value in discussing various approaches (statement 14), however, they allow for personal discovery in problem-solving (statement 8) to a (relatively) lesser degree. Yet, they hold a neutral stance on the efficiency of solutions and the strict adherence to standard procedures (statements 2 and 9), and a skepticism about the usefulness and effectiveness of practical, hands-on experiences that deviate from conventional curricula (statement 10). This suggests a more balanced view that appreciates both the journey of learning and the flexibility in approaches, without a complete disregard for structure or efficiency. People of this type navigate between structured learning and the exploratory process, aiming to foster a deep understanding of mathematics through exploration and discussion of multiple problem-solving methods.

4.3 RQ3: results from the interviews about the Q sorts

The third research question (QUAN $\rightarrow$ qual) focusses on the insights on the types of beliefs from the Q sort that can be drawn from

Composite Q sort for Factor 1

-3	-2	-1	0	1	2	3
** ◀ Hands-on mathematics experiences aren't worth the time and	The best way to do well in mathematics is to memorize all the formulas.	Non-standard procedures should be discouraged because they	** ◀ It is helpful for pupils to discuss different ways to solve	Pupils can figure out a way to solve mathematical problems	In addition to getting a right answer in mathematics, it is important to	Teachers should allow pupils to figure out their own ways to solve
		When pupils are working on mathematical problems, more emphasis should	Pupils learn mathematics best by attending to the teacher's	Time used to investigate why a solution to a mathematical problem works		
		It doesn't really matter if you understand a mathematical	To be good in mathematics you must be able to solve problems quickly.	Teachers should encourage pupils to find their own solutions to		
			Pupils need to be taught exact procedures for solving mathematical			

Composite Q sort for Factor 2

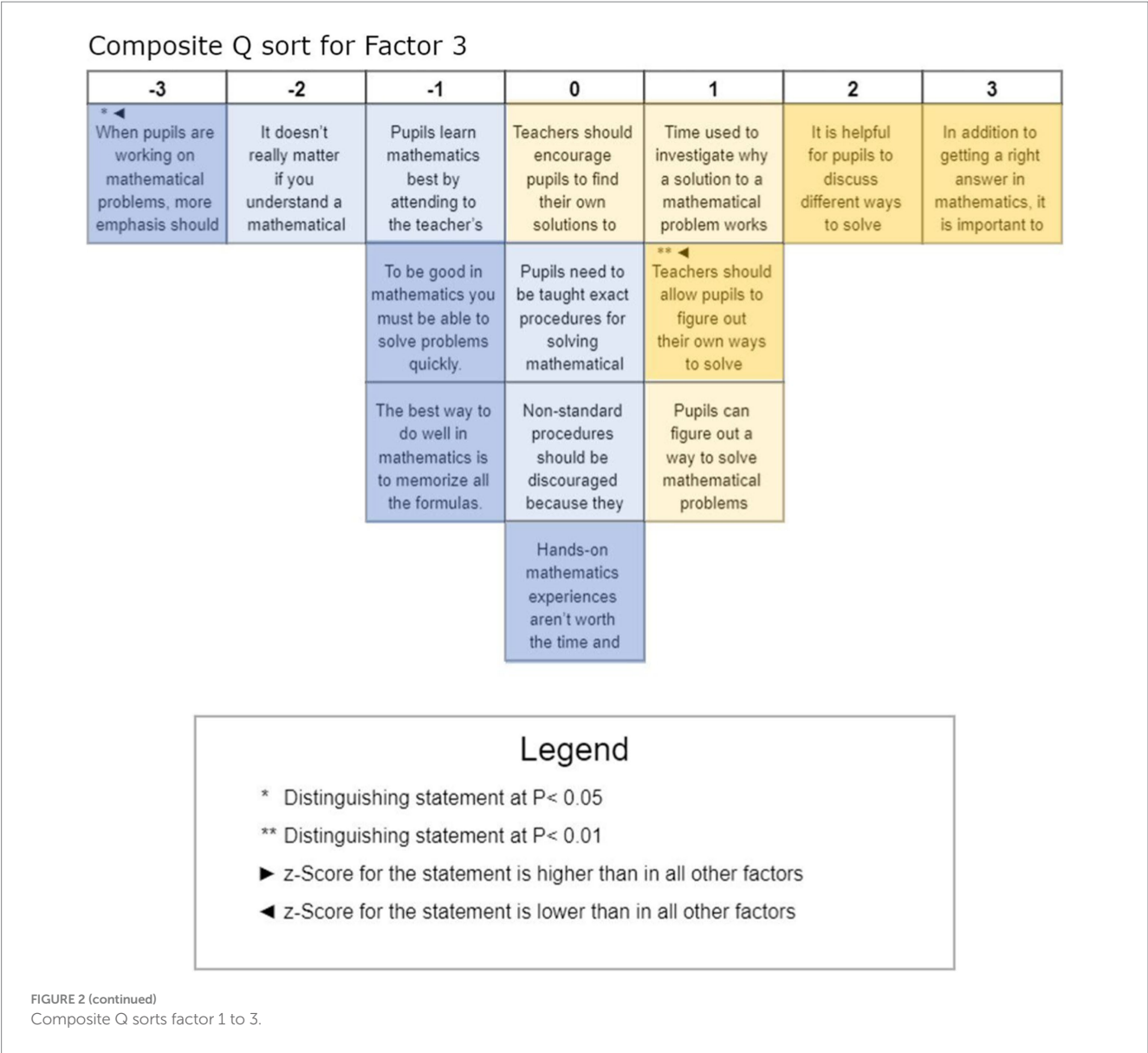
-3	-2	-1	0	1	2	3
** ◀ To be good in mathematics you must be able to solve problems quickly.	It doesn't really matter if you understand a mathematical	Pupils need to be taught exact procedures for solving mathematical	Pupils can figure out a way to solve mathematical problems	* ◀ In addition to getting a right answer in mathematics, it is important to	It is helpful for pupils to discuss different ways to solve	Teachers should allow pupils to figure out their own ways to solve
		Non-standard procedures should be discouraged because they	Pupils learn mathematics best by attending to the teacher's	Time used to investigate why a solution to a mathematical problem works		
		When pupils are working on mathematical problems, more emphasis should	Hands-on mathematics experiences aren't worth the time and	Teachers should encourage pupils to find their own solutions to		
			** ▶ The best way to do well in mathematics is to memorize all the formulas.			

FIGURE 2 (continued)

the different prioritization of items in the Q sorts with respect to the subjective evaluation of the items. In the following sections, results with respect to the three types are presented. The quotations used for illustration of the results were translated by the authors. Emphasis is marked in italics.

4.3.1 Explaining type 1: “understanding-oriented constructivist”

With regard to the reasons for sorting statement 8 and 7, which were agreed with the most in relative terms, the subjective statements of participants assigned to Factor 1 show the high individual level of



an orientation towards mathematical understanding and their belief of the importance of students finding their own solutions. The pre-service teachers of this type for example, judge this as very important for weaker students and in connection with the acquisition of problem-solving skills. With respect to their own teaching practice, this can generally also mean deviating from traditional approaches (16MAIG; 23SAEN).

“Yes, I think that [this] is simply a super important point in mathematics. Of course, that contradicts a bit of what I said earlier about [weaker] individual students who are better able to cope with being given a method to work with. But I think you should also give them the opportunity to find their own solutions first. And I simply believe that it's really important for students to deal with problems in order to acquire these problem-solving skills, which they might be less likely to acquire if you simply provide them with solutions.” (16MAIG, factor loading 0.85).

“I then also thought a bit about my own learning groups and [...] they were always happy to get their points for perhaps strange solutions that were nevertheless correct. But they were not necessarily happy to have to do it first because they were quite unsure about it. So perhaps this would have deserved a higher priority again so that the learners could become more confident. But in any case, I thought it was more important if they went their own way, not to sanction them in any way, but to say that if the way they went was right and not the one I had given them, then that was fine and I would accept it.” (23SAEN, factor loading 0.67).

At the same time, the individual justifications for the strongly rejected statements 10 and 1 reflect a collectively held constructivist belief of this type that successful mathematics learning goes far beyond the mere memorization of formulas. Again, the participants emphasize the great importance that understanding mathematical concepts and applications has for them. It is clear that a deep understanding of the subject matter and the practical application of

mathematics are seen as essential for learning success (20SRRA; 23SAEN). In addition, the subjective value of practical experiences is emphasized (16MAIG; 20SRRA), as they help to better anchor what has been learned in the memory and deepen the understanding of mathematical concepts.

“If you memorize all the formulas, it does not mean you are good at math. It just means you are good at memorizing. I’m really against memorization.” (20SRRA, factor loading 0.69).

“And most of the time, these formulas give you prescribed ways to do it, the p-q formula or something. Sure, if you can memorize them, you can get through calculations quickly, but if you know what you are doing mathematically, then you can actually reach your goal quite well without this formula. And accordingly, in comparison with the other statements [...], I found that it was no longer so important to simply be able to memorize the formulas, but to have understood the structure and to work with it.” (23SAEN, factor loading 0.67).

“Hands-on mathematics experiences aren’t worth the time and expense. Yes, that’s another very extreme statement. That’s why it was easy for me to categorize it as very extreme in this case, because I think you can simply disagree with it. So especially in this area, I think time is never wasted [...]. So, in this case I think it’s particularly important to gain these experiences, but basically experiences are always somehow worth the time and worth the effort.” (16MAIG, factor loading 0.85).

“No, practical experience is always linked to this, it stays in the head for longer.” (20SRRA, factor loading 0.69).

4.3.2 Explaining type 2: “time-conscious co-constructivist”

Individuals of this type place higher value on allowing students to explore and find their own solutions, seeing personal discovery and the application of mathematical concepts as crucial to learning (statements 8). They prioritize the student’s personal autonomy in learning, and the co-construction of knowledge by discussion, valuing the individual’s process of understanding and the development of personal methods as more important than the mere acquisition of the correct answer. Moreover, both pre-service teachers 08SUDE and 19SULZ think that the discussion of various solutions already implies understanding a solution.

“So first of all, I think I found statement 8 more important than statement 14, because here the students simply approach the tasks individually themselves and filter out what they can do. Then this card [points to statement 14] is important because it’s a different skill to talk about [solutions]. So, for me, statement 8 was more the basic idea and, for me it actually reinforces the fact that you know why the approach is right. You know that automatically when you have found your own way. But why? So, for me, that [points to statement 8] is a bit of an overarching point that implies the other. And that’s why I thought it made sense.” (08SUDE, factor loading 0.84).

“That you should find your own way and give the students this opportunity. Because otherwise far too much is taken away in terms of discoveries or your own thinking and structure. Even if as a teacher you do not always understand what students are calculating, but as long as it works for them and it’s a constant that they can manage, then that’s worth the most to me, so it has to be on the far right side [+3].” (19SULZ, factor loading 0.84).

Pre-service teachers of this type strongly reject the notion that speed and the immediate correctness of answers are the main objectives in mathematics education (statements 4 and 3). This type believes that understanding mathematical structures and the ability to apply them thoughtfully are far more critical than being able to solve problems quickly. They are even frustrated by the educational focus on speed and express that understanding and describing mathematical processes should not be rushed, which is why they act time-consciously in their own teaching (11HERG).

“At first, I think I actually laid out the card with the formulas [statement 1], but then I thought about it. Okay, maybe you should know this one formula for percentages, even if you can perhaps derive it yourself, whatever. I was a bit hesitant at first, but then I swapped it, but then I was like, speed, if I somehow stress students or somehow want them to come up with a solution quickly. So somehow, I do not see any added value in that. Maybe that’s just the reality, unfortunately, if you do not have the time, but from my point of view, I would not want it. Maybe it’s just because you only have five minutes for a task because otherwise the lesson is over. So maybe there’s the counter-example of someone sitting at it for far too long, but it depends on whether they are just looking at it all the time or whether they are really still in a thought process and are just approaching a task, i.e., the solution. But I did not find the speed factor so relevant.” (08SUDE, factor loading 0.84).

“Because that’s what annoys me most about teaching math! [...] It annoys me to no end that you always have to be fast in math [...]. I do not understand why. It annoys me so much! [...] Because I think that understanding and applying the structures of math and learning heuristics and things like that are much more important for the applications you want to do with it. [...] All of that, that’s important, that I understand what’s happening and that I describe very well, but not that I describe quickly. So why do I have to be able to do it quickly? But it’s always like that in mathematical education. And that’s why I set it to ‘do not agree at all’, because it upsets me so much.” (11HERG, factor loading 0.53).

Interestingly, the “time-conscious co-constructivist” is neutral about the transmission-oriented need for memorizing formulas (statement 1), recognizing that while formulas can be helpful tools, merely knowing them is not synonymous with being good at mathematics (23UREN). They emphasize the importance of understanding how to apply formulas rather than just memorizing them, indicating a balanced view that recognizes the practical benefits of memorization but does not see it as the end goal (01BALN). However, this attitude also stems in part from the compulsion to assign transmission-oriented statements in the Q sort.

“The fact that I chose statement 1 was again a bit of a box-ticking exercise and you have to know the formulas, but you also have to understand how to apply them and just because I know formulas does not automatically make me good at math. I can memorize all sorts of things, but that does not mean that I’m good at it or really well educated or anything like that.” (23UREN, factor loading 0.84).

“Here I had far too much ‘do not agree at all’ and then I had to think about which of the things I can still get on with and I thought to myself, well, mathematics, that you have to memorize formulas, so it helps a lot that if you are at school and have to solve or prove something, maybe you remember certain formulas, I do not know, for example, for circles and cylinders, whatever. To be able to solve something in geometry, for example, formulas are an advantage. But I think ... ‘best way ... to memorize all the formulas,’ that’s a bit, so ... huh, I do not really agree with that, but it has to go somewhere that’s why I moved it to neutral.” (01BALN, factor loading 0.64).

4.3.3 Explaining type 3: “balanced process-product navigator”

Like Type 1, the balanced process-product navigators express a strong subjective agreement with the idea that understanding why a mathematical solution is correct is paramount (statement 7). Depending on the mathematical content they personally value various solution methods as foundational to comprehending the rationale behind answers, like stated in statement 14 (06STEN). This is reinforced by the emphasis on the significance of grasping mathematical concepts and the process, rather than merely calculating the correct result (16BIEK).

“Because it is important to understand why a solution works or why the solution is correct and to understand the background knowledge and the result is of secondary importance, which is not so tragic, as long as you have perhaps understood the mathematical concept. It’s not good, but it’s more important to understand the concept behind it and the content than simply writing down a correct result. And, above all, to be able to justify why this result is correct and no other.” (16BIEK, factor loading 0.80).

“I think I’ve actually just said that I think it’s super important that the students are not taught that there is always this one solution only. There is only one approach and anything else is all wrong. That’s why I think it’s very important that they find their own way and maybe even figure things out on their own. Okay, there’s not just one procedure, but different possible approaches and that they can go through their own process without being told what to do and how to do it. Of course, it works better for some topics and worse for others, but I think it’s a very important approach. Definitely in the classroom.” (06STEN, factor loading 0.79).

Correspondingly, this type firmly rejects the notion that getting the correct answer should be prioritized over understanding the problem-solving process (statement 6). They distinguish between

mere test performance and genuine learning, advocating for a comprehension-based approach to education that transcends rote memorization and applies to real-life situations. They also refute statement 3 and the idea that a single method should be used mindlessly without grasping the underlying mathematical principles (03SARG; 16BIEK).

“The fact that you do not have to have understood something, you just have to have come up with the right solution, that may be true at the point where you have to pass an exam. But in my view of education, that does not fit in. I would differentiate between the educational process in general and an examination situation, in the way that how examination situations are designed at the moment. I would say that the educational process in general is about enabling people to understand and solve problems and thus arrive at a solution, because whether the solution is right or wrong may be clear in many places in mathematics, but it is also not clear in all places. The reason why I no longer have statement 3 under ‘strongly disagree’ but under ‘disagree’ is that I thought that the result of statement 6 is important in the exam situation, but even there, students get partial points for the solution.” (03SARG, factor loading 0.77).

“Because I think – that’s also the fact that you somehow only apply one procedure and do not actually know what you are doing. This is almost exactly the opposite of statement 7, where you simply state the result, not even perhaps a calculation, but do not even know why this is correct and perhaps cannot even apply it to more complex situations, but simply do something without understanding. Somehow that does not have much to do with math.” (16BIEK, factor loading 0.80).

However, interestingly, there is a neutral attitude of people of this type toward non-standard procedures (statement 9). These individuals subjectively recognize the potential of non-standard methods in learning but also see the value in learning correct, standardized procedures initially (28ILEN), which is a more transmission-oriented view. Similarly, while they see the application of mathematics beyond textbooks as valuable, they remain neutral on the time and effort required for practical, hands-on experiences (statement 10), suggesting they weigh the relevance and accessibility of mathematics in the real world against the practicalities of such educational approaches (16BIEK).

“And, for example, non-standardized procedures should be avoided because they can interfere with learning the correct procedure, [...] I think, when it comes to learning mathematics, for example, when learning a correct procedure, then a standardized procedure is really important at first. Using a non-standardized procedure at the end is also good, but in the middle or at the beginning could be really detrimental. So, in my opinion, you should really use the standardized procedure at the beginning and then take a non-standardized approach afterwards. That’s why it depends on what this statement means. That’s why I set it to neutral, which I thought was fine.” (28ILEN, factor loading 0.60).

“Hands-on mathematics experiences aren’t worth the time and expense.’ That’s always a bit of a question: What exactly does hands-on experience or gaining experience mean? That’s why I did not actually find it that difficult here. [...] I do not think I had that much of a problem with the neutral here.” (16BIEK, factor loading 0.80).

4.4 RQ4: results from the interviews about the preference of the method of survey

Finally, research question 4 ((quan + QUAN) → qual) looks at the insights on the preferences of the methods to survey beliefs (Likert scales vs. Q method) that can be drawn from the interviews. Based on the statements about the preferences of either Q sort or Likert questionnaire, in most cases (28 of 33), the participants in the study could be clearly assigned a preference for one survey method. Eight pre-service teachers favored the Likert questionnaire and 20 pre-service teachers preferred the Q sort when it came to describing which of the two survey methods they considered more suitable for expressing their beliefs towards the teaching and learning of mathematics. Five pre-service teachers rated the perceived advantages and disadvantages of the survey methods roughly equally and did not express a preference for a particular method. However, there was no systematic correlation with the assigned types, as can be seen in Table 4. It is interesting to note, however, that the majority of participants who were assigned to time-conscious Type 2 expressed a preference for the Q sort, i.e., the preference for an intensive but time-consuming examination of the statements was also evident here.

The participants gave different reasons for preferring one or the other survey method. Based on their statements on the limitations or possibilities of the different approaches to capture or represent their beliefs, different patterns of justification were identified. Above all, the majority of participants found that the Q sort depicted the personal thoughts on the statements better and in a more differentiated way (24EVCK), mostly because the individual statements had to be placed in relation to each other during sorting and were not considered in isolation from each other (28ILEN). However, the higher degree of reflection was largely perceived as more challenging (08SUDE).

“Because [with the Q sort] you are forced to think about what is more important to you. I can theoretically tick ‘I completely agree’ everywhere on the questionnaire. But that has relatively little significance for you and for me, too.” (24EVCK, Type 3).

TABLE 4 Preference for the survey method.

	Likert-questionnaire	Q-sort	Undecided
Type 1	3	6	2
Type 2	1	7	0
Type 3	3	6	1
Unassigned	1	1	2
Total	8	20	5

“The difference between the methods is that here [within the Q method] I have to compare the statements and also weigh up which statement is more important to me, or not so important, where I tend to agree, where I agree less. With the other questionnaire method, I have the freedom to weight many more things equally. On the other hand, with the sorting method you are more concerned with the statements and you compare them much more, which you do not do with the questionnaire, but with the questionnaire you can look at each question separately.” (28ILEN, Type 3).

“I think this method allows you to deal with things in a completely different way. You just do it more consciously. Because then I also imagined that when you ask me, why is this [points to card 7] more important to you than this [points to card 14], that I then have to have a reason for it. Somehow, both were somehow equally important to me. [...] You just have to decide. But I always think it’s good when you are encouraged to self-reflect. That’s why I always find it really good for me, because I realize that I think I’m just too intuitive on the questionnaire. And that somehow makes [the Q Sort] more fun. It’s all somehow, as I said, in relation to each other. I tick here [points to the questionnaire] and have already forgotten the other one. Here [points to the grid] I’m exchanging ideas the whole time, thinking ‘Oh, I had that now, why is that more important to me now?’” (08SUDE, Type 2).

However, many participants also commented that the intensive cognitive engagement was related to the forcing of the mandatory structure of the Q sort, which was perceived both as stimulating (03SARG) and as a burden (05ERLG). In particular, the presence of a neutral area in the middle of the Q-sort, in contrast to the questionnaire, was also perceived as a key difference between the survey methods (11HERG), which was also perceived as challenging (24BERG).

“The questionnaire is more time efficient, but the fact that it was mostly congruent in the middle range and that only the extreme positions differed, I would say that the Q method was more suitable or represents a more accurate picture, not more suitable. I would say that this is generally true, that you open up the hierarchy, that you get more differentiated images, because you have to prioritize what is on the very outside. In my sort, the things that are further out follow on from the things that are further in the middle. It’s exciting to make connections. That can be productive.” (03SARG, Type 3).

“In the questionnaire I can give as many ‘I fully agree’ crosses as I want. [...] What I definitely find a disadvantage here [in the Q sort] is that you have cards on the right for which you have no fields and you think to yourself, they have to go here, otherwise I have no space. You do not have that at all with the questionnaire. That’s a disadvantage here.” (05ELRG, Type 1).

“Here [points to the questionnaire] I was basically missing this neutral thing, which is why I was sometimes a bit unsure about statements. And then [points to the grid] with this neutral part I could also think again quite well ‘Okay, if I had felt rather undecided about the things’, by filling this neutral thing with a few

things where I was sure, I then had to decide on a few things where I was also unsure, but still had to decide what is now more 'agree', what is more 'disagree'. That's somehow one thing that struck me here." (11HERG, Type 2).

"I just found it very difficult with this neutral part, because I do not think I would have ticked 'neutral' so often. That, [...] yes, [...] I think that was the difference, that it's difficult for me to see a 'neutral' at all anyway. So, for me, neutral means [...] that I do not have an opinion on it, perhaps. And I would not say that about any of the statements. I think I have more 'disagree at all' or 'disagree' and 'agree.'" (24BERG, Type 1).

5 Discussion

The integration of data proved invaluable in our study, particularly in the selection of cases for qualitative analysis based on quantitative results. This approach ensured that the qualitative interviews were informed by the underlying quantitative patterns, facilitating a deeper exploration of why certain beliefs were held by pre-service teachers. For example, the fine-grained analysis of types identified in the quantitative Q sort analysis was enriched by qualitative insights, revealing the underlying reasons for pre-service teachers' prioritization of certain beliefs over others. This integration also enriches our understanding of pre-service teachers' beliefs and allows for a more dynamic formulation of belief patterns with regard to the teaching and learning of mathematics. Our study contributes to a deeper understanding by moving beyond the static dichotomy of transmission-orientation vs. constructivism to accommodate the complex, sometimes contradictory nature of personal beliefs. This provides a deeper understanding of the complexity of personal beliefs with all their shades and facets. From a theoretical perspective, this enables us to understand more precisely why pre-service teachers have certain beliefs and which underlying frames of reference have led them to certain (dis)agreement of the facets of constructivist or transmission-oriented beliefs. If we understand these frames of reference more deeply and take them seriously, we might—as a practical implication of our study—find a starting point to influence the development of beliefs, for example in the context of teacher study programmes. Studies are needed to investigate a possible connection between courses focusing on certain elements from the background frames of reference and the development of pre-service teachers' beliefs. In addition, further studies are also needed to analyse the relation between the differentiated belief types, the underlying frames of references and the teachers' specific teaching practices in the classroom. In particular, the connection between beliefs, teaching practices and student performance is a promising field of mathematics educational and psychological research.

One of the critical achievements of integrating quantitative and qualitative methodologies in the mixed methods research design was addressing the blind spots associated with each. The Likert scale surveys, for instance, provided a broad overview, indicating a general preference for constructivist beliefs among pre-service teachers, but lacked the depth to explore the contextual and nuanced understandings that pre-service teachers hold. The Q sort, on the

other hand, brought these subjective nuances to the foreground, highlighting individual variations in belief structures. This dual approach of using mixed methods allowed for a more comprehensive understanding of the pre-service teachers' beliefs, highlighting both commonalities and variations that might be obscured if only a single method were employed. Thus, our study showed the richness of a mixed methods approach, yet, bearing in mind the rising amount of resources needed for the time consuming process of data collection and evaluation.

The identification of three factors in our study is partially consistent with, but also goes beyond, the constructs found in previous research. Jaschke (2018) identified a distinct constructivist type and a mixed type of transmissive and constructivist orientation in his dataset. The constructivist type consists of $n = 14$ pre-service teachers who agree more strongly with all constructivist-influenced items than with transmissive-oriented ones. Thus, there is a clear distinction between the items in the prototypical Q sort with a split Q sort grid into a blue (transmission-oriented items) and a yellow (constructivist-influenced items) half. In addition to this constructivist type, Jaschke (2018) also reports a mixed type ($n = 6$) in which there is no strict separation between the transmission-oriented and constructivist-influenced belief items. The number of individuals loading on each factor shows that in his sample, as in ours, the constructivist-influenced beliefs about teaching and learning mathematics seem to be stronger. We could not find such a mixed type in our data set. Yet, we were able to further differentiate between "understanding-oriented" and "time-conscious" constructivism. These distinctions revealed underlying practical orientations that were significant to the pre-service teachers depending on different contextual teaching situations and own teaching experiences, showcasing Q methodology's strength in revealing typologies that are usually concealed in Likert scale evaluations. Additionally, the process of engaging with the Q sort was found to be particularly motivating for the majority of participants, suggesting that this method can enhance engagement and yield rich, reflective data—of course, at the cost of a time-consuming survey method and the participants forcing of sorting statements in an order. The findings nevertheless underscore the potential of mixed methods research in educational and psychological settings, particularly in studying complex constructs like beliefs. Q methodology, combined with traditional Likert survey techniques, offers a robust framework for capturing the rich, complex system of beliefs that pre-service teachers hold. As a methodological implication for further research, it also suggests a pathway for refining Likert-scale instruments to include more situation-specific items, potentially increasing their validity in terms of their sensitivity to the varied contexts in which teaching and learning occur. For example, our results could be used to develop additional items that reflect teacher beliefs on the teaching and learning of mathematics even better than only a set of 14 items, which has been used in many studies for reasons of economy, but has also been criticized for its validity (Aeschbacher and Wagner, 2016). Furthermore, this study's approach could serve as a model for future psychological research into other domains of teacher beliefs or even extend into different fields where understanding the depth and diversity of personal beliefs is crucial. In general, we think that future research should also consider Q studies or—even better—mixed methods involving Q methodology to investigate other affective constructs that are influential for teaching or learning mathematics. Thus, a more fine-grained investigation of notions like

mathematical identity, motivation, resilience, or self-concept might offer valuable insights to better understand teaching and learning of mathematics. We see even more potential in intercultural studies that might be able to better explain differences found in the data.

Despite these strengths, the study faced several limitations. First, the Q methodology does not refute the critiques often directed at the items used in such studies; it does not directly address potential biases or limitations in item design. As our results show, the 14 items used in many studies on mathematics teachers' beliefs are quite suitable for mapping the beliefs of mathematics pre-service teachers, but our results also show that, based on the types identified, additional items developed in this direction could provide further insights. Moreover, the Q-sort process was time-intensive, which may limit its applicability in large-scale studies or under time-constrained conditions in general. Another challenge arises with participants who find little distinction between statements, as the forced distribution required in Q sorts can lead to artificial polarizations, potentially skewing results. Furthermore, Q methodology allows only for relative statements (e.g., "Statement X is more prioritized than Statement Y," cf. Jaschke, 2018), which can restrict the depth of absolute belief analysis. In this study, we counteracted this possible polarizations and shortcomings by presenting both Likert and Q sort survey formats to the participants and allowing them to express their preferences for one format and also any perceived bias. However, our results could still be biased by the selection of the sample, as we had to rely on a random sample from only two universities. Against the background of the partially contradictory findings to Jaschke (2017, 2018), it cannot be ruled out that this contributed in particular to the strong constructivist orientation of the sample and that we were therefore unable to identify any mixed types. The small sample size also presented significant challenges for conducting a confirmatory factor analysis (CFA). While the use of a validated survey instrument has helped to mitigate some concerns about the reliability and validity of the Likert scale data, it cannot completely overcome the limitations imposed by sample size. Researchers interested in using a combination of Likert scales and Q sort within a mixed methods study should therefore either interpret the results with due caution, especially when newly developed items are used, or use the results of the Q sort analysis to validate the Likert items. The use of the items within both Likert and Q research approaches had the advantage in our study that both approaches could be assessed by the pre-service teachers in the same way, so that their judgement related exclusively to the methodological survey of teacher beliefs. However, this configuration also means that the more in-depth types of beliefs could only be identified by applying Q methodology within the known range of items.

Despite these challenges, the integration of Q methodology with traditional Likert scales significantly enriches the research landscape. It allows for a more detailed description of subjective perspectives and provides empirical evidence of belief types that typically remain hidden in Likert scale evaluations. The qualitative feedback from the interviews added substantial depth, revealing the contextual nuances and expertise-driven motivations behind participants' responses, which are invaluable for comprehending the complex terrain of mathematics teachers' beliefs.

There has been considerable debate about whether Q methodology qualifies as a mixed methods approach (Newman and Ramlo, 2010).

Q methodology inherently blends qualitative and quantitative techniques, making it a hybrid method. Stephenson, the founder of Q methodology, emphasized that it was designed to study both subjective and objective behaviors, rejecting the separation of objectivity and subjectivity (Stephenson, 1953). This integration is seen as aligning well with the mixed methods philosophy, which acknowledges the coexistence of multiple kinds of knowledge and combines qualitative and quantitative approaches (Johnson and Gray, 2010). Newman and Ramlo (2010) and Stenner and Stainton-Rogers (2004) have argued that Q methodology fits well within the mixed-methods continuum because it utilizes quantitative techniques like factor analysis to interpret qualitative data from Q sorts. This blend allows researchers to derive statistically robust patterns of subjectivity and subsequently interpret these patterns qualitatively, providing a comprehensive understanding of the research topic. Q methodology's integration within the mixed methods framework is supported by its dual focus on qualitative insights and quantitative rigor. The methodology's ability to provide context-rich, detailed descriptions while also allowing for statistical generalization makes it a powerful tool for mixed methods research.

6 Conclusion

This study utilized a mixed methods approach, combining quantitative Likert-scale surveys and Q methodology in a quantitatively driven concurrent-sequential (quan + QUAN) → qual research design (Morse, 1991; Schoonenboom and Johnson, 2017) to capture a comprehensive view of 33 pre-service mathematics teachers' beliefs on the teaching and learning of mathematics. With regard to the Likert scale surveys, the quantitative results indicated that pre-service teachers tend to hold constructivist-influenced beliefs. The quantitative analysis using Q methodology furthermore identified distinct constructivist belief systems within our sample, delineating them based on their prioritization of statements. This was further enriched by qualitative insights from post-sort interviews, which illuminated the reasons behind participants' prioritization of certain statements and provided context to these choices. In conclusion, we emphasize that while Likert-scale surveys can deliver broad insights across extensive samples, the Q methodology provides deeper insight into individuals' subjectivity. Our results not only highlight the complexity of pre-service teachers' beliefs about the teaching and learning of mathematics but also demonstrate the efficacy of integrating multiple research methods to capture this complexity fully. Such approaches are crucial in advancing our understanding of psychological phenomena and in developing more effective, context-sensitive instruments for measuring psychological traits, suggesting a promising pathway for future research in mathematics teacher education and beyond.

Data availability statement

The datasets presented in this article are not readily available because access to the data or parts of the data is strictly limited and only accessible to researchers who are specifically authorized and have

undertaken to comply with data protection regulations. The data was collected solely for the purpose of the study and cannot be used for other purposes. This ensures that the data is used exclusively for defined scientific purposes and that the integrity of the data is maintained. Requests to access the datasets should be directed to Nils.Buchholtz@uni-hamburg.de.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. All data used in this study was completely pseudonymized. At no time was the data processed or stored in such a way that it was possible to identify the individuals involved. There was no risk to the privacy or rights of the individuals involved in the study at any time. The study was conducted in accordance with internationally recognized scientific and ethical standards, without using personal data in a way that would have required approval by an ethics committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

NB: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. MV: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software,

Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Longitudinal mixed-methods analysis of tertiary students' dropout considerations

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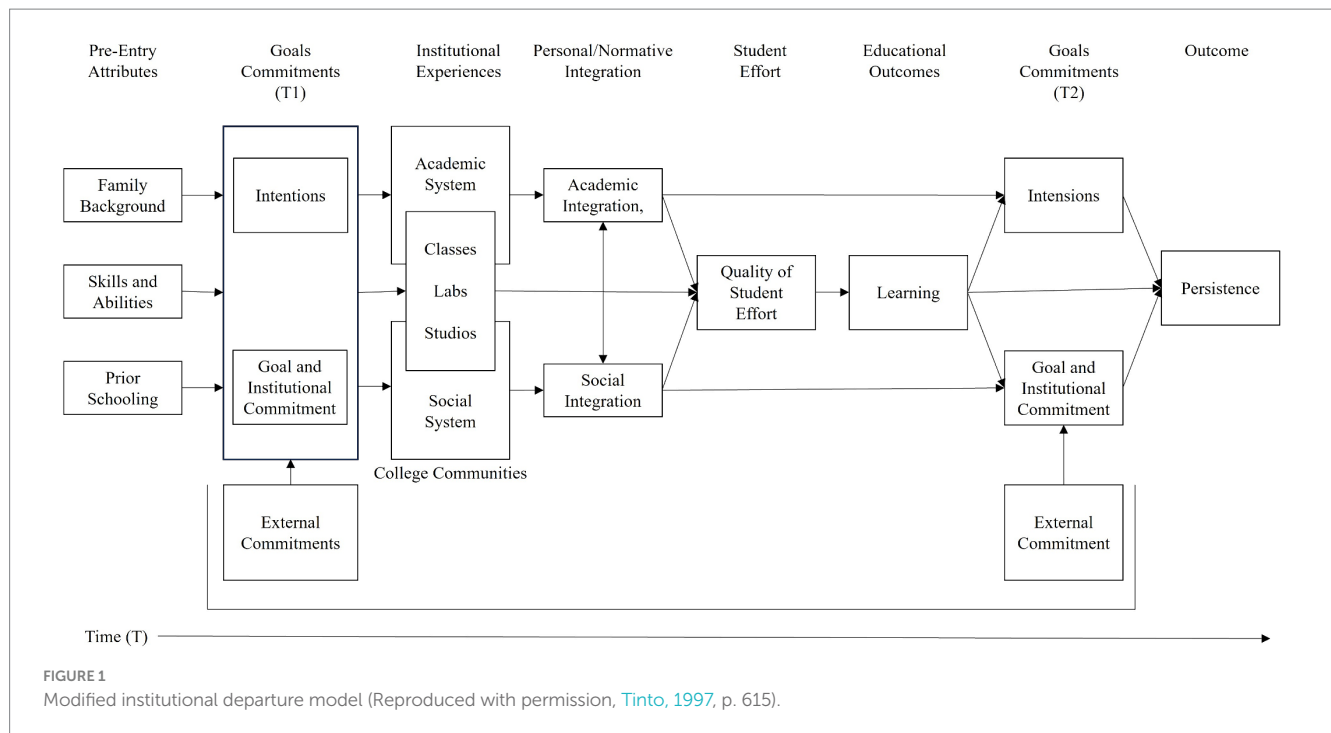
The paper presents a longitudinal mixed methods study investigating tertiary humanity students' dropout considerations, utilizing Tinto's institutional departure model as theoretical background. The research question is: How do students' dropout considerations take form and evolve throughout tertiary education? Methodically we have collected half-yearly register and survey data from 2,781 tertiary humanities students matriculating in 2017–2019. Additionally, we have conducted half-yearly interviews with 14 focus students that had high dropout considerations in the first survey round. Quantitative analysis of all humanity students and qualitative analysis of three case students are presented and discussed. The complementary analysis provides an in-depth understanding of the complex interplay between individual characteristics and institutional factors in shaping different students' dropout considerations and decisions in tertiary education. We find that there is a stable share of students with low, medium, and high dropout considerations throughout time. However, although we find stable shares, we identify primary movements from high dropout considerations towards dropout, and from low dropout considerations towards completion, we also find considerable secondary movement (i.e., from low dropout considerations towards dropout). As is also confirmed in the qualitative analyses, there are significant fluctuations in some students' dropout considerations. Dropout considerations are thus malleable and do not necessarily accumulate linearly over time to dropout. Individual students' dropout considerations change repeatedly in interaction with their experiences, their expectations for the future as well as with current challenges in meeting academic and personal requirements. Challenges are often about a lack of alignment between expectations and experiences and how well students and the study programs' norms and values match. We find students who seek to improve this match through personal transformations and others who try to change their study program. In both regards successfully improving the match seems to be a profitable strategy to prevent dropout.

KEYWORDS

tertiary education, Tinto's institutional departure model, dropout considerations, expectancies and experiences, mixed methods, longitudinal studies

Introduction

In 1975, Tinto introduced his institutional departure model as a counter-response to dropout models focusing solely on students' psychological factors and individual characteristics (Aljohani, 2016; Gore and Metz, 2017). Tinto's model (see [Figure 1](#)) proposed to understand dropout as a longitudinal process involving a complex matrix of interactions between the



individual (including background variables such as gender, age, social background, and prior educational experiences) and an academic system with subcategories such as interaction with personnel and academic achievements and a social system with subcategories such as extracurricular activities and interactions with fellow students of the institution. The 1997 model places classroom activities (classroom, labs, studios) as straddling both the social system and the academic system, suggesting that they overlap the two systems and are keys to improving student integration or identification.

The systems continually modify the student's academic and social integration, leading either to *persistence* (the choice to continue studying) or *departure* (the choice to drop out). This focus as well as the variables *intentions* and *goal commitment*, which in the model are proposed to mediate between the institutional meeting and persistence/departure, leave space for individuality and for dropout to be understood as the student's active decision.

Tinto's model has been suggested to indicate a change in paradigm in the field of dropout research and it is still today one of the most used and cited models in the field of higher education student dropout (Braxton and Hirschy, 2004, p. 89). Two of the central interrelated variables are suggested to be students' considerations regarding or intention of dropout (Tinto, 1975) and their motivation to or intention of persistence (Tinto, 1997). These variables are also described as important mediators for dropout in a number of later dropout theories (e.g., Bean, 1983; Astin, 1984; Bean and Metzner, 1985; Eaton and Bean, 1995; St. John et al., 1996; Tierney, 1999; Sandler, 2000; Bean and Eaton, 2002). Based on this, considerations regarding or intentions of dropout are often used as an early alert proxy for dropout (Eicher et al., 2014; Truta et al., 2018). However, in a newly study on dropout among students in humanities study programs, we found dropout considerations to be a weak predictor of dropout. Although, as we show in this current article, there is a stable and high percentage of students with dropout considerations throughout the education course

(between 19 and 24%), dropout considerations across semesters predict less than 10% of students' actual dropout (Qvortrup and Lykkegaard, 2024a). Considerations about dropping out are apparently something that many students have, without it necessarily ending up with them quitting their study program. The question is then, how can we understand these considerations? In a meta-analysis of studies on human regrets, Roese and Summerville (2005) find that the two choices in life that people most often regret are their educational and career choices. Are the dropout considerations thus an expression of regret regarding the choice of education already starting during their education? Another possibility is to understand the dropout considerations not as a regret (i.e., a feeling which is linked backward to the educational choice one had made), but as a fundamental doubt linked to the future opportunities that the education provides. It is not unreasonable to assume that such a forward-oriented feeling linked to the choice of education has increased with a heightened sense of existential vulnerability and declining trust in democratic institutions (Common Worlds Research Collective, 2020). This kind of doubt is not necessarily negative, as suggested by Herrmann et al. (2015) who describe a kind of doubt among university students that is related to their academic identity and experience of meaningfulness. This doubt, they suggest, is constructive, because it causes the students to shape themselves and their identity in interaction with their social and academic environment. Furthermore, it causes them to make informed choices (Herrmann et al., 2015). This is a completely different form of student doubt than the negative one described in Hovdhaugen and Aamodt (2009), which is rooted in either administrative requirements that the student cannot handle, or in a (not always well-founded) fear of not being able to fulfill academic standards. The relevance of distinguishing between constructive and non-constructive doubt is confirmed in Hovdhaugen (2009), who shows that doubt reasoned in a lack of alignment between expectations for and experiences of the educational content in the study program, to a greater extent resulted

in a change of study than doubt reasoned in other conditions, which led to dropout. However, the consequences may not be as one-sided as one risks suggesting by linking them alone to conditioning factors and results. Studies on apprentices who remain in their apprenticeship, find that dropout considerations can undermine work satisfaction and commitment (Allen et al., 2010), engagement (Halbesleben and Wheeler, 2008), and future performance (Bakker and Costa, 2014), and additionally associated with stress at work (Allen et al., 2010). Furthermore, it is suggested that the dropout considerations reflect a negative experience (Eicher et al., 2014) which may accumulate over time (Hobfoll, 2011). Because of the complexity of the character and possible consequences of dropout considerations, they are worth examining in their own right, as also suggested by Powers and Watt (2021).

In this article, we investigate dropout considerations among students in tertiary education programs in the humanities. Reasoned in the findings described above, there are two major purposes to this article: To understand (1) what characterizes students' dropout considerations and (2) if students' dropout considerations accumulate over time (cf. Hobfoll, 2011). The research question is:

How do students' dropout considerations take form and evolve throughout tertiary education?

The research question will be answered focusing on different identified evolvments in students' dropout considerations. The purpose of the article is not to reach general conclusions about the origin or size of students' dropout considerations, or to produce final knowledge about which evolvments are most or least frequently occurring, but to draw a varied picture of different possible evolvments in students' dropout considerations and point to possible psychological and structural reasons for these evolvments.

Materials and methods

To answer the research question focusing on the characteristics and evolvment of students' dropout considerations, the article builds on a mixed method design with longitudinal survey, register, and interview data from tertiary Humanities students matriculating in 2017–2019. Data was collected every half year as long as the students were enrolled in the program. Our choice of design and methods for the study is based on a belief that the longitudinal data collection with the various methods provides the best basis for investigating how students' dropout considerations might take form and evolve over time. When choosing a mixed method design, Greene (2008) accentuates the importance of having a strong inquiry logic, which must be underpinned by coherence and connection between the constituent parts (i.e., methods). In our case, the survey provides knowledge about fluctuations in students' self-reported dropout considerations, while register data allows us to examine whether these dropout considerations accumulate to actual dropout. Interview data nuances our understanding of the fluctuations and of how students' explain high and low dropout considerations, respectively. However, how and if different parts (i.e., methods) fit together must be determined not only based on the research interest, but also in the epistemological framework of the study. Epistemological paradigms offer logics of justification and frames of

inquiry for selecting and discussing methodologies and methods that can help design and discuss how to best answer research questions and explain and discuss the relevance of different methodologies and methods (Carter and Little, 2007; Qvortrup and Lykkegaard, 2024b). The epistemology that has guided the choices of methodologies and methods in this article relates to the thinking of dropout in Tinto's institutional departure model. The epistemological aspects of Tinto's institutional departure model have resulted in the chosen design, which relates to the model being socio-psychologically rooted. We, therefore, chose methods that gave us the possibility of examining characteristics and fluctuations of the students' dropout considerations, from both a focus on individual/psychological perspectives and social mechanisms/structures. We chose to do this by asking students in interviews to describe and explain individual experiences or perceptions, referring to social structures, and by looking at patterns in individual experiences or perceptions as these are represented in students' survey responses. We visualize the survey and register data by using Sankey diagrams, which identify patterns across item responses and thus lead to identifiable paths. We do not claim that this is the full breath of possible paths, but we use these identified collective paths to detect themes that must be explained by something other than the individual, psychological perspective, namely social mechanisms or structures. By combining interviews with register and survey data we get a 'diversity of views' and get the chance to 'change perspective' (Greene et al., 1989; Greene, 2007; Bryman, 2016). Regarding the change in perspective, we increase both the breadth and depth of our analyses of students' dropout considerations by moving from patterns identified across students to individual students' experiences or perceptions. We thus seek to expand and strengthen our interpretation and the validity of the quantitative data by combining it with complementary interview data. Our approach is, quantitatively variable-oriented (with a focus on dropout consideration changes) and qualitatively case-oriented (with a focus on students' reasons for and experiences of these changes).

The study employs data integration as participating students in the qualitative part are a subsample of the quantitative participants. Moreover, the study employs interpretation integration, as the qualitative case student are analyzed and presented as narrative joint displays referring to previous (quantitative and qualitative) presented data and results.

Register and survey data

We collected longitudinal survey and register data from all students in Humanities at the University of [anonymized for the sake of review] matriculating in 2017–2019 ($N=2,781$) half-yearly until they were no longer enrolled (i.e., graduated or dropped out). Student descriptives are presented in Table 1. Register data were collected with exact dropout/completion dates and counted for the beginning and middle of each semester. However, unless students who dropped out actively contacted the university to let them know that they would not proceed their studies, there was a delay in dropout dates, as administrative dropout registration was not registered before students missed obligatory classes or exams.

Register data on students' study progress (i.e., enrolled, leave of absence, graduated, or dropped out) were provided by the university

TABLE 1 Descriptive statistics for participating students ($N = 2,781$).

Descriptive statistics	Percentages			
Educational level	Bachelor's degree: 59.9%		Master's degree: 40.1%	
Gender	Male: 28.7%		Female: 71.3%	
Homeland	Denmark: 88.3%		Other countries: 11.7%	
Age at matriculation	20 or younger: 19.8%	Age 21–25: 57.5%	Age 26–30: 14.3%	31 or older: 5.8%

TABLE 2 Item loadings and Cronbach's alpha values for the dropout consideration factor for each semester.

Study intentions	Items	Loadings pr. semester					
		1	2	3	4	5	6
Dropout considerations	I have considered dropping out during the last six months.	0.815	0.731*	0.792	0.844	0.863	0.898
	I have during the last six months sometimes felt uncertain about whether I should continue with this program.	0.986	0.960	1.004	1.022	0.981	0.898
	I have during the last six months talked to friends and/or family about possibly dropping out.	0.890	0.954	0.911	0.977	0.864	0.898
Persistence intentions	I expect to complete my program	0.343*	–	–	0.330*	–	–
	Cronbach's alpha	0.861	0.906	0.908	0.852	0.870	0.867

*(on loading) = Alpha increases if item is removed.

along with mail addresses for all students. The survey was distributed electronically to the students' study mails halfway through each semester and teachers were encouraged to set aside time in class for students to fill out the survey, to minimize overall dropout. We acknowledge that students self-reported dropout considerations in the middle of the semester might very possibly be different than dropout considerations at the beginning and/or end of the semester. We thus, do not perceive the dropout considerations that students indicate halfway through one semester as a proxy for dropout considerations for the entire semester. Instead, we perceive them as experiences situated in time, which we can compare to situational experiences at other times (halfway through previous and subsequent semesters). We do not anticipate linear development between points in time.

The response rates varied from semester to semester from 58% in the first semester to 15% in the sixth semester. The dramatic drop in response rates might be due to the COVID-19 shutdown, where students were home-taught and teachers thus were not able to set aside time for the survey during (physical) classes.

In this article, we focus on a subset of four survey items (see Table 2) related to students' dropout considerations, answered using a five-point Likert scale. Participants were provided the option to respond "I do not know/I do not wish to answer" for all questions, and these responses were treated as missing values in the analysis.

Explorative factor analysis

Data were transferred to SPSS and all statistical analyses were conducted in SPSS v.28 and Excel. Data were screened for impermissible values (no values were outside the 1–5 range) and subsequently screened for missing data.

The dataset's suitability for factor analysis was evaluated using Kaiser-Meyer-Olkin measure of sampling adequacy ($KMO > 0.5$) and Bartlett's test of sphericity. Exploratory factor analysis (EFA) was used to openly investigate the underlying factor structure. Since the

correlation test (using direct oblimin rotation) showed very small correlations, orthogonal Varimax rotation was used. Kaiser's criterion (eigenvalues ≥ 1) was used to determine the number of factors, and items with loadings above 0.4 were included (Rahn, 2014). The factor reliability was tested with Cronbach's Alpha (we use standardized α), where $\alpha > 0.6$ was chosen as accepted (Ursachi et al., 2015). We performed the EFA for individual semesters (1–6) and found the same one-factor structure each time, as indicated in Table 2. Noticeably the fourth item does only load on the factor on two semesters, and for each of these semesters the loadings are below the cutoff value of 0.4 and additionally, the Cronbach's Alpha value will increase if this item is deleted. According to Schönrock-Adema et al. (2009), a factor should contain at least three items with significant loadings and items loading on the same factor should share the same conceptual meaning. Based on this we continue our work with the three-item dropout consideration factor.

A mean value for the accepted dropout consideration factor was calculated for all students for all semesters.

Descriptive statistics and visualisation

Dropout considerations (values 1–5) were analytically divided into three groups of low, medium, and high dropout considerations, as represented in Table 3. For each semester, students who had dropped out were given the value 0 (from the register data) and likewise, students who had completed their studies were given the value 6 (from the register data).

We quantified the share of students with low, medium, and high dropout considerations, respectively, as well as the share of students who had dropped out from or completed their program in each semester.

From the total population of 2,781 students, 141 students had completed surveys for all semesters while they were still enrolled in their program. We used Sankey diagrams to visualize these students' fluctuations between low, medium, and high dropout considerations

and towards either dropout or completion across the data collection points. Sankey diagrams are particularly suitable to illustrate flows and have previously been proven appropriate to visualize educational trajectories (Sadler et al., 2012; Lykkegaard and Ulriksen, 2019).

Finally, we quantified the total movements between adjacent semesters from low, medium, and high dropout considerations respectively, and towards low, medium, and high dropout considerations as well as towards actual dropout and completion.

Interviews

A sample of 14 students was selected from the first survey round based on their belonging to the group of students with high dropout considerations and because they had ticked off a box in the survey permitting them to be contacted for follow-up interviews. We chose students with initially high dropout considerations, as we wanted to enhance the possibility that some of the interviewed students would end up dropping out during our study (Hobfoll, 2011). Students' dropout considerations were longitudinally investigated by half-yearly qualitative, semi-structured individual interviews throughout tertiary education until they graduated, dropped out, or did not respond to any more requests from the researchers. The first interview was conducted at the students' school, the following interviews were conducted by phone while students were at home. In total 62 interviews were conducted, which each lasted between 10 and 50 min (20 min on average). The first interviews were the longest. Each interview was conducted by the first author and followed the thread and theme from the previous interview regarding students' study

experiences and accounts of their dropout considerations. All the qualitative interviews were recorded and transcribed verbatim.

For the present analysis, we selected three case students based on maximum variation (Flyvbjerg, 2004) with one case student who completes her program, one student who drops out of her program, and finally one student who changes to another program which she completes.

Qualitative analysis

In the interview transcripts, the first author extracted the sections where the students explicitly or implicitly referred to their dropout considerations, and—true to Tinto's Model—their experiences of the social environment, the academic environment, and classroom activities. From these extracts, the first author wrote three case stories. The stories were then analyzed one by one by the second author (with no prior knowledge of or relationship with the students) based on the theoretical framework presented in the introduction focusing on the three students' reasons for having or not having dropout considerations, on the students' forward/backward reasoning, on the influence of administrative and academic requirements on dropout considerations, and alignment between study expectations and experiences. Finally, the first author, with her year-long relationship with the students—validated these analyses, and we jointly wrote case presentations, illustrating the anonymized students' tertiary educational stories and referring back to the quantitative data and between the case students' stories.

Results

Results are presented in two subsections. The first section presents the fluctuations in the students' dropout considerations over time (quantitative), and the second presents the three case students' individual (qualitative) dropout considerations stories and our analysis hereof.

Fluctuations in dropout considerations

Table 4 illustrates that the share of students indicating to have low, medium, and high dropout considerations remains stable across the semester (63–71%, 9–15%, and 18–24% respectively). This stability is

TABLE 3 Categorisation and values assigned to register and survey data outputs.

Assigned values	
Register data	Dropout considerations (factor mean)
Dropped out (value 0)	
Enrolled	High dropout considerations (values: 1.00–2.35)
	Medium dropout considerations (values: 2.35–3.65)
	Low dropout considerations (values: 3.65–5.00)
Completed (value 6)	

TABLE 4 Study progression and dropout consideration descriptives pr. semester.

	Semester					
	1	2	3	4	5	6
Study progression status (register data)						
Enrolled	2.754 (99%)	2.551 (92%)	2.409 (87%)	1.623 (58%)	1.477 (53%)	793 (29%)
Completed	0 (0%)	14 (1%)	22 (1%)	732 (26%)	821 (30%)	1.467 (53%)
Dropped out	27 (1%)	216 (8%)	350 (13%)	426 (15%)	483 (17%)	521 (19%)
Dropout consideration status (survey data)						
Low dropout considerations	1.048 (66%)	534 (63%)	483 (68%)	237 (67%)	143 (65%)	82 (71%)
Medium dropout considerations	257 (16%)	114 (13%)	92 (13%)	39 (11%)	33 (15%)	11 (9%)
High dropout considerations	284 (18%)	204 (24%)	135 (19%)	79 (22%)	44 (20%)	23 (20%)

noticeably consistent among the enrolled students throughout a period where more and more students either drop out or complete their study program. This could indicate that some students accumulate their dropout considerations and drop out, after which approximately the same share of new students start accumulating dropout considerations without accumulating to drop out. However, the Sankey diagram in Figure 2, tells a different story, contributing to challenge the suggestion of Hobfoll (2011) that students' dropout considerations accumulate over time.

Figure 2, visualizes fluctuations in students' dropout considerations between low, medium, and high dropouts. The horizontal dimension shows time with the six semesters indicated at the bottom. The surveys were answered in the middle of the semester whereas the register data were accumulated and plotted for the beginning and middle of the semester. The vertical dimension presents the distribution of the 141 students in five different groups according to dropout, dropout considerations (high, medium, low), or study completion at each semester. The colored bands illustrate the identified flows between the five groups. The widths of the individual colored bands are proportional to the share of the 141 students in it. The proportion of students identified to have "low dropout rates" is thus the wide light green band at the left top thinning out across time (moving right). This band includes both students who continually indicated low dropout considerations and those who came from medium (i.e., the yellow band) or high (i.e., the orange band) dropout considerations.

The range of different identified patterns/fluctuations represented in Figure 2 emphasizes the dynamics in students' dropout considerations. Although there seems to be a primary movement from high dropout considerations (orange) towards dropout (red) and from low dropout considerations (light green) towards completion (dark green), there are also considerable secondary movements, e.g., from low dropout considerations (light green) towards dropout (red)—see second and third semesters in Figure 2. Likewise, there are noticeable

movements from high dropout considerations (orange) toward study completion (dark green) in the fourth and sixth semesters. It is important to note, that we cannot assume linearity in dropout considerations from one measurement point to the next. Underneath the identified patterns—primary as well as secondary movements—there might be additional oscillations.

Table 5 illustrates a summed view of the students' identified movements from low, medium, or high dropout considerations in one semester to their dropout considerations, dropout, or completion in the next semester. The dropout rate is highest for students with high dropout considerations (30%) and the completion rate is highest for students with low dropout considerations (9%), however, there is also considerable dropout for students with low dropout considerations (6%) and likewise noticeable completion rates for students with high dropout considerations (5%). With this table, it is therefore firmly established that dropout cannot, at least not for all students, be understood as a result of linear accumulated dropout considerations. We have groups of students for whom the fluctuations in dropout considerations follow a completely different non-accumulating pattern. Perhaps some of these students' high dropout considerations are of the positive type that we referenced Herrmann et al. (2015) to describe. For other students, particularly those with low dropout considerations that drop out, the mechanism must be completely different and rapidly changing. Regarding the students, whose dropout considerations do accumulate towards dropout, based on Table 5 and Figure 2, we can conclude that the accumulations occur at different speeds (orange to red, yellow to red, and green to red in consecutive semesters).

Case students' tertiary educational stories

Table 6 shows the educational status over time of the 14 focus students participating. The color shows whether the students are

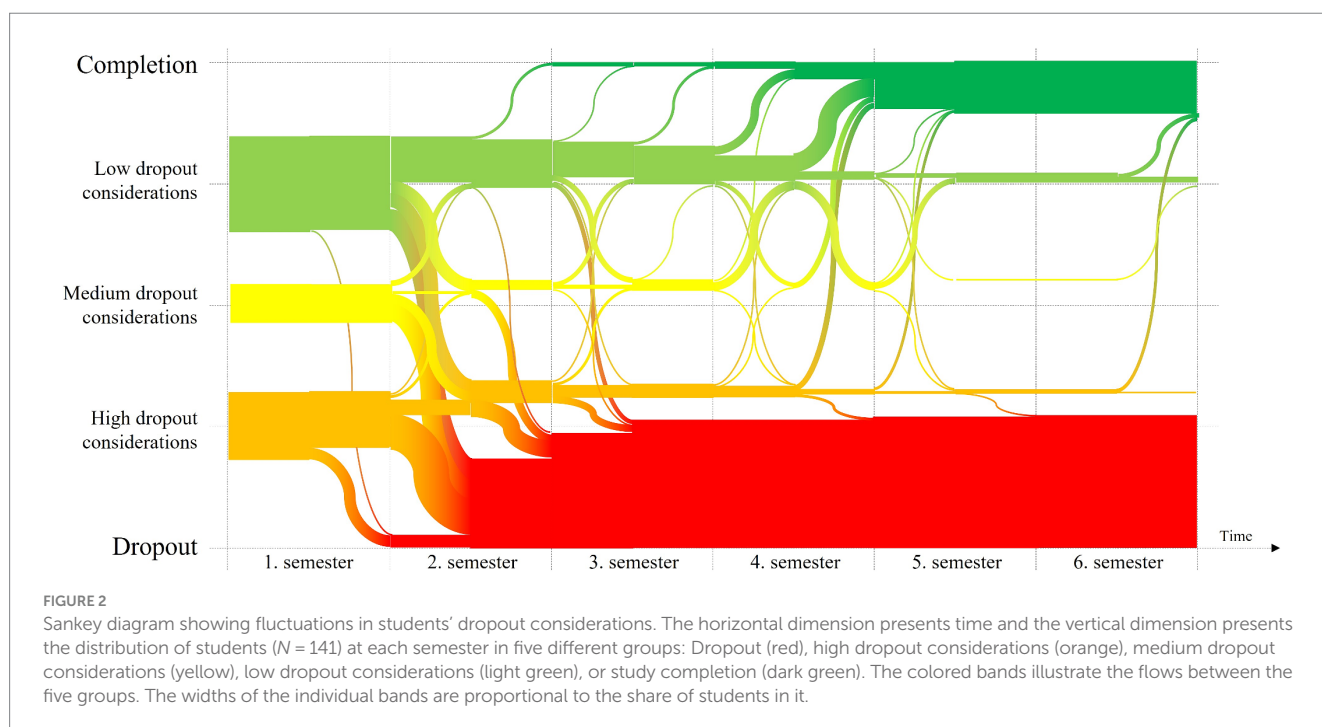


TABLE 5 Movements in dropout considerations and study progression between adjacent semesters.

	Completion	Low dropout considerations	Medium dropout considerations	High dropout considerations	Dropout
Low dropout considerations (N=308)	9%	73%	8%	5%	6%
Medium dropout considerations (N=104)	6%	18%	47%	9%	20%
High dropout considerations (N=176)	5%	3%	3%	59%	30%

Share of students at one semester (left column) with, respectively, low (light green), medium (yellow), and high (orange) dropout considerations and their particular dropout consideration (light green, yellow, orange), completion (green) or actual dropout (red) the following semester (adjacent columns). Note, as the 114 students answered the survey each semester as long as they were still enrolled in their program, the total number is of adjacent semester movements are 588.

TABLE 6 Students' individual educational trajectories.

	Semesters								
	1.	2.	3.	4.	5.	6.	7.	8.	9.
Mona	X								
Mae	X	X							
Ingrid	X	X							
Cathrine	X	X							
Mahir	X	X	X						
Abi	X	X	X	X					
Carina	X	X	X	X					
Sue	X	X	X	X	X				
Lucy	X	X	X	X	X	X			
Cathrine	X	X	X	X	X	X			
Sarah	X	X	X		X	X			
Maria	X	X	X	X	X	X			
Yalina	X	X	X	X	X	X	X	X	
Idhar	X	X	X	X	X	X	X	X	

Yellow: Still enrolled. Green: Completed study program. Red: Dropped out. Orange: Dropped out and changed to a new study program. White: Researchers were not able to get in contact with the student.

Xes denotes interview times. Blue squares highlight the three focus students.

enrolled (yellow), dropped out (red), or have completed their study program (green). The focus students—who all had high dropout consideration in the first semester—were interviewed half-yearly (marked by Xes in the table) throughout tertiary education until they graduated (8 students), dropped out (4 students), or did not respond to requests from the researchers (white—2 students). Two students quit their original study program and entered a new program. The semester where they started a new program is marked by orange in the table. The three selected case students whose individual educational trajectories and dropout consideration stories will be presented in the following are indicated in the table with blue squares around. The case students are thus selected to illustrate a student who dropped out of the study, a student who completed the study, and a student who dropped out of the first study program and started a second program.

Ingrid

Ingrid is a middle-aged woman, who has been working as a youth care worker with vulnerable children for several years.

"Well, I really loved my job, but the working conditions have deteriorated so much that sometimes I can't even look myself in the mirror and hardly stand behind what we do at work. So, I felt I had

to pull the plug. And I can't have any influence in the position I'm in now. So, I had many considerations about if I wanted to have an impact and make a difference, bring something else into the field of work I have, primarily with neglected children, then I needed to have different knowledge and a different title to put on it, to be able to do something else." (First interview)

Ingrid's reason for starting her tertiary study (masters' program) can be understood with reference to the distinction we made in the introduction between feelings referring backward (regrets) and feelings referring forwards (opportunities). Ingrid justifies her choice of study by referring backward (she loved her job but had to leave because of the working conditions). However, the quote shows that she is also influenced by forward-oriented feelings, as she sees future opportunities (different knowledge and a different title). However, it becomes clear that the forward-oriented feelings do not necessarily have a clear direction, as she is unsure of what exactly she will use the education for: *"I've been toying with the idea of doing something else for the past three years. Not specifically what it should be, but I could feel that I needed something different in terms of work."* (First interview). Her lengthy process of deciding to quit her job has resulted in great motivation for her new tertiary education. The motivation is furthermore based on already positive experiences with successfully

pursuing some other tertiary education and looking forward to more. However, when Ingrid started her studies, she felt overwhelmed:

"I was very surprised, and I felt completely thrown off. I thought, 'You can't be so stupid and clueless that you don't understand this.' I was really knocked down. I can't exactly say what it was that knocked me down, but it was as if my entire identity was being torn apart in some way." (First interview)

Ingrid herself sees one reason for her feeling that her identity is being torn apart is the academic level (cf. [Hovdhaugen and Aamodt, 2009](#), academic requirements):

"Because I could feel it in the academic field, and we even started quite slowly, I think, looking back now, but I could feel that having to sit down and engage with reading a text and then understand it afterward, and try to extract from it with the knowledge I had back then, it was a big task." (First interview)

In addition to the difficulties in meeting administrative and academic requirements (suggested by [Hovdhaugen and Aamodt, 2009](#)), Ingrid believes that her age also affects her experience of the academic requirements: *"And I can also feel that I'm not quite young anymore. My age also plays a role. I do not have the same reading speed anymore, and I do not have the same working memory when it comes to approaching new things."* (First interview). Ingrid additionally points out some personal issues. She had to work full-time alongside studying because she could not take leave from her job. This is uncommon in Denmark, where the government provides financial support ("SU") for education. She would also like to *"have time for her family"* and she believes that *"It can be difficult to fit it in compared to starting a study at the age of 20"*:

"And this whole thing about losing... Not having anything stable, not having this structure around it, it has taken me some time to build it up." (First interview)

In addition to the academic requirements, Ingrid thus faces personal requirements within two sub-categories: financial and family care, referring to her resources, costs, and values. The academic and personal requirements jointly fueled Ingrid's dropout considerations:

"It's been a really tough start. And I've also been close to quitting and thought that I shouldn't expose myself to this [...] My goal was that I would try until the fall break [the semester starts in September and the fall break is in October]. I said that I had to do that, otherwise, you simply can't just quit. But until the fall break was my goal, and then it had to bear or break, whatever was going to happen then. Also, if I found out whether I could even learn this. And if I can figure out how to write in this way. And I have now realized that I can. It just takes time for me. It takes time for me to read, understand, and use it academically. [...] And when I had written it [exam assignment during the fall break], been through it, and passed it, I could feel that I had the courage for more. Because I've always found this incredibly exciting. It's incredibly exciting to be enriched by different knowledge and knowledge from completely different angles than the ones I encounter in my work practice and

in my social circle. It gives me a lot to encounter knowledge in this way." (First interview)

Thus, Ingrid's dropout considerations were fueled by negative experiences, as described in [Hovdhaugen and Aamodt \(2009\)](#). However, as the above quote shows, the dropout considerations also seem to be counteracted or diminished by positive experiences. Ingrid has the experience that she has cracked the academic code. At times she seems surprised and impressed by her knowledge and her new study approach. She says, *"And sometimes I can hear myself saying 'how do you know that?'; 'what is it based on?'. I have suddenly started to be much more critical regarding what I read. In what I am asked to do, and in the way I approach things."* (First interview). At this point, she no longer had dropout considerations:

"No, because then I took the next step, which was until Christmas. I have taken it very gradually to keep myself up saying, this is what I need to do right now. My considerations about it are that I cannot have both a full-time job and study on the side. And I don't want to do that to myself. I don't want to do both things halfway. So, I have to make a decision soon about what I'll do. And it's simply because I can only get SU [student grant], and I can't live off that. I must realize that I simply can't. I don't want to have to sell my house and everything for that..." (First interview)

Ingrid's experience of being able to master requirements added to her personal transformation:

"It has taken me a long time to set aside my youth care worker title and get used to the student title. This thing about being a student. I might be a youth care worker, but right now, I am a student, and this is where I am, and this is what I have to deal with." (First interview)

However, the dropout considerations returned, and at the end of the first semester, she says *"But I can feel now that the study has taken a turn because I am currently experiencing that it has become really difficult. It's because there is a lot of literature in English, and it requires even more of me to deal with it."* Once again, she has given herself a new deadline. She said: *"Now I have at least tried to finish it until Easter [halfway through the second semester] where there will be a change again."* (First interview). By the time of the second interview, Ingrid says:

"Well, the way it's gone is that shortly after we talked, I think it's at that point I go on sick leave. Or at least I become ill. And I am sent to the hospital for a check, with the aim of diagnosing cancer in my stomach and then subsequently cancer in my throat." [...] After about a month and a half in the diagnostic process, fortunately, cancer is not found. Something else is found, but it is not life-threatening in any way. But after that period, there is an exam, and I would say that's when I really hit rock bottom." (Second interview)

"And then I couldn't bear the idea that I had to be in it [...] So, the study is on hold because I haven't enrolled in classes here after. And I haven't done that because then I completely fell out of the system. And I could see that I couldn't catch up within the standard time that the study is set for." (Second interview)

Ingrid therefore drops out. She says:

"It was very much about the content. And what can one say about the teaching or the teachers, it has been very different [...] I think I became unsure of those times when we had subjects where we had multiple teachers. And where those teachers disagreed on how the teaching should be." (Second interview)

"I guess it was me who didn't really fit into it. And I had become too old. And it was also nonsense that such an old woman like me should engage in it. That's how you can quickly belittle yourself." (Second interview)

Ingrid describes difficulties in figuring out and managing what she was supposed to do. She, on the one hand, finds herself unfit for studying. On the other hand, she still finds the study program interesting.

"Right now, I'm thinking that, for one thing, I really miss reading a lot. I miss incredibly much this thing with the knowledge [...] And it's incredibly interesting at the same time as it's also insanely challenging. And I could feel that it had been many years since I had been in a classroom. [...] I hope that I can find a solution and come back to it [the study]. Because I really think it was really fantastic." (Second interview)

Through the course of our study, Ingrid experienced many fluctuations in her dropout considerations. It was by no means a cumulative one-directional movement that made her dropout, it was ups and downs, and in the end, she explains her dropout with a heavy personal experience. However, we cannot help wondering, whether this experience also in some way set her free from her academic struggles.

Table 5 and Figure 2 illustrated movements and fluctuations based on our survey and register data, we saw how some students' dropout considerations followed a non-straightforward movement. Ingrid illustrates, such non-straightforward movements. Her story additionally show that these movements can take place over rather short time intervals. In the following, we present Abi's story and the movements in her dropout considerations.

Abi

Abi is a newly graduated journalist, and after spending 6 months searching for jobs and feeling that she lacked some academic knowledge to convey, she applied for a two-year master's degree program:

"I could sense that it was something I thought could be exciting. But I just think that what happened quite quickly when I started the program was, I didn't feel like it lived up to what was described about it." (First interview)

What Abi describes early on in her study, is an example of the lack of alignment between expectations for and experiences of the educational content in the study program, as described by Hovdhaugen (2009). Abi justifies her expectancy-experience frustrations by the fact that she was not familiar with the way of working at universities. This issue is discussed by Abi throughout her studies:

"There are some things I notice because my education was so practical compared to those who are used to studying at home. You read, you attend lectures, then back home." (First interview)

"And it also became very clear to me during the method project because then I chose to ally myself with someone who was quite academic and who came from the history study. And there were just so many things that she knew as a matter of course about how things should be structured, and so there were many of the things I had written that she asked me to make more academic because I'm brought up in a completely different way. Things should ideally be as understandable as possible. Where sometimes it can seem like almost the opposite is what you aim for in those assignments." (Third interview)

According to Hovdhaugen (2009), dropout considerations reasoned in expectancy-experience misalignment might lead to a change of program (instead of dropout). For Abi, however, her decisiveness, caused her to stay in the program.

"So, there's also something in my upbringing, in that I would feel it as a personal failure if I dropped out of something I had committed to and started. In terms of my future, for example, I have a father who really wants to further his education, he's a vocational teacher, and it's really difficult for him to do anything because he doesn't have a higher education than that. There's also something in that, that regardless of whether I feel like I can use it for much right now, I think it's really nice to have that master's degree with me. And I also went into this education with the premise that it's just a year in the classroom, and then I would have this internship in the third semester, and then the master thesis for another half year, and that's it. So now I'm also so far along, so I think I'll stick with it. If I get an internship placement, that is, I've been applying a bit now." (First interview)

Here we see, just like with Ingrid, that the way Abi handles her dropout considerations is based on feelings referring backward, both to her own experiences of not being allowed to fail, but also to experiences from her father's lack of success. However, she also briefly mentions some forward-oriented feelings with the wording that it's nice to have that master's degree with me. But to realize the opportunities described as part of the forward-oriented feelings, there is a hard battle to be fought. Fortunately, Abi has a genuine interest in the field:

"But somehow, what's at the core of the study, that is still what I find interesting." (First interview)

However, her decisiveness and interest does not stop her from momentarily being filled with dropout considerations:

"But here in January, for example, when we had this week-long exam, and when I otherwise had time off, I was looking at job postings a lot. Because it takes something to hold onto someone like me, because I know that I have an education that I could just go out and use for something. In principle, I could just go out and enter the job market now." (Second interview)

Abi's considerations about dropping out largely revolve around the study program or what Tinto (1975) terms the academic system. She did not feel that she was sufficiently challenged academically:

"I attend the classes and I study my material. I want it to make sense to me. But then you sit, for example, in this class yesterday, and I feel like it's the same thing that was covered last week. And it's also because they have to consider that we come from so many different places, but some things are really spoon-fed. Where you think, we can probably move on to something else now." (First interview)

In addition to the academic level, Abi thought the program lacked depth, that it tried to cover too broad a spectrum, and she says that she often "misses the point" of the texts they read and therefore questions their relevance. Interestingly, Ingrid's experiences of lack of understanding lead her to criticize herself (lack of skills), while Abi directs the problem at the study program. It seems that the former inward orientation increases dropout considerations, while the latter outward orientation decreases them.

A final outward critique from Abi, has to do with her being dissatisfied with the teachers, and her dropout considerations are therefore also reasoned in Tinto's (1997) category 'Classroom activities'. Abi has been openly critical of the teachers since the first semester, and this criticism continues throughout the rest of the interviews:

"I actually think we had some really bad teachers." (First semester)

"I mean, I also think I've said this many times during our interviews, that they are indeed very academically skilled teachers. It's just that some of them are so academic that they also forget to be good at conveying information. And that's probably because they primarily prefer to be researchers rather than teachers. But they do know a lot about what they're teaching." (Fourth interview)

When Abi addresses the problematic issues she sees in her study program, she is repeatedly told that it will get better in the next semester, that it will then make sense e.g.: "we were constantly told by our tutor that this teacher is a bit special, but after the fall break, it will get better." (First interview), but that is not her experience. Thus, the consequences of a lack of alignment between expectations and experiences described in the introduction referring to Hovdhaugen (2009), apply not only to Abi before and after the start of her study, but also during it. Abi is not comfortable leaving the gap between expectations and experiences open, perhaps because she does not believe that it will be possible to close the gap she is experiencing. Abi finds it unsatisfactory that things do not "make sense" in the present:

"And that's what made me really dissatisfied in the first semester. You must get a feel for everything but don't know what to grasp. And then you sat there until January and had to do a week-long exam and write an assignment, and maybe it was only then that you had time to understand the theories you needed for the assignment." (Second interview)

Abi does what she can to close the gap between expectations and experiences and make sense of the theories herself. As part of this sense-making, she decides that she wants to do an internship as part

of her education in the third semester. However, she cannot find any information about it anywhere. She knocks down doors until she succeeds in arranging an information meeting for herself and for her classmates:

"There wasn't meant to be an info meeting, no. Which has come about because I could sense that there were many who were interested in hearing about this internship. But it's a cumbersome process, and it's something you have to be passionate about to get through." (Second interview)

As illustrated in the above quote, Abi constantly encounters challenges, but as we saw earlier, she does not turn the problems inwards to the same extent as Ingrid, she turns them outwards and acts. All in all, Abi's frustrations several times make her react and try to change things in her program and classes. Other times, it makes her sit quietly in class:

"I find it difficult to constantly... Well, this bad atmosphere that's actually in the class about the teaching... You can't just complain without doing something about it either. But it's also very unclear what to do about it. So, I probably try to keep quiet sometimes." (First interview)

As is obvious from the above quote, Abi cares about the atmosphere in her class, however, she was not initially that socially invested in her class, and she does not believe that her class's social environment is that good. However, Abi shares how she strategically chose her study group partners. Particularly the girl, already mentioned, who came from a completely different background than her.

"I had singled out her who I knew was really sharp in those, you know, overarching academic things from uni, and then we also found a third person." (Fourth interview)

And a bit to her surprise, Abi ends up getting quite close with her study group. "The two I wrote the method project with, I've become quite good friends with them." (Third interview). However, when it came to her earlier dropout considerations, Abi used only her family, boyfriend, and friends outside the university to discuss this:

"My boyfriend also listens to a lot. And one of his friends, who is actually doing a Ph.D. [...] I've actually talked to him quite a bit because he says he just loves studying and thinks it's great. He really keeps saying that I should drop out. He thinks I should drop it and that you shouldn't do something you're not happy with. But I actually had a successful experience with this [latest] exam. And it was really nice to get grades on that because I had kind of set it as a goal, that if it didn't go well with that, then I actually didn't understand at all what we were doing in this study program, and then I shouldn't be here. But it went well." (Second semester)

Hovdhaugen and Aamodt (2009) describe how a (not always well-founded) fear of not being able to fulfill academic standards, might increase dropout considerations (like for Ingrid), however, for Abi the positive experience of being able to fulfill requirements helped reduce dropout considerations.

During the second semester, Abi got the internship placement she wanted, which helped things fall even more into place for her. *“The whole second semester was actually also in the light of knowing that I was going to intern in the third semester,”* and when asked about her dropout considerations in the third semester, she responds: *“No no no, we are finishing it now, unless it completely messes up in the master thesis, of course.”* Abi did a so-called product-based master thesis. Again, she struggled to find information on how such a thesis could or should be constructed:

“And I can sense from my teachers that it's not because they have a lot of experience with these product theses either. But I think maybe it's up to me to figure out how to put it together.” (Third interview)

“However, in terms of my concern about figuring out what I can use the program for, there must be something I can figure out because I got an A for the thesis.” (Fourth interview)

It is a great success for Abi to overcome the challenges she has been through. The reason for her expectancy-experience gap and continuous challenges and dropout considerations not cumulating to actual dropout, might be, that she, unlike Ingrid, attributes these challenges outwards and thus, does not need to face challenging personal transformation.

In the following, we present our third case student, Idhar. She too is experiencing challenges and has dropout considerations. For Idhar the challenges led her to change her study program.

Idhar

Idhar is a young woman, who is very motivated to continue studying and to attend a university study after upper secondary school. However, she has had a hard time figuring out what bachelor's program to choose:

“And my grades aren't very high, so I couldn't just apply to any program that I had in mind. Before I even applied to any programs, I wanted to study to become a social worker, even though it's not at the university. Also, because it suits me more. But I couldn't because of my grades. So, I had to see what else I was interested in.” (First interview)

After upper secondary school, she applied for different bachelor programs, but did not get into her first choice: *“But then I was accepted into another one, and I thought I would give it a chance because now I had chosen it as my second priority”* (first interview). Idhar had expectations for the educational content and level of this program and when asked, she said that the academic level was very appropriate, but that she did not like the teaching that much:

“[In a specific class], I think everyone there is about to fall asleep. It's very heavy. It's like you get a million new terms thrown at you, and you just have to learn it at that point when you're reading it [...] It's more because you want to discuss because maybe you have some other viewpoints. But I can't really do that because it's not the place for it.” (First interview)

Idhar experiences a gap between her expectations for and experiences with Tinto's (1997) category ‘Classroom activities’.

We wonder whether this classroom expectancy-experience gap was what later resulted in Idhar's change of study, as Hovdhaugen (2009) argues, that doubt reasoned in expectancy-experience misalignment of the educational content, to a greater extent results in a change of study than doubt reasoned in other conditions. In any case, Idhar has had many dropout considerations right from the start of the program.

“But when I started, I felt a bit already on the first day that it wasn't really for me after all. It just wasn't what I had expected. I don't know how to explain it. But I just feel that it was very different from what I had anticipated. So, I was actually quite disappointed. And then I thought, ‘okay, it's only the first day, you just have to give it a chance.’ And now I'm in the second semester, and I still feel the same way.” (Second interview)

Even though Idhar from day one did not feel a match with her current study program, she stayed in it for a while. This was for her (like Abi) a question of not being a quitter:

“[I'm thinking] that I want to give it a chance. Because I don't want to be someone who just drops out right away without giving it a chance. You can't really judge it from one day or a few weeks. So, I thought I just had to try to see how it would go. And if it doesn't start to become more interesting over time. It could be that it just seemed a bit dry at the beginning. But now I've concluded that I'll probably switch to something else when I get the chance.” (First semester)

The studies described in the introduction found that increasing or cumulative dropout considerations might lead to reduced work satisfaction, commitment, engagement, and stress (Halbesleben and Wheeler, 2008; Allen et al., 2010). However, Idhar manages to accept her position and it seems that something different than assumed from these studies is happening. She keeps her learning motivation high, despite her likewise high dropout considerations:

“Even if it's not interesting or something I'll need in the future, I feel that all knowledge is good knowledge. Because then I know those things. Because it may be that I'll need it at another time, or if we need something similar in the new program. Then I already know it. So, it's not like I've completely tuned out and just shown up and sat and listened to nothing. Because many asked if I wasn't wasting my time. But then I replied that I don't feel like I am because I'm still learning something. Maybe it's not what I'll be studying in the future, but I can still use it in some way at some point.” (First interview)

Idhar feels that her current study does not fit her, and thus we also here identify aspects of the need for inward or outward changes to reach a match. Idhar does not engage in inward personal transformation, as we saw Ingrid did. She does not either work to change the program to create a better match, as we saw Abi do. For Idhar, the mismatch increases, which increases her dropout considerations but still does not lead to dropout. Idhar decided to stay in the program for a full year until she could apply for and start the new study program. Hovdhaugen (2009) suggests that expectancy-experience gaps can lead to students changing programs. However, Idhar's decision to stay at the old program for a year is more difficult

to explain. For Idhar, there might be a sociocultural reason behind this. For a long time, she did not share with her parents that she wanted to drop out and start a new study program, and when she did, it took some time for her parents to understand her decision. From her description of this, one gets the feeling that when Idhar emphasizes her not being a quitter, it can be related to her parents' concerns about wasting time, getting into—what we refer to as—a cumulative trajectory toward dropping out, and not taking advantages of the opportunities they did not have:

"And then my mom asked how it was going with my studies, and I replied that it was fine, but that I still don't know if it's what I want. And she had a little trouble understanding it because she wondered why I had chosen it. Because parents are just like that, if you choose something, then it's also the only thing you have to do for the rest of your life." (First interview)

"My sisters, they've been quite indifferent. I mean, they can't really see the problem in changing program, but my mom had a bit of a hard time understanding it because, for her, she felt like I had just wasted a year on nothing. And also, because she thinks that since I'm changing program now, I'll probably get tired of it at some point and want to change again and stuff like that." (Third interview)

"I think it's a general thing with Arab parents. Because, for example, many who come to Denmark don't have such great chances of getting an education and then maybe there have just been some linguistic barriers and such. And then they just want you to achieve what they didn't achieve." (Fifth interview)

Idhar ends up changing to another program and she is initially very happy about it. She excitedly talks about her new program, and links her excitedness closely to aspects of the social system in [Tinto's \(1975\)](#) model:

"So, I'm very pleasantly surprised, but I also think that the social aspect has a lot to do with it because, in the last couple of years of lower secondary school and throughout upper secondary school, I just haven't really been in any classes where I felt like I belonged. Or where I fit in [...] There are a lot of people on this program who are just like me." (Third interview)

As she approaches the end of her bachelor's degree, when she begins to look forward to a master's degree, she cannot imagine that it will be as good socially in a subsequent master's program, as it is in her current bachelor's program: *"I actually think it will be a little more difficult."* (Eighth interview). Idhar also experiences that the good social environment (and the small class size) influences the teaching of her new program.

"I also think it plays a role, the relatively small size, it's very small so we're not very many. So, it also provides an opportunity to talk to everyone across the class." (Fourth interview)

Idhar is also very enthusiastic about the academic system (cf. [Tinto, 1975](#)) in her new study program;

"And I don't really feel like I've had that, what can you say, that eagerness or that enthusiasm for classes before. Or just for showing

up at all. So, I can definitely feel that it has made a really big difference to go to a place that you're happy with and to have good people around you whom you also talk to and can share your frustrations with regarding the study and exams, and so on. So, I just think that it's really important that you're satisfied with what you're doing because it also affects everything else." (Fifth interview)

As she progresses further into the program, she experiences that there is a big difference in the quality of the teaching she receives.

"So, basically, I really think it has been very varied, depending on what semester you've been on, so, I would definitely say, well, that there are some teachers who have been much more equipped for the job than others." (Eighth interview)

Her overall experience of the classes depends a lot on the fluctuating teacher quality, and for Idhar, [Tinto's \(1997\)](#) category of classroom activities seems to be decisive for the development of dropout considerations.

Thus, although Idhar was very enthusiastic about her new program, with time her enthusiasm began to fade.

"The first year, and the first semester of the second year, I think, has been the most exciting part of the study. We had some insanely good classes there, and also some really sharp teachers, so yeah, well, then I was convinced that this was the path I wanted to take because it also paved the way for what I was considering in terms of career and so on." (Eighth interview)

"Because I had just lost the enthusiasm, these last two semesters actually here on the bachelor's." (Eighth interview)

Even though Idhar is starting to feel a bit weary of her program, it is important for her to complete not just the bachelor's degree but also to pursue a master's degree afterward.

"I really want to finish it. Otherwise, I'll have to listen to a lot of annoying comments again [laughs]. No, well, initially, I really want to complete my bachelor's, and then maybe I'll do something else until I want to start on the master's." (Fifth interview)

Idhar begins a master's degree directly after her bachelor's degree. She does not explain why she does not end up 'doing something else' before matriculating a masters' program. We wonder, again, if it for Idhar is for sociocultural reasons. Anyhow, we will conclude her story, with a general observation she makes about societal expectations regarding education:

"For example, when you're in primary school or upper secondary school and you're about to apply for tertiary education or talk about it. I feel like society has this idea that if you choose a program, you should just finish it quickly, right after completing upper secondary school. I think it's mainly because we're in such a hurry. Even though I'm only 21 and about to start my second year at university [...] Well, there's just no room for taking your time, you know? The educational opportunities are abundant, so it's not like you could ever fall behind. People are studying, even some in their 40s who are still studying to complete upper secondary school."

So, it's never too late. I just think it's a general mentality we have."
(Fifth interview)

Idhar experiences a lack of harmony between what for her is a dominating idea in society, namely that educational trajectories must proceed linearly and pacey through unproblematic transitions, and her desire to take her time to engage in and reconsider her studies. Idhar's concluding remark is an excellent starting point for summing up the article's interest in understanding students' dropout considerations and whether they contribute to developing or challenging young people's educational self-images.

Limitations

The presented findings rely on students' self-reported dropout considerations, collected through surveys and interviews, and relates these to actual dropout and study completion data from institutional register data. While self-reported data is essential for understanding individual dropout considerations, it inherently introduces the possibility of social desirability bias. We thus acknowledge that the students interviewed may not have disclosed all the reasons for their dropout considerations. However, we hope that our prolonged engagement with the students helped mitigate some initial social desirability bias, enhancing the credibility of the data as suggested by [Lincoln and Guba \(1985\)](#).

Our study aimed to investigate how students' dropout considerations fluctuate over time and to point to possible psychological and structural reasons for these evolvments, rather than provide generalizable conclusions about the prevalence or origins of these considerations. This aim affects the generalizability of the article's results, as findings are situational and may differ if conducted in a different context. For example, it may influence Danish students' dropout considerations significantly that they receive public support (SU) for tertiary education regardless of social standing, which is not necessarily the case in other countries. Additionally, both the demographic composition of our sample, i.e., the share of minority students (see [Table 1](#)), and the mix of bachelor's and master's students, could impact the results. As the purpose of the article was to draw a varied picture of different possible evolutions in students' dropout considerations and point to possible psychological and structural reasons for these evolutions, we found it relevant to include a variety of student types. However, it is important to note that the selected students may not represent the full spectrum of student experiences and dropout consideration fluctuations. Adding to this, we might also have arrived at a different understanding of dropout considerations, if we had not chosen solely students with initially high dropout considerations for the qualitative part of our study. Finally, the timing of our surveys—conducted halfway through the semester—may have influenced the findings, and different results might have emerged if we had surveyed students at the start or end of the semester. In sum, our study has several contextual limitations, and we encourage future research to validate, extend, or challenge our findings in other contexts.

Discussion

When focusing on the entire student group, we find that there is a stable share of students with low, medium, and high dropout

considerations throughout time. In that sense, it could be explained with the suggestion of [Herrmann et al. \(2015\)](#), that doubt is a faithful—thus stable—study companion. However, although we find stable shares of low, medium, and high dropout considerations, we also find that this is not an expression of stability in the individual student's dropout considerations, nor does it mean that students' dropout considerations accumulate linearly over time. Both the quantitative and qualitative studies make clear that there are significant fluctuations in some students' dropout considerations. Based on this, the study confirms both the article's hypothesis that dropout considerations are malleable and the relevance of [Tinto's \(1975\)](#) suggestion to include time as an interacting variable when it comes to understanding student development in relation to dropout and persistence, respectively.

Our detected dropout considerations fluctuations challenge [Hobfoll's \(2011\)](#) suggestion that students' dropout considerations accumulate over time. Although there seem to be primary movements from high dropout considerations towards dropout, and from low dropout considerations towards completion, there are also considerable secondary movements (i.e., from high dropout considerations to completion). Instead of a cumulative development, it is rather the case that the individual student's dropout considerations change repeatedly in interaction with the students' previous experiences, expectations for the future as well as changes in the student's academic and personal circumstances.

Like [Hovdhaugen and Aamodt \(2009\)](#) we find a relationship between uncertainty regarding the ability to meet administrative and academic requirements and dropout considerations. Conversely, we also find that considerations about dropping out may be fueled by students' feelings of not being sufficiently challenged academically. The reason for experiencing academic shortcomings can thus be linked both internally to the students themselves and externally to the academic program. Furthermore, to the academic requirements, we add personal requirements as drivers of dropout considerations. We find personal requirements linked to dropout considerations in both the form of financial requirements and family care (which are linked to the student's resources, costs, and values). For both academic and personal requirements, we find that the challenges are often about a lack of alignment between expectations and experiences, as described by [Hovdhaugen \(2009\)](#).

We suggest that the gaps between expectancies and experiences could be explained by how well students and the study programs' norms and values go along (i.e., academic language as a norm, valuing that teaching must make sense in the moment, describing oneself as not being a quitter, etc.). This is what [Eccles et al. \(1997\)](#) describe as a person-environment fit. From previous studies of educational person-environment fits, we know that a lack of fit can affect students' well-being, motivation, interest, behavior, academic performance, and future job opportunities ([Eccles et al., 1997; Tuominen-Soini et al., 2012; Holmegaard et al., 2014; OECD, 2022](#)). Thus, the outward or inward changes to improve person-environment fit, which we see some students in our study engage in, might be a profitable strategy. It is interesting that we not only find that dropout considerations can be nurtured by negative experiences, as suggested [Hovdhaugen and Aamodt \(2009\)](#), but can also be reduced by positive experiences.

Data availability statement

The datasets presented in this article are not readily available for privacy reasons. Requests to access the datasets should be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

EL: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. AQ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources,

Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Mixed methods research teams: leveraging integrative teamwork for addressing complex problems

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Mixed methods research teams have garnered increased attention for their leveraging of diverse disciplinary and methodological expertise in pursuit of complex problems. We advance our theoretical viewpoint of integrative mixed methods research teamwork as necessary with empirical evidence demonstrating the equipping mixed methods researchers to study complex problems involving interacting systems and lacking known solutions. Integrative mixed methods research teamwork is distinguishable by the purposeful integration of qualitative and quantitative perspectives to generate novel outcomes that are greater than the sum of individual members' contributions. Among the key dilemmas faced by mixed methods researchers wanting to work integratively within a team is the lack of practical guidance for how to get started, how to recognize the emergence of synergistic outcomes, and how to sustain a team's integrative work. To begin addressing this gap, we describe three practical insights gleaned from examining our team interactions and outcomes using a reflection-in-action process during a recent empirical mixed methods case study of literacy practices. In our examination, we test the practical usefulness of a theoretical framework for demystifying the development of a mixed methods research team's integrative capacity. Our insights contribute to refining teamwork practices by identifying enablers of integrative capacity and proposing ways to overcome hindrances that have not been previously elucidated. We argue that the capacity for integrative teamwork is essential for researchers employing mixed methods, allowing them to leverage inherent synergies when addressing complex problems.

KEYWORDS

mixed methods research, research teams, integrative team capacity, complex problems, complexity science

Introduction: integrative mixed methods research teamwork

Teamwork that integrates diverse disciplinary and methodological expertise is increasingly recognized as optimal for addressing more complex mixed methods research problems (Archibald, 2023; Oppert et al., 2023; Poth, 2018, 2019). Mixed methods research is well positioned to address complex problems because it uses innovations in methodology needed to address complexity (Mertens et al., 2016). Complex mixed methods research problems are characterized as involving interacting systems, lacking known solutions, and benefiting from the purposeful integration of qualitative and quantitative perspectives (Poth, 2018). Complicating the work of mixed methods researchers is that addressing complex problems

requires unique sets of expertise and procedures that align with research questions that are difficult to predetermine. We posit complex problems benefit from mixed methods research teams who can effectively integrate individual team member contributions and accommodate emerging understandings of the required expertise and procedures.

Various accounts of mixed methods research team experiences point to challenges (Bowers et al., 2013; Curry et al., 2012, 2013), but a lack of focus on their synergistic potential highlights the need for guidance specific to integrative teamwork. Integrative teamwork has been distinguished from the combined efforts of researchers contributing individually as a group. Instead, integrative teamwork involves interactions that draw upon members' broad diversity in expertise, experiences, and intuition in ways that cannot be predetermined and generate synergistic outcomes that are greater than the sum of individual members' contributions (Poth, 2019). A growing number of authors refer to the presence of 'synergies' emanating from disciplinarily and methodologically diverse teamwork (Curry et al., 2013; Oppert et al., 2023; Poth, 2018), yet their descriptions lack the practical guidance offered in this paper. Among the key dilemmas faced by mixed methods researchers wanting to work integratively within a team involves guidance for how to get started, how to recognize the emergence of synergistic outcomes, and how to sustain a team's integrative potential. By advancing our theoretical viewpoint with empirical evidence, we advocate the importance of integrative teamwork for mixed methods researchers tackling complex problems. We present a viewpoint that such teamwork is essential to leverage the limitless synergistic outcomes that arise from the integration of diverse expertise and lived experiences.

Providing practical guidance for developing integrative teamwork begins with complexity science to create a new, more realistic way to study complex problems (Poth, 2018). As a collective of theories and conceptual tools, complexity science guides the interpretation of interactions and outcomes of integrative teamwork as an organic and holistic process. A recent effort by Poth to demystify the development of a mixed methods research team's integrative capacity advanced a complexity-informed theoretical framework comprising four interrelated elements: membership, contributions, interactions, and performance (Poth, 2019). This departs from more conventional approaches to developing mixed methods research teams in three ways: First, it depicts the team development process as non-linear, with its four elements as interrelated and the teamwork outcomes as emergent and unpredictable. Second, it considers three embedded systems (intrapersonal, interpersonal, and societal) in which teamwork takes place as influencing and being influenced by each of the interrelated elements. Third, it recognizes integrative teamwork as the emergent property emanating from the interactions that can be observed as synergistic outcomes that surpass the sum of individual team member contributions.

To guide others wanting to develop the integrative capacity of their mixed methods research teams, we tested the practical usefulness of the theoretical framework. We begin this paper by describing our team's development process and outcomes from a recent mixed methods case study using a reflection-on-action process. Then, we discuss how the four interrelated elements (membership, contributions, interactions, and performance) of the theoretical

framework together informed our relating of three practical insights to guide the development of integrative mixed methods research teamwork. Our results and discussion should be considered in light of the single empirical mixed methods case study on which this manuscript is based and the transferability of our guidance to other contexts should be further explored.

Results: experiential reflection

With the aim of demystifying the development of integrative teamwork, we use the four interrelated elements of the theoretical framework to guide our reflection-on-action process (Mäkelä and Nimkulrat, 2018; Schön, 1991). Our process involved reviewing study documentation created by team meeting notes and personal reflections, identifying key events in our teamwork, and then discussing their significance both as individuals and as a team. Figure 1 visually depicts the non-linear team development process with double-ended arrows linking the four elements of the theoretical framework as the outer circles with each other and as influencing to and by the three embedded systems in which teamwork takes place. Intrapersonal systems describe the individual research team member's influences, such as personal motivations, educational training, and research orientations, on both the societal and interpersonal systems. Interpersonal systems convey the social dynamics and differences in perspectives among members of a team, often attributed to lived experiences involving training and disciplinary backgrounds that influence both the societal and intrapersonal systems. Societal systems include the influences of research priorities as well as institutional influences and world events on both the interpersonal and intrapersonal systems. We represent our novel insights gleaned from our experiential reflection in the Figure in the descriptors of the four interrelated elements.

Membership fluidity

The first element of membership involves seeking diverse team members with the aim of responsively forming a team with expertise, experiences, and perspectives relevant to addressing the complex problem. Our team's complex problem focused on literacy practices with a specific focus on exploring the multifaceted leadership role an effective principal assumed in the deployment of evidence-based literacy practices in their school (Kierstead et al., 2023). The study and our team development took place during the time period of 2020 to 2022 while society as a whole was still grappling with the uncertainty of the global Covid-19 pandemic. The impetus for our teamwork was to address the impact of reading difficulties in early elementary for students who experienced school closures due to COVID-19. It was a call for proposals from teams involving both educational faculty members and school-based community members that led us to recognize the potential of a team that integrated our diverse expertise, experiences, and roles.

From our initial meeting notes, it is evident that we acknowledged the importance of each other's distinct contributions. Each of our four team members brought specialized and relevant knowledge to the complex problem: Georgiou is a world-class researcher on the

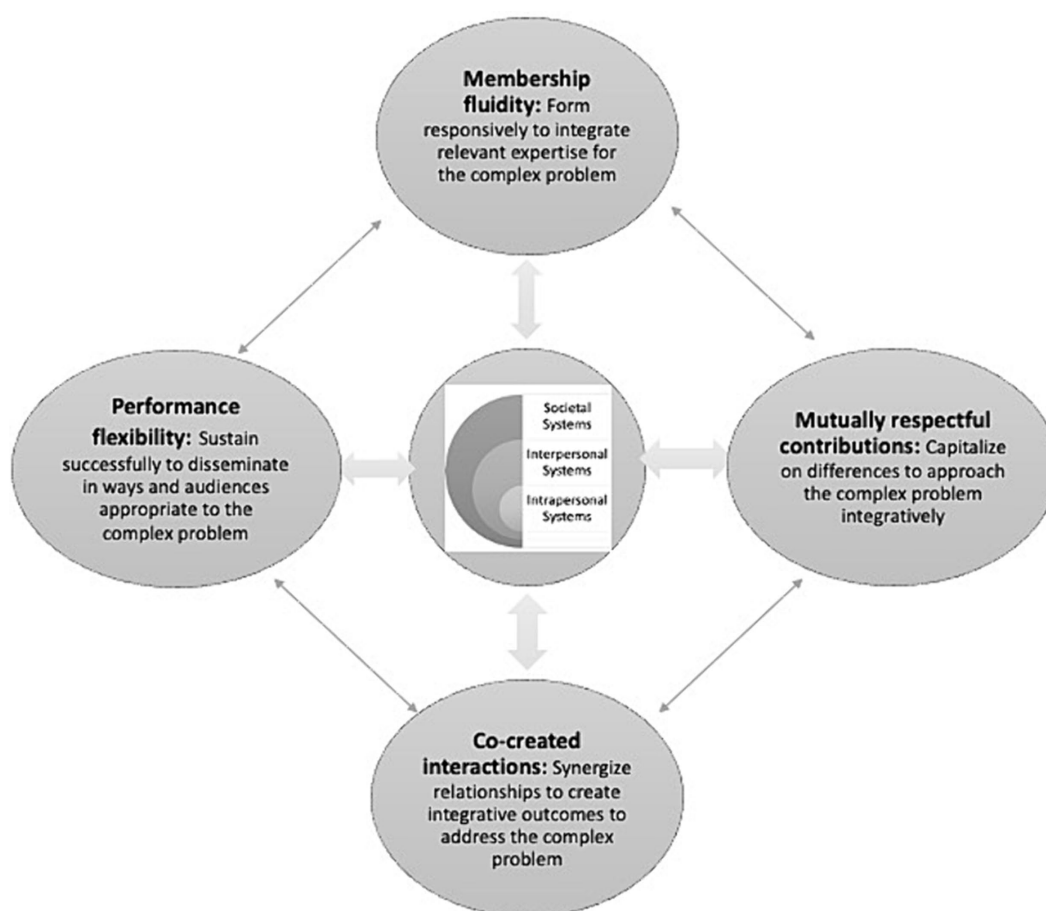


FIGURE 1
The non-linear integrative mixed methods research teamwork development process.

prevention and remediation of reading difficulties with extensive experiences working with teachers in the classroom informed by his lived experiences as an elementary teacher and with assessing intervention impacts quantitatively. Kierstead is a school principal with more than 25 years of administration experience and recently completed doctoral studies on addressing reading difficulties by enhancing teachers' content knowledge and monitoring children's responses to intervention. Poth is a globally recognized expert in mixed methods research, qualitative research, and case studies whose work in educational settings is informed by her lived experiences as a teacher and administrator. Finally, Mack is a doctoral candidate in counseling psychology with research interests in mixed methods and invention studies. Although our team collectively possessed several qualities associated with success, such as breadth, depth, and history in our specific expertise (NIH, 2018), Poth observed in her field notes that the team's openness to the possibilities of mixed methods research was notable. This receptivity stemmed from the fact that many team members had prior experience with the necessary integration of qualitative and quantitative research. Poth also observed that the team exhibited a 'good rapport,' an understanding of the necessity for 'fluidity' in our involvement, and a willingness to engage with one another. When our team began forming, some members already had existing relationships, though they had not interacted as a group. For

instance, Georgiou and Poth had been colleagues in the Faculty of Education for more than a decade, Georgiou and Kierstead had collaborated for more than five years working within school communities, and Mack had recently taken two courses instructed by Poth. We recalled that during our first meeting, identifying our diverse expertise was facilitated by the previously established relationships among us.

Unbeknownst to us, our team membership would remain stable throughout our study. The source of fluidity would not be in membership but rather in terms of the intensity of member involvement throughout the study. In Poth's broad experience, many scenarios required new members to be sought, including but not limited to the arising need for specific expertise, graduate students moving on to other opportunities, or those working in schools who could no longer focus on research.

Mutually respectful contributions

The second element of contributions refers to building respectful relations with the aim of capitalizing on team member differences in perspectives relevant to the complex problem. Our case study mixed methods design involved integrating the lived experiences of 11

school staff (principal, learning support teacher, and classroom teachers) with the reading scores of 122 Grade 1 to 3 students in Alberta (Canada). As a reading consultant and researcher, Georgiou was well-known in the local educational community for his work with teachers and advocacy for curriculum changes relating to literacy. As a school-based principal in the local community, Kierstead worked daily with teachers and brought intimate knowledge of the types of challenges they were experiencing during the rapidly changing COVID-19 pandemic context. Key to our study's feasibility was leveraging Georgiou's ongoing collection of student reading data and Kierstead's insight on the best way to organize the focus group data collection with school staff. With extensive experience collecting qualitative data, Poth and Mack worked together on the focus group protocols to tailor them to the different participant groups. Not surprisingly, challenges emerged related to competing interests that needed to be resolved. For example, the draft protocols were reviewed by Georgiou, with his feedback focused on what would be relevant questions for reading and by Kierstead for what would be relevant questions specific to the different principal and teacher roles and what time they could dedicate to our study. In so doing, we capitalized on our different perspectives to help focus our data collection activities and demonstrated mutual respect for our differing but complementary contributions. During our team reflection, we reviewed some of the challenges attributed to differing disciplinary perspectives (Bowers et al., 2013; Bryman, 2006; Szostak, 2015). We surmised that our teamwork was helped by our common training in the field of educational psychology. Still, we also recognized the challenges that our differing epistemologies introduced to our work together. For example, all four had initial training in quantitative methods where we had assumed a more post-positivist viewpoint; Poth and Mack's orientations now assumed a more constructivist viewpoint reflective of their qualitative experiences. We agreed that our commonalities in training helped us recognize the nature of these differences and navigate our differences in ways that might not be possible for others.

What is likely to be a shared challenge with other research teams is the challenge our team encountered with busy schedules, prompting us to recognize the crucial role of computer-mediated meetings in overcoming this obstacle. We found opportunities to discuss how adjustments of individual contributions are essential to our teamwork success.

In the data collection phase, Georgiou and Kierstead led the gathering of student data, while Mack focused on collecting data from school-based personnel through focus groups. Poth assumed the role of team taskmaster, organizing and overseeing the integration of student data with staff focus group insights. Poth's request for regular meetings to check the progress of data collection and later to discuss integrated outcomes introduced a note of tension to the group dynamics. Virtual meetings emerged as a pivotal solution, facilitating frequent team meetings and demonstrated by our commitment—no scheduled meeting had ever been canceled. The team collectively interpreted this commitment as a sign of our dedication to the project. To underscore our commitment, Georgiou and Kierstead recalled joining a meeting in a car while traveling home together after meeting with teachers.

According to Poth, educating the entire team about the time and expertise required for credible integration was an ongoing and crucial

effort in establishing realistic expectations for deliverables. Notably, our early identification of the need to integrate quantitative student data with qualitative school personnel data in our funding proposal allowed the team to focus on a mixed methods design. Upon reviewing our meeting notes, it was evident that individuals gradually shifted their emphasis from individual contributions to a shared focus integration. These frequent opportunities to meet and listen to one another helped build mutual respect for our unique contributions and realize our synergistic potential.

Co-created interactions

The third element of interactions revolves around the co-creation of productive team routines. It is essential to highlight the sources of tension experienced before, during, and after meetings. Acting as the taskmaster, Poth sent agendas a few days before a scheduled meeting as a way of reminding team members of the meeting purpose and preparation expectations. Team members generally found these agendas helpful, ensuring that each team member had an opportunity to articulate their contributions and to seek feedback. However, there were occasions when the agendas were perceived as potentially constraining. It's noteworthy that, due to the dynamic nature of our teamwork and meetings, no two agendas were alike. Team members stressed the importance of allowing the agendas to evolve alongside the changing meeting purposes. In practice, the agendas were seldom followed as outlined initially. Instead, the team demonstrated an ability to adapt, with this flexibility being recognized as fostering the flow of natural conversations and allowing for the emergence of new insights that might have been missed if a rigid schedule had been strictly adhered to. The manageable size of our four-member team was also noted for its facilitation of meeting scheduling and more fluid interactions. However, one team member expressed curiosity about the scalability of this approach to a larger, more diverse group.

Team members perceived meetings as significantly impacting their understandings as the team collectively navigated a path forward through back-and-forth discussions. The opportunities for interactions were also regarded as instrumental in building a shared identity and accomplishing the study's integration goals. Mack noted that the team meetings demonstrated that while individual contributions were necessary to the study, it was insufficient for individuals to work alongside each other. Team meetings were instrumental in clarifying understandings and identifying the next steps. A review of meeting notes indicates that team members relied on each other's expertise to undertake the merged mixed analysis strategy that revealed four interdependent influences pointing to novel understandings of principal contributions to a school literacy culture (Kierstead et al., 2023). Such novel findings emphasize the possible benefits of diversity, dissonance, and divergence in exploring methodological puzzles in mixed methods research (Archibald, 2016). The team identified the sign-off process during manuscript submission as a pivotal moment where the study's goal was realized. This process involved each team member confirming their comfort with the interpretations and conclusions as written, marking a crucial point in the development of the team's integrative capacity (Bowers et al., 2013).

Performance flexibility

The fourth element of performance highlights the need for sustaining team integrative performance and points to the need for prioritizing communication to enable the team to be flexible. Mack described a meeting that took place during data collection where it became clear from the analysis of focus group interviews that some of the participants were using the materials in different ways and to varying degrees in their classrooms. During the meeting, the team considered the importance of these differences and how best to move forward. Similarly, our team's original timeline and plans for dissemination shifted in response to the outcomes that were generated by our integration. Our findings shed light on the complexity inherent in the roles of principals and their interactions with others in developing evidence-based literacy school cultures that improve students' performance. This was not easy to achieve, and it took several discussions and creative thinking about how the interactions of the principal were both influencing and being influenced by others. We found being flexible with one another about the time needed to perform as a team and the audience for the deliverables as necessary.

In our teamwork, communication systems involving meetings and emails emerged as essential to sustaining interactions and conversations. Not surprisingly, we found our most 'useful' and innovative ideas came about not on email but in 'real-time' virtual meetings. We were fortunate that our team agreed to continue working together beyond the short timeline of funding. Despite facing fluctuations in availability due to competing commitments, we remained steadfast in our dedication to making our findings accessible to our audiences.

Discussion: integrative teamwork practices

To better equip researchers for tackling new challenges that demand innovative solutions, we advance three teamwork practices centred on developing communication systems, engaging in reflexive questioning, and attending to emergent properties. Effective communication represents a well-described and essential enabler for mixed methods research teams. Similar to other documented accounts (Oppert et al., 2023), our team development benefited from the availability and use of computer-mediated communication technologies. In particular, the seamless integration of online team meetings and shared access to meeting documentation proved invaluable. These tools facilitated frequent interactions among team members and the building of shared understandings. Utilizing agendas as a starting place to guide meetings and meeting notes to document the next steps for accountability purposes, our team managed to avoid some of the common frustrations associated with differences in project management approaches among team members. Together, this approach allows the team to focus on developing their integrative capacity.

Reflexivity, as a practice, involves researchers explicitly acknowledging their contributions to study decisions and understanding how these contributions influence the research process (Creswell and Poth, 2024). The insights gained from our team reflexivity practices

underscore its value in fostering awareness and understanding of one's positionality (Popa and Guillermin, 2017) and the lenses the team brought to our mixed methods case study. Through engaging in team reflexivity, we came to recognize our growing reliance on each other's expertise to realize our shared vision and transcend our individual boundaries. This realization contributes to our understanding of boundary transcendence and the potential of integrative teams to generate innovative solutions to complex problems and expand the existing knowledge in this practice area (Hesse-Biber and Johnson, 2013).

Grounding our work in a recent theoretical framework informed by complexity science helped bridge theory with practice and inform the preparation of future educational psychology researchers for effective and integrative teamwork by bringing attention to the emergence of synergistic outcomes. This discussion seeks to extend Poth's initial attempt to introduce the concept of emergent opportunities in mixed methods research, which we acknowledge that we still do not fully understand (Poth, 2019). Growing evidence points to its underpinning role in the development of integrative capacity: Our own experiences highlight that emergence is not something that can be executed by members of a mixed methods research team based on a plan. Rather, as we experienced, team members have to be attentive listeners and responsive to conversations that appear to be leading to new understandings beyond what could have been achieved by individuals. The continual adjustments we sought in our procedures, expectations, and the ways in which we worked together were necessary, yet adopting such a mindset and way of working takes work. A mindset of continual adjustments is challenging for many researchers to adopt, including us, given that much of our methodological training has assumed stability in the context and has focused on careful planning and implementation of research plans. By sharing this perspective, we hope to inspire others to describe how their team developed, the nature of their teamwork, and the insights they gained. We aim to help mixed methods researchers realize their synergistic potential for addressing complex problems.

Data availability statement

The datasets presented in this article are not readily available because meeting and team reflection notes are not publicly available. Requests to access the datasets should be directed to Cheryl Poth cpoth@ualberta.ca.

Ethics statement

The studies involving humans were approved by the Ethics review board of the University of Alberta. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

CP: Conceptualization, Formal analysis, Funding acquisition, Writing – original draft, Writing – review & editing. GG: Data

curation, Funding acquisition, Writing – review & editing. EM: Writing – review & editing. MK: Writing – review & editing.

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Conflict of interest

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Analysis of motor behavior in piano performance from the mixed methods approach

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Introduction: The focus of this study centers on the extraction, analysis, and interpretation of the motor behavior of advanced-level pianists using observational methodology, itself framed within the field of mixed methods, paying particular attention to those aspects that characterize the pressed and struck touch. The aim of this research was to analyze the motor interactions of activation or inhibition associated with the production of a type of touch in the movements of the right upper limb of the participating pianists.

Methods: An *ad hoc* observational instrument was built that was incorporated into the software Lince Plus for data recording and coding. Data reliability was guaranteed applying Cohen's Kappa coefficient, and an analysis of polar coordinates was carried out to identify the motor interactions involved in piano playing.

Results: The study provided significant information about the interaction of motor functions linked to two types of touch, such as those that occur in the sliding finger movement over the key in the pressed touch or the lifting finger movement above the key in the struck touch, obtaining clearly identified patterns of piano touch motor behavior.

Discussion: This research represents an innovative perspective of the study of piano-playing movement via the direct and perceptible observation of the pianist's motor behavior in an everyday context. Observational methodology is distinguished by its low degree of internal control, which makes it possible to scientifically study the spontaneous behavior of pianists in their natural environment. This model allows us to describe and analyze piano touch for its application in the field of piano performance and teaching, emphasizing the practical implications of motor interactions in piano touch.

KEYWORDS

piano performance, mixed methods, observational methodology, pressed touch, struck touch

1 Introduction

The study of piano touch is an essential aspect of piano playing, as much on a pedagogical level as on a biomechanical, technical, and, above all, artistic level. The sound and expressive intentions of the pianist are reflected on the keyboard through motor actions of the upper limbs. The control of the quality and precision of piano playing is acquired over many years

of practice and study, geared towards perfecting the pianist's motor abilities (Furuya et al., 2010; Goebel et al., 2005). The studies of Furuya et al. (2014a, 2014b) highlighted optimized finger movements and a higher independence of these, achieved via musical practice, suggesting a plastic adaptation of the neuromuscular system associated with the control and independence of finger movement. Similarly, the pianist can specify the sound quality—defined from a timbral viewpoint—with gesture and type of touch (Bernays and Traube, 2013; Dogantan-Dack, 2016). In MacRitchie's multi-disciplinary review of piano touch (2015), it was noted that, in addition to the different individual characteristics of each pianist, the sound of the piano also differed depending on the technical resources used, with type of touch—pressed versus struck—playing a significant role. Goebel et al. (2005) analyzed these two types of touch, observing large differences in the depression of the key and in hammer speed patterns. They examined the contact times of the whole set of pieces that make up the percussion mechanism of the piano, highlighting the importance of touch in movement control. They showed that, at the same speed, there is greater sound control with the pressed touch than the struck touch, with manipulation of the instrument and playing technique influencing perception of the sound quality of the playing. Furthermore, the pianist's movements are a relevant factor in the effective communication of the musician with the audience (James, 2018; Li, 2022).

Advances in the scientific research of piano touch have revealed that these two types of touch exhibit different motor behaviors of the upper limbs (Goebel et al., 2014; Furuya et al., 2010) that imply different muscular loads, along with different sound qualities. The integration of both types of touch is suggested, although highlighting that a staccato articulation would carry a higher risk of injury, above all in the shoulder (Degraeve et al., 2020; Goebel et al., 2004).

MacRitchie and Zicari (2012) highlighted the importance of the connection between the pianist's musical intention and the resulting physical gesture, concluding that the musician's conscious control over their body influences the sound produced.

The timbral quality of a performance, from the pianists' viewpoint, does not only depend on the intensity and duration of the sounds, but includes various aspects that make up the performance: melody, articulation, tempo or dynamics. They use adjectives and metaphors such as shiny, rounded, dry, thick or velvety to describe different timbral nuances (Bernays, 2013; Li and Timmers, 2021). The embodiment of these musical conceptions requires the interaction between the plasticity of the neuronal system and the motor system, characterized by its flexibility in organizing an inordinate number of degrees of freedom in the upper limbs (Bernstein, 1967; Kay et al., 2003; Furuya and Altenmüller, 2013).

In the last few decades there has been a significant increase in research into acoustics and biomechanics in the field of piano playing. The majority of these studies use technical measuring systems equipped with high precision sensors attached to both the pianist's body and the instrument itself (Goebel, 2017). These studies have provided valuable scientific information that sheds light on the artistic area of piano technique, and specifically—in the case that concerns us—on the knowledge of piano touch procedures. See the research of MacRitchie and McPherson (2015), Bernays and Traube (2014) or Turner et al. (2021), among others, as clarifying examples.

However, it remains a challenge to study the pianist's body movements in a natural and minimally intrusive environment that

does not significantly affect their performance (Goebel, 2017). As MacRitchie (2015) points out, there is a need to develop non-intrusive measurement systems that can be incorporated into piano lessons, outside of a laboratory setting and without restrictions.

The application of observational methodology to this approach is considered appropriate, since it is characterized as a scientific method adapted to the reality of natural situations, in which the control of other methodologies is not suitable, given that it requires the spontaneity of human behavior developed in its usual context (Anguera et al., 2019). Until now, observational methodology has been primarily applied to the study of movement in motor contexts such as physical activity and sports (Anguera et al., 2017). However, it has not been used in the analysis of body movement in the field of instrumental music.

This study seeks to fill this gap in the scientific literature related to this subject by applying observational methodology to the study of piano-playing movement which contributes—in addition to a non-intrusive method of capturing movement—a new analysis of the behavioral flow of piano touch that implies an order of motor actions. Lag sequential analysis and polar coordinate analysis appear as a powerful medium for estimating patterns of behavior that reflect activation and inhibition relationships of movements that precede or follow a particular behavior, in such a way that they reflect behavioral tendencies that can be useful for detecting motor behavior patterns that could be avoided in order to prevent injury or perfect both technique and musical expression. Lag sequential analysis of piano performance is different from other purely quantitative analyses due to its implication in the process of transition and interconnection between some behaviors and others, involving a continual systematic observation process that takes into account the technical and expressive requirements of the musical piece. This analysis can provide a deeper understanding of the piano touch technique.

This project puts forward an innovative approach to the study of the motor behavior of two advanced level pianists, using observational methodology (OM)—considered mixed method in itself—(Anguera et al., 2017, 2018b; Anguera and Hernández-Mendo, 2016), for its adaptability and flexibility in detecting and analyzing, via direct and perceptible observation, the motor behavior patterns that are shown in the expressive production of piano sound in natural contexts. OM integrates the qualitative and quantitative phases (QUAL-QUAN-QUAL) of the research via rigorous procedures (quantitizing) that render it robust by making data analysis possible, not only through the scrutiny of behavior occurrences with the frequency parameter, but with the parameters of order and duration, from the production of a data record in the form of a code matrix (Anguera et al., 2020).

The main aim of this research was to identify relationships between motor behaviors that differently characterize pressed and struck touch. To this end we present and justify the construction of an *ad hoc* observation instrument based on field format, for its open, multidimensional, multiple-code and self-regulatory character (Anguera, 2010), integrated into the software LINC PLUS for systematic observational study (Soto-Fernández et al., 2022).

The observation produced a large set of qualitative data that was analyzed quantitatively via lag sequential analysis (Bakeman and Gottman, 1989; Bakeman and Quera, 2011) and polar coordinate

analysis (Sackett, 1980). This analysis yielded novel results regarding the detection of motor interactions linked to piano-playing movement.

2 Pressed touch and struck touch

The study of piano touch covers diverse aspects related to motor behavior, such as the movement of fingers, hands, upper arms and forearms, wrists and shoulders, along with speed or the pressure applied to the keys, analyzed from different pedagogical, biomechanical and technological perspectives. Type of touch is a highly important procedural parameter, given that it produces different sound and expression qualities that are perceived both by the musician and the audience (Goebel, 2017). Pianists are unanimous in distinguishing between pressed and struck touch, with the different motor behaviors that each one generates (Goebel et al., 2014; Furuya et al., 2010) and the repercussion in the quality—both of sound and expression—in piano playing (Goebel et al., 2005). The pressed touch is initiated from contact with the surface of the key, increasing shoulder mobility during the anticipatory rocking movement of pressing the keys (Verdugo et al., 2020, 2022); while the struck touch is characterized by lifting the finger a certain distance from the key before pressing it, producing an additional noise in the piano sound (Goebel et al., 2005; Kinoshita et al., 2007). Furuya et al. (2010) described a sound with a “hard” timbre if the key is pressed after previously lifting the finger and a “soft” timbre if the keystroke starts with the finger in contact with the key. Similarly, Goebel et al. (2014) showed that the timbre and the sound quality of the piano are not only influenced by the speed with which the hammer reaches the string. It was shown that applying the same speed to the keys, but with different touches, it was possible to detect the noise made by the finger-key and key-bottom impact if struck touch was used, which did not happen with the pressed touch. On the other hand, with the pressed touch, the sound reflects a gradual increase in the key speed, while the struck sound involves a sudden initial peak. With the struck touch, the time the finger stays on the key is shorter given that the finger hits the key at speed and leaves it quickly; while in the pressed touch the finger leaves the key by sliding off it in gradual acceleration, remaining on the key longer (Ortmann, 1925; W, 1925) and thus lengthening the acoustic qualities of the piano. While the struck touch is ineffective for this purpose, it is effective for strong sounds and rapid movements (Goebel et al., 2014). In terms of finger movement during the keystroke, Furuya et al. (2010) compared the pressed touch with the struck touch, finding that in the former the finger traces a trajectory from the distal phalanx (DP) to the proximal phalanx (PP), while in the latter it was from the PP to the DP; thus a gentler sound is produced—from a psychoacoustic perspective—in the pressed touch than in the struck touch. The trajectory of the pressed touch is therefore closer to the *carezzando* style of Chopin and the Lisztian touch, characterized by pressing the key with the finger and releasing it by sliding over it from the fingerpad towards the palm of the hand (Bellman, 2001; Ott, 2003).

James (2012) considers the use of the pressed touch essential for obtaining tonal quality; this is because the contact surface area of the fleshy part of the finger is larger, due to the fingers being slightly extended, providing the musician with greater tactile feedback. Regarding the position of the fingers, Furuya et al. (2012) also concluded that in the pressed touch the fingers are more extended

than curved, facilitating a larger surface contact. In this sense, Goebel and Palmer (2008) highlighted that the mechanoreceptors in the skin of the fingerpad transmit sensorial signals to large cortical areas responsible for tactile processing, with the proximity of the fingers to the keys being significant (Dalla Bella and Palmer, 2011). This is essential for the precision and spatial exactitude necessary for controlling the speed of contact with the key, the articulation and *tempo*, together with obtaining different tonal nuances (James, 2012; Kojucharov, 2014; Kojucharov and Rodà, 2015). According to the pianist, pedagogue and precursor of the scientific study of piano touch, Marie Jaëll, the fingerpad touch enables the musician to obtain an ideal sound via a system of reciprocal influence of movement, thought and internal hearing (Robb, 2022).

With reference to the pianist's control of the touch, Goebel and Palmer (2008) observed that this depends on the parameters of *tempo* and dynamics, with the struck touch being more common in faster *tempi*, whilst in slows *tempi* pianists have greater control over the type of touch. Furthermore, use of the pressed touch stands out in gentle dynamics, whilst the struck touch is preferred in stronger dynamics (Goebel et al., 2005). In their study of time control and the efficiency of expert musicians' hand movements, Goebel and Palmer (2013) observed that the fingers act independently at different *tempi*. They also observed that wrist movements of supination, pronation, flexion and extension remained stable in different *tempi*, as opposed to the finger joints which had greater ranges of motion. Hadjakos et al. (2008) highlighted shoulder and elbow participation—together with wrist and finger joints—in octave repetition, the forearm being lifted with inertia to avoid tiredness during the pianist's performance. In terms of wrist action, Oikawa et al. (2011) observed that the flexor muscle in the wrist is what acts as an agonist in the movement, with rapid activation to press the key, while the extensor stabilizes the wrist and finger joints. Using surface EMG, they concluded that a neutral wrist position at *fortissimo* intensity is the best option for reducing the musculoskeletal load on the forearm during the keystroke. The height of the finger when preparing to press the key also varied with changes in rhythm and dynamics (Dalla Bella and Palmer, 2011). One of the most important aspects of the keystroke is the movement and shape of the fingers. Among the aspects that influence the keystroke, Berman (2002) included: the weight placed on the key, the mass and speed applied, the comparison between the finger that reaches the key bottom and that which superficially touches it, the curve of the fingers and the contact applied to the key by the finger pad or tip; along with the position inside or outside the keyboard with pressure on the keys or remaining at a distance without a strong grip on them. Far from being of little relevance, these characteristics define the timbre quality of a performance and distinguish one pianist from the next (Sandor, 1981). Regarding the shape of the palm area of the hand, Brown (2000) suggested that flattening the arch of the hand at the point of the knuckles creates tension in the forearm and fingers. Following this logic, Del Pueyo (1990) maintains that the hand should be reinforced and balanced with firm fingers, forming a hollow by the marked lowering of the outer fingers. With the purpose of avoiding blocking the hand, Lee (2005) makes reference to the piano technique of Franz Liszt, which involves the suspension and sliding of the fingers—just like the bow of a violin when it falls onto the strings and slides over them—lightening the weight to enable a wide expression of different dynamics, thanks to retropulsive force characterized, according to Ott (2004), as:

A light suspension of the shoulder and upper arm that allows the forearm to tilt its pressure towards the hand while a large fleshy surface of the fingers pulls on the keys, retaining this general retropulsion at the key bottom which provides strength and speed without causing any blocking (p. 37).

The hand no longer stays still but begins to move freely to the right and left, excluding verticality, highlighting the role of the finger flexors for this purpose. Uniformity in the fingers is achieved through gradually supporting the forearm and upper arm, avoiding the heaviness produced by the force of gravity (Ott, 2004). In his treatise about piano playing technique, *On piano playing: motion, sound and expression*, Sandor (1981) explains free-fall movement: consisting of the upper arm, forearm, hand and fingers lifting and then falling using gravitational force, with no muscular intervention whatsoever during the lowering movement of the arms. When the fingers reach the keyboard a slight elevation of the hand is produced while the fingers remain over the keyboard. On the other hand, regarding the complex motor behavior of piano touch, Bernstein (1967) and Bernstein and Popova (Kay et al., 2003), showed how muscle strengths were reorganized from a biomechanical viewpoint depending on the *tempi*, in such a way that the forearm participated in a slow *tempo*, whilst only the wrist flexion intervened in a rapid *tempo*. This showed the motor system's capacity for self-organization contingent on mechanical restrictions, along with the possibility that different movements produce similar results (Kursell, 2006). Furuya and Kinoshita (2008) evidenced the importance of training for expert pianists, in their study of motor control of the upper limbs in the interaction of complex multi-joint movement—shoulder, arm, elbow, wrist and metacarpophalangeal joints—during piano touch. Such training is fundamental for achieving greater physiological efficiency, along with a greater exactitude of movement, which implies a necessary muscular control of the upper limbs as a whole. The precursor of scientific research into the piano touch mechanism, Marie Jaëll, in her empirical study of hand movement (Caruso, 2016), considered that musical perfection is achieved through a corporal awareness of piano playing, avoiding the automatic repetition of movements (Guichard, 2004). For Jaëll, isolation and paying attention to minimal variations in touch is similar to tuning in to the aesthetic content of a musical work (Weinstein-Reiman, 2021). Emphasizing this aspect, it is important to underline the importance of conscious activity in order to intervene in muscular counter-tension that counteracts the motion impulse of the arm, hand and fingers. This is achieved via a continuous movement that enables muscular control of finger rebound on the keys, acting in the opposite direction to this, using tension in opposition to the force of gravity that develops muscular elasticity starting from points of support (James, 2012). In short, the pianist's body movements are related to the control of the kinematic chain from the shoulders to the finger pads, combining speed—according to the *tempo* and dynamics—with musical expression (Goebel, 2017).

3 Methods

3.1 Design

A mixed method approach was applied to this study using observational methodology (Anguera, 1979). Following the three dichotomous dimensions proffered by Anguera et al. (2011), the design proposed in this research was of an N/P/M type (nomothetic

in being aimed at the observation of each of the two participants and the independent study of them being of interest; punctual, as the recordings were carried out in one single session and in the same conditions for both participants although with intra-session monitoring from the start to the end of the session; and multidimensional, since different behaviors are observed which entail different levels of response, with corresponding repercussion in the observation instrument). The systematic observation carried out was non-participatory and the observed components were completely perceptible (Anguera et al., 2018a; Bakeman and Quera, 2011).

3.2 Participants

The participants in this study were two male pianists aged 28 and 27, identified as Participant 1 (P1) and Participant 2 (P2), respectively. Both had advanced qualifications in the specialty of piano, with 21 and 20 years of professional experience, respectively, in the study of classical piano.

Experienced pianists were required with a view to maximizing the degree of control in the sound production in their performance. Both musicians gave their written informed consent in accordance with the principals of the Helsinki Declaration, and a favorable assessment was obtained of the methodological, ethical and legal aspects from the Bioethical Commission of the University of Barcelona.

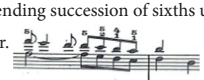
3.3 Instruments

3.3.1 Observation instrument

An *ad hoc* observation instrument was constructed for the observation and record of the motor behaviors of the participants during the piano playing performance. The aim was to detect, select and analyze patterns of motor behavior in the piano touch of each of the two musicians. As it is a multidimensional study, the observation instrument was based on the field format, which contained 13 dimensions deployed in 53 behaviors in total, the mutual exclusivity of these behaviors being governed in each of the dimensions (Table 1). The base dimension for the construction of the observation instrument were the motor functions of the right upper limb in piano playing, under the technical premises of the struck touch and the pressed touch. The segmentation criteria were based on selecting units of behavior according to the technical requirements of the musical excerpt performed, taking into account the specific purposes of the research, which focus on observing the piano touch of two expert pianists during the performance. Nine behavioral segments were delimited after the exploratory phase of the study. These are shown in Dimension 1 of the observation instrument (Table 1), with the molar and molecular levels of the behaviors observed, taking into account the different levels of granularity (Schegloff, 2000) of the units—from larger (molar level) to smaller (molecular level) –, and considering their relative nature, included within the dimensions and behaviors of the observation instrument.

Dimension 1 (Musical extract interpreted) was deployed in nine behaviors/elements, each one containing musical extracts selected for observation, taking into account the technical requirements of piano playing, described textually and graphically in the observation instrument. Dimension 2 (Start of keystroke) was deployed in three

TABLE 1 Observational instrument.

Dimensions	Dimension code	Behaviors/elements	Behaviors/elements description	Behaviors/elements code
1. Musical extract performed	ExMu	1st demarcation Mozart Sonata N° 13 in B-flat major	Moment immediately prior to the start of the performance.	Mzt1_1
		2nd demarcation Mozart Sonata N° 13 in B-flat major	Playing of the first note of the beginning of the Sonata, note “G,” in the attack and release of the key. 	Mzt1_2
		3rd demarcation Mozart Sonata N° 13 in B-flat major	Beginning of the Sonata until the second beat of the first bar, except the already analyzed first note “G.” Descending succession of sounds by consecutive degrees. 	Mzt1_3
		4th demarcation Mozart Sonata N° 13 in B-flat major	2nd bar: appoggiatura on the note “F” and note “E-flat”/“G” semiquaver of the third beat of the 2nd bar and movement from “C” at the end of the 2nd bar to the 3rd bar with appoggiatura in “B-flat” of the first beat of the bar. 	Mzt1_4
		5th demarcation Mozart Sonata N° 13 in B-flat major	4th bar: appoggiatura of double notes at a distance of a 3rd interval of the first beat (A-C) and double notes in a 3rd interval of the second beat of the bar (B-flat-D). 	Mzt1_5
		6th demarcation Mozart Sonata N° 13 in B-flat major	Movement from 4th to 5th bar. 	Mzt1_6
		7th demarcation Mozart Sonata N° 13 in B-flat major	5th bar: syncopation of the third beat of the bar: “D-C-A.” 	Mzt1_7
		8th demarcation Mozart Sonata N° 13 in B-flat major	7th bar: 3rd and 4th beat (appoggiaturas), and “B-flat” of the 8th bar. 	Mzt1_8
		9th demarcation Mozart Sonata N° 13 in B-flat major	Whole of 9th bar and two first beats of the 10th bar: Syncopation and descending succession of sixths until the end of the first theme of the Sonata with the note “B-flat” of the second beat of the 10th bar. 	Mzt1_9
2. Start of keystroke	IPT	From contact with the key	The finger initiates the keystroke from the surface contact with the key.	Dcontsup
		Lifts finger before contact with the key	The finger lifts before contact, with extension of the metacarpophalangeal joint.	DelvextM
		Lifts the arm before the keystroke	Arm lifted prior to the keystroke.	Levprevbz
3. Fingers	DS	M flexion and slight P and D extension	With flexion of the metacarpophalangeal joint and slight extension of the proximal and distal interphalangeal joints.	DfxMligextPD
		M, P and D Flexion	With flexion of the metacarpophalangeal, proximal and distal joints.	DfxMPD
		M flexion and P and D extension	With flexion of the metacarpophalangeal joint and extension of the proximal and distal interphalangeal joints.	DfxMextPD
		M extension and P and D flexion	With extension of the metacarpophalangeal joint and flexion of the proximal and distal interphalangeal joints.	DextMfxPD
		M, P and D extension	With extension of the metacarpophalangeal, distal and proximal joints.	DextMPD
4. Fingers: surface contact with the key	DSct	Fingerpad	Makes contact via the fingerpad.	Dcy
		Distal phalanx	Makes contact by resting the distal phalanx on the key.	DcfgD
		Distal and proximal phalanx	Makes contact by resting the distal and proximal phalanx on the key.	DcfgDP
		Fingertip	Makes contact with the fingertip.	Dcpt
		Lateral in supination	Makes contact with the lateral part of the finger rotating in supination.	Dcrsup
		Lateral in pronation	Makes contact with the lateral part of the finger rotating in pronation.	Dcrpro
		No contact	No contact with the key.	DNoc

(Continued)

TABLE 1 (Continued)

Dimensions	Dimension code	Behaviors/elements	Behaviors/elements description	Behaviors/elements code
5. Thumb: surface contact	PScT	Lateral	Makes contact via the lateral part of the thumb.	PcL
		Fingerpad	Makes contact via the fingerpad with extension of the interphalangeal thumb joint.	PcY
		Fingertip	Makes contact via the fingertip with flexion of the interphalangeal thumb joint.	PcP
		No contact	Makes no contact with the key.	PNoc
6. Finger: key release	DLibT	Sliding over the key	The finger releases the key by sliding over it towards the palm of the hand.	Ddz
		Lifting above the key	The finger releases the key by lifting from the point where contact is made in the moment of the keystroke.	Delv
7. Finger placement	DsCol	Similar	The fingers are placed in a similar way close to the surface of the keys.	DsSim
		Disparate	The fingers are placed in a disparate way: in contact with the key, separated from the key, curved or extended.	DsDisp
8. Thumb: movements	P	Thumb pass with forearm rotation	The thumb moves under the palm of the hand via rotation of the forearm and lifting of the elbow.	PpsR
		The thumb pivots to allow passage of other fingers	The thumb rotates on itself, acting as a pivot, at the same time that the other fingers pass over it. The hand rotates to change position.	PpivtPsDs
		Thumb slides to allow passage of other fingers.	The thumb slides over the key to facilitate the passage of the other fingers over it, with lateral hand displacement without change of position.	PdzPsDs
		Lateral thumb movement	The thumb moves laterally with the hand remaining in the same position, while the other fingers slide to let it through.	PdpzLt
9. Hand: palm area	MP	Cupped	Cupped palm area due to flexion of the metacarpophalangeal joints.	Moq
		Flat	Flat palm area due to extension of the metacarpophalangeal joints.	Mpl
10. Hand: action	Macc	Sliding movement	The fingers slide to facilitate movement of the hand over the keyboard without modifying its position.	MdlzD
		Movement with pronation turns	The hand moves over the keyboard turning in pronation, modifying its position.	Mgirpro
		Movement with supination turns	The hand moves over the keyboard turning in supination, modifying its position.	Mgirsup
		White keys area	The hand develops the action in the white keys zone.	MaccBlan
		Back of keyboard	The hand develops the action at the back of the keyboard.	MaccFond
		Away from the keyboard	The hand develops the action with the palm area away from the keyboard.	MaccFuer
		Jumping movement	The hand jumps over the keyboard.	MaccSalt
11. Wrist	Mca	Neutral position	Wrist in neutral position.	McaN
		Raised position	Wrist lifted via joint flexion.	McaF
		Low position	Wrist lowered via joint extension.	McaEx
12. Forearm	AtBz	High	Stays lifted sloping down toward the keyboard.	AtBzA
		Low	Stays lowered with the elbow facing the floor.	AtBzB
13. Placement of the body in front of the keyboard.	CC	High	Sits high up forming an obtuse angle between the upper arm and the forearm, with the forearm facing the keyboard.	CCa
		Low	Sits low down forming an acute angle between the upper arm and forearm.	CCb
		In line with the keyboard	Sits in line with the keyboard forming a right angle between the upper arm and forearm.	CCr

behaviors related to finger or arm movement prior to the keystroke. Dimension 3 (Fingers) was deployed in five behaviors related to the different flexion or extension behaviors of the metacarpophalangeal joints (MJ) and the proximal (PJ) and distal interphalangeal finger joints (DJ). Dimension 4 (Fingers: surface contact with the key) was deployed in seven behaviors related to the part of the finger that made contact with the key (pad, tip, distal phalanx (DP), distal phalanx and proximal phalanx (DP and PP), lateral part in pronation or supination or no contact with the key). Dimension 5 (Thumb: contact surface) was deployed in four behaviors relating to the surface contact of the thumb with the key, taking into account the morphological difference of the thumb with respect to the other fingers. Dimension 6 (Finger: key release) was deployed in two behaviors, taking into account whether the finger releases the key by sliding over it or lifting it off the key. Dimension 7 (Finger placement), deployed in two behaviors, had the aim of observing the behavior of the fingers in terms of coordination or lack of coordination between them, taking into account similar or disparate placement of each finger with respect to the others. Dimension 8 (Thumb: movements) was deployed in four behaviors, taking into account the thumb movements via rotation or sliding over the key. Dimension 9 (Hand: palm area) was deployed in two behaviors, taking into account the cupped position of the palm, via flexion of the MJ, or the flat position, via extension of the MJ. Dimension 10 (Hand: action) was deployed in six behaviors, taking into account the hand movements or where the hand is placed on the keyboard when it is motionless. Dimension 11 (Wrist), was deployed in three behaviors according to the neutral, flexed or extended position of the wrist. Dimension 12 (Forearm) was deployed in two behaviors according to the position of the forearm in relation to the keyboard, being high when it is sloping down toward the keyboard and low when the elbow is facing the floor. Dimension 13 (Placement of the body in front of the keyboard) was deployed in three behaviors related to the height chosen by the pianist in front of the keyboard, according to the formation of an obtuse, acute or right angle by the upper arm and forearm. The dimensions and behaviors are shown in [Table 1](#).

3.3.2 Recording instruments

Filming was done using two Casio EXF-1 digital cameras which, prior to determining the system of reference, were placed on both sides of the participating pianists, at the height of the keyboard. The recording rate was 100 frames per second.

For the data record and coding process the program LINC PLUS (v.2.1.0) ([Soto-Fernández et al., 2022](#)) was used. [Bakeman \(1978\)](#) established four types of observational data, and this classification is still valid. From these, we used Type IV data in this study, which require a multidimensional observation instrument, as is our case, and also that the duration of each co-occurrence of behaviors (in addition to their frequency and order of presentation) be recorded. They are the most powerful data and have allowed us to obtain a record with the maximum level of information, enabling us to then proceed to a robust analysis of that record. Type IV data are concurrent and time-based; i.e., they incorporate the parameters of order and duration, in addition to co-occurrence, given the multidimensional nature of the observation design.

3.3.3 Audio recording instrument

Audio recording of the musical fragment performed by the participants was done with the software Ableton Live v.8, sound card

Roland Edirol UA 101. The sound was recorded with no equalizing or added effects.

3.4 Procedure

For this study a musical fragment was selected, consisting of the first 10 bars of the first movement of Sonata for N° 13 in B-flat major, K. 333/315c, by Wolfgang Amadeus Mozart ([Figure 1](#)). Eleven advanced level pianists were offered the opportunity to take part in the recording of this musical fragment, and their written informed consent sought. They were subsequently assessed by a group of three experts, two of these being teachers from a Spanish advanced music school, and the third a teacher from a Belgian music school. The selection was based on the evaluation of sound quality via a description using five adjectives considered by [Bernays \(2013\)](#) as the most common for describing nuances of timbre on the piano. Similarly, each of the audio recordings was given a score by the experts on a scale from 1 to 10. Finally, the two pianists who obtained the highest score from the experts were selected for this study (P1 and P2).

The participating pianists were asked to study the musical fragment for 5 min each day for a week. Following this practice time, the participating pianists were then recorded in both video and audio format playing the musical fragment on a Steinway grand piano placed center stage, in one single session which took place in the concert hall of the Auditorio Manuel de Falla in Granada, Spain. Each participant played the selected fragment with their own fingering, without using the pedal and in a *tempo* of 4 = 116. The recordings were carried out with two cameras placed on the sides of the piano keyboard, in such a way that the right upper limb study object could be observed from two different angles, to enable full inspection of it.

3.4.1 Data quality control: inter-observer agreement

The record of the observed behaviors was done by two observers with a high degree of experience and knowledge of the substantive field of this study ([Anguera et al., 2018a](#)). One of them is a music teacher, with a qualification in piano teaching, an advanced qualification in dance and a qualification in the Dalcroze method based on the teaching of music through movement. The other observer is a professor of piano in an advanced music school and also a concert pianist. Both underwent 3 weeks of training in the observation process and use of the recording instrument for this study, prior to recording. Data record reliability was guaranteed by calculating the level of agreement with Cohen's Kappa coefficient ([Cohen, 1960, 1968](#)), via the program Lince Plus, version 2.1.0 ([Soto-Fernández et al., 2022](#)). In line with [Landis and Koch \(1977\)](#), the inter-observer agreement level was "almost perfect," obtaining results of 0.90 with participant P1, and 0.95 with participant P2.

3.4.2 Data analysis

Once data reliability had been confirmed, the data were then analyzed. The robustness provided by observational methodology comes not only through the scrutiny of behavior occurrences with the first frequency parameter, but also because the parameters of order and duration enable lag sequential analysis and polar coordinate

13. Sonate in B

KV 333 (315^c)^a)



FIGURE 1
Excerpt of Sonata N° 13 for piano in B-flat major, K. 333/315c, by W. A. Mozart.

analysis, among others, thus rendering it necessary to obtain a data record in the form of a code matrix (Anguera et al., 2020).

Lag sequential analysis (Bakeman and Gottman, 1989; Bakeman and Quera, 2011), which was done from the obtained records, enables the detection of sequential patterns or chains of significant behaviors that show regularities in which patterns of motor behaviors can be observed, associated with a given behavior criterion, which is the behavior proposed in each analysis as the trigger of the behavioral pattern. The results are obtained in the form of adjusted residuals.

Polar coordinate analysis (Sackett, 1980), which requires as data the adjusted residuals obtained from the lag sequential analysis, is a powerful data reduction technique for determining the inhibition or activation relationships between a focal behavior (considered nuclear in each analysis) and one or various conditioned behaviors, which are all those of which we want to determine their activating or inhibiting relationship with the focal behavior. The associations between the behavior dyads are represented graphically via vectors.

Polar coordinate analysis was done in this study with the program HOISAN (Hernández-Mendo et al., 2012), version 2.0, with the observation record files being exported from LINCE PLUS to HOISAN.

As a preliminary step, lag sequential analysis was done to obtain prospective and retrospective patterns of behavior with respect to a given focal behavior. The lag sequential analyses were carried out prospectively (from +1 to +5 lags) and retrospectively (from -1 to -5 lags); the significance level was set at $p < 0.05$. The calculation of adjusted residuals gives positive (activation effect) or negative (inhibitive effect) values between the criterion behavior (that would play the role of focal in the polar coordinate analysis), and each

conditioned behavior, which shows the degree of connection between both behaviors.

The volume of initial results produced was reduced via a powerful algorithm, based on the parameter $Z_{\text{sum}} = \sum Z / \sqrt{n}$, proposed by Cochran (1954) which is calculated prospectively (from the focal behavior onwards) and retrospectively (from the focal behavior backwards). This Z_{sum} parameter enables us to obtain the length and angle of the vectors that show the type of inter-relationship between the focal behavior and each conditioned behavior (depending on the quadrant they are in, and therefore the angle), and the intensity of this relationship (depending on the length of the vector).

In this study, polar coordinate analysis was used to analyze the focal and conditioned behaviors of the participants P1 and P2 that are shown in Table 2, in line with the aim of this study, where the codes corresponding to each behavior are indicated and the description recorded in the observation instrument (Table 1).

Polar coordinate analysis allows us to obtain the prospective and retrospective Z_{sum} parameters of each conditioned behavior with respect to the focal behavior, and to visualize it via a vector map divided into four quadrants, where the prospective and retrospective Z_{sum} parameters are represented on the X and Y coordinate axes respectively, and the vector corresponding to each behavior is located in one of the four quadrants. This means there are four possibilities: quadrant I (++) indicates that the focal and conditioned behaviors are mutually activated; quadrant II (- +) indicates the prospective inhibition and retrospective activation of the behaviors, i.e., the focal behavior inhibits the conditioned behavior but is also activated by it; quadrant III (- -) indicates mutual prospective and retrospective inhibition; and quadrant IV (+ -) indicates prospective activation

TABLE 2 Description and codes of the given focal behaviors and conditioned behaviors/elements of participants P1 and P2 in the polar coordinate analysis.

P1 Focal behaviors/elements	P1 Conditioned behaviors
Fingers with flexion of the metacarpophalangeal joint and slight extension of the proximal and distal interphalangeal joints. [DS_DfxMligextPD]	Start of keystroke_From contact with the key [IPT_Dcontsup]/_Lifts finger before contact with the key [IPT_DelvextM]/_Arm lifted prior to the keystroke [IPT_Levprevbz]
	Fingers surface contact with the key_Fingerpad [DSct_Dcy]/_Distal phalanx [DSct_DcfgD]/_Distal and proximal phalanx [DSct_DcfgDP]/_No contact [DSct_DNoc]
	Finger key release_Sliding over the key [DLibT_Ddz]
	Finger placement_Similar [DsCol_DsSim]
	Hand: palm area_Cupped [MP_Moq]
	Wrist_Neutral position [Mca_McaN]/_Raised position [Mca_McaF]/_Low position [Mca_McaEx]
	Forearm_High [AtBz_AtBzA]
	Placement of the body in front of the keyboard_High [CC_CCa]
Fingers with flexion of the metacarpophalangeal, proximal and distal joints. [DS_DfxMPD]	Start of keystroke_From contact with the key [IPT_Dcontsup]/_Arm lifted prior to the keystroke [IPT_Levprevbz]
	Fingers surface contact with the key_Fingerpad [DSct_Dcy]/_Distal phalanx [DSct_DcfgD]/_Distal and proximal phalanx [DSct_DcfgDP]/_No contact [DSct_DNoc]
	Finger key release_Sliding over the key [DLibT_Ddz]
	Finger placement_Similar [DsCol_DsSim]
	Hand: palm area_Cupped [MP_Moq]
	Wrist_Neutral position [Mca_McaN]/_Raised position [Mca_McaF]/_Low position [Mca_McaEx]
	Forearm_High [AtBz_AtBzA]
	Placement of the body in front of the keyboard_High [CC_CCa]
Thumb: surface contact via the lateral part of the thumb. [PScT_Pcl]	Thumb slides to allow passage of other fingers [P_PdzPsDs]/_Lateral thumb movement [P_dpzLt]
	Hand: palm area_Cupped [MP_Moq]
	Hand: action_Sliding movement [Macc_MdlzD]/_White keys area [Macc_MaccBlan]
	Wrist_Neutral position [Mca_McaN]/_Raised position [Mca_McaF]
	Forearm_High [AtBz_AtBzA]
	Placement of the body in front of the keyboard_High [CC_CCa]
9th demarcation Mozart Sonata N° 13 in B-flat major. [ExMu_Mzt1_9]	Start of keystroke_From contact with the key [IPT_Dcontsup]/_Arm lifted prior to the keystroke [IPT_Levprevbz]
	Fingers with flexion of the metacarpophalangeal joint and extension of the proximal and distal interphalangeal joints [DS_DfxMextPD]/_with extension of the metacarpophalangeal, distal and proximal joints [DS_DextMPD]
	Fingers surface contact with the key_Fingerpad [DSct_Dcy]/_Distal phalanx [DSct_DcfgD]/_Distal and proximal phalanx [DSct_DcfgDP]
	Thumb: surface contact via the lateral part of the thumb
	[PScT_Pcl]/_Fingertip [PScT_PcP]
	Finger key release_Sliding over the key [DLibT_Ddz]
	Finger placement_Similar [DsCol_DsSim]
	Hand: palm area_Cupped [MP_Moq]/_Flat [MP_Mpl]
	Hand: action_Sliding movement [Macc_MdlzD]/_White keys area [Macc_MaccBlan]/_Jumping movement [Macc_MaccSalt]
	Wrist_Neutral position [Mca_McaN]/_Raised position [Mca_McaF]
	Forearm_High [AtBz_AtBzA]
	Placement of the body in front of the keyboard_High [CC_CCa]

(Continued)

TABLE 2 (Continued)

P2 Focal behaviors/elements	P2 Conditioned behaviors
Fingers with extension of the metacarpophalangeal joint and flexion of the proximal and distal interphalangeal joints. [DS_DextMfxPD]	Start of keystroke_Lifts finger before contact with the key [IPT_DelvextM]/_Arm lifted prior to the keystroke [IPT_Levprevbz]
	Fingers surface contact with the key_Fingertip [DSct_Dcpt]/_Distal phalanx [DSct_DcfgD]/_Distal and proximal phalanx [DSct_DcfgDP]/_No contact [DSct_DNoc]
	Finger key release_Lifting above the key [DLibT_Delv]
	Finger placement_Similar [DsCol_DsSim]/_Disparate [DsCol_DsDisp]
	Hand: palm area_Flat [MP_Mpl]
	Wrist_Neutral position [Mca_McaN]/_Raised position [Mca_McaF]/_Low position [Mca_McaEx]
	Forearm_High [AtBz_AtBzA]/_Low [AtBz_AtBzB]
	Placement of the body in front of the keyboard_High [CC_CCa]
Fingers with flexion of the metacarpophalangeal, proximal and distal joints. [DS_DfxMPD]	Start of keystroke_From contact with the key [IPT_Dcontsup]/_Lifts finger before contact with the key [IPT_DelvextM]/_Arm lifted prior to the keystroke [IPT_Levprevbz]
	Fingers surface contact with the key_Fingertip [DSct_Dcpt]/_Fingerpad [DSct_Dcy]/_Distal phalanx [DSct_DcfgD]/_Distal and proximal phalanx [DSct_DcfgDP]/_No contact [DSct_DNoc]
	Finger key release_Lifting above the key [DLibT_Delv]
	Finger placement_Similar [DsCol_DsSim]/_Disparate [DsCol_DsDisp]
	Hand: palm area_Flat [MP_Mpl]/_Cupped [MP_Moq]
	Wrist_Neutral position [Mca_McaN]/_Raised position [Mca_McaF]/_Low position [Mca_McaEx]
	Forearm_High [AtBz_AtBzA]/_Low [AtBz_AtBzB]
Thumb: surface contact via the lateral part of the thumb.[PScT_PcL]	Thumb: movements_pass with forearm rotation [P_PpsR]/_pivots to allow passage of other fingers [P_PpivtPsDs]
	Hand: palm area_Flat [MP_Mpl]
	Hand: action_Movement with pronation turns [Macc_Mgirpro]/_Movement with supination turns [Macc_Mgirsup]/_White keys area [Macc_MaccBlan]/_Back of keyboard [Macc_MaccFond]/_Away from the keyboard [Macc_MaccFuer]/_Jumping movement [Macc_MaccSalt]
	Wrist_Neutral position [Mca_McaN]/_Raised position [Mca_McaF]/_Low position [Mca_McaEx]
	Forearm_High [AtBz_AtBzA]
	Placement of the body in front of the keyboard_High [CC_CCa]
9th demarcation Mozart Sonata N° 13 in B-flat major [ExMu_Mzt1_9]	Start of keystroke_Lifts finger before contact with the key [IPT_DelvextM]/_Arm lifted prior to the keystroke [IPT_Levprevbz]
	Fingers with flexion of the metacarpophalangeal joint and extension of the proximal and distal interphalangeal joints [DS_DfxMextPD]/_with extension of the metacarpophalangeal, distal and proximal joints [DS_DextMPD]
	Fingers surface contact with the key_Fingerpad [DSct_Dcy]/_Distal phalanx [DSct_DcfgD]/_No contact [DSct_DNoc]/_Fingertip [DSct_Dcpt]
	Thumb: surface contact_Lateral [PScT_PcL]/_Fingertip [PScT_PcP]/_No contact [PScT_PNoc]
	Finger: key release_Lifting above the key [DLibT_Delv]
	Finger placement_Similar [DsCol_DsSim]/_Disparate [DsCol_DsDisp]
	Hand: palm area_Flat [MP_Mpl]
	Hand: action_Back of keyboard [Macc_MaccFond]/_Jumping movement [Macc_MaccSalt]
	Wrist_Neutral position [Mca_McaN]/_Raised position [Mca_McaF]/_Low position [Mca_McaEx]
	Forearm_High [AtBz_AtBzA]

and retrospective inhibition, i.e., the focal behavior activates the conditioned behavior, although this inhibits the focal. The length of the vector (radius) is considered statistically significant ($p < 0.05$), when it measures from 1.96 onwards. The vector angle (angular coordinate) determines its location in one of the quadrants: I [0 to 90°]; II [91° to 180°]; III [181° to 270°]; IV [271° to 360°].

4 Results and discussion

4.1 Descriptive analysis

A total of 462 visualizations were carried out with participant P1, and 568 visualizations with P2, with the distribution by dimensions,

behaviors and percentages of visualizations shown in [Tables 3, 4](#), respectively.

In line with [Anguera \(1982\)](#), corporal movements are non-verbal behaviors that occur quickly, can produce a large quantity of responses—each varying in frequency of occurrence—and can be present or absent in a given moment. Consequently, the frequency of occurrence measurement becomes relevant, given that it is possible to discover the action probability of a specific response and its comparison with other types of behavior. As the frequency data in [Tables 3, 4](#) shows, there is a different set of motor behavior occurrences in the two participants.

With reference to participant P1, [Figure 2](#) shows the middle finger pressing the “F” key, starting from contact with the key surface (behavior ITP_Dcontsup achieved 100% of the visualizations), tracing a finger trajectory that goes from the DP to the PP ([Furuya et al., 2010](#)). The hand is cupped due to the marked lowering of the thumb and little finger and the flexion of the MJ (the behavior MP_Moq obtained 95.6% of the visualizations), it remains high due to the high position of the forearm (behavior AtBz_AtBzA obtained 93.3% of the visualizations), which lightens the weight avoiding the hand blocking, and all the fingers remain in contact with the keys (the behavior DsCol_DsSim obtained 100% of the visualizations).

In the case of participant P2, [Figure 3](#) shows prior finger elevation before pressing the “F” key, separating it from the key via extension of the MJ and flexion of DJ and PJ (the behavior IPT_DelvextM obtained 48.1% of the visualizations), tracing a finger trajectory that goes from PP to DP ([Furuya et al., 2010](#)). The hand is flat due to extension of the MJ and its position on the piano is low (the behavior MP_Mpl obtained 94.1% of the visualizations), due to a neutral wrist position (the behavior Mca_McaN obtained 72.5% of the visualizations) and the low position of the forearm (the behavior AtBz_AtBzB obtained 29.4% of the visualizations). The fingers are in disparate positions (observe the elevation of the index finger with the DJ and PJ extended and the middle finger with DJ and PJ flexed) (the behavior DsCol_DsDisp obtained 51% of the visualizations).

In keeping with the motor behavior patterns detailed above and those reflected in [Tables 3, 4](#), two different types of touch are apparent—pressed and struck—which correspond to participant P1 and participant P2, respectively.

4.2 Polar coordinate analysis

The results of the polar coordinate analysis of the focal and conditioned behaviors shown in [Table 2](#).

Participant P1. Motor interactions of the fingers that act with MJ flexed and PJ and DJ slightly extended (DS_DfxMligextPD) with the actions of start of keystroke (IPT), finger-key surface contact (DSct), key release actions (DlibT), finger placement (DsCol), shape of the palm area of the hand (MP), wrist position (Mca), forearm position (AtBz) and the placement of the body in front of the piano (CC).

The results of the analysis of the focal behavior DS_DfxMligextPD and the conditioned behaviors expressed in [Table 2](#) for participant P1 were significant, as can be seen in block 1 of [Table 5](#). In the corresponding vector map, shown first on the left in [Figure 4](#), quadrant I shows the mutual activation of the focal behavior with the key release action of the fingers via sliding over it (DLibT_Ddz), along with a cupped palm shape (MP_Moq). The behavior relating to the finger-key

surface contact is found in quadrant III, which means that it mutually inhibits the focal behavior, due to the moment of the action, prior to the key release via sliding. High forearm placement (AtBz_AtBzA) is found in quadrant IV, which means that the fingers in MJ flexion and slight PJ and DJ extension activate the high forearm. At the same time the high forearm retrospectively inhibits the behavior of the fingers with flexed MJ and slightly extended PJ and DJ, which shows the rocking behavior of the forearm that acts in suspension, enabling the free movement of the fingers on regulating the pressure applied to them and avoiding the heaviness of the gravitational force ([Ott, 2004](#)). All this shows that the behavior of the fingers with MJ flexed and PJ and DJ slightly extended interacts with the cupped shape of the hand and the behavior of the high forearm. These behaviors facilitate key release via a sliding motion, motor behaviors that are characteristic of the pressed touch ([Bellman, 2001](#); [Furuya et al., 2012](#); [Ortmann, 1925](#); [Ott, 2003](#)).

Participant P1. Motor interactions of the fingers that act with flexion of the MJ, PJ and DJ, (DS_DfxMPD), with the actions of start of keystroke (IPT), finger-key surface contact (DSct), key release action (DlibT), finger placement (DsCol), shape of the palm area of the hand (MP), wrist position (Mca), forearm position (AtBz) and the placement of the body in front of the piano (CC).

The results of the analysis of focal behavior DS_DfxMPD and the conditioned behaviors expressed in [Table 2](#) for participant P1 were not significant in behaviors DSct_DcfgDP, DSct_DNoc, DLibT_Ddz and CC_CCa, as can be observed in block 2 of [Table 5](#), while the rest of the results were significant. Second from the left in the corresponding vector map represented in [Figure 4](#), clearly different motor behaviors and their location in opposing quadrants (activation–inhibition) are shown. In quadrant I the mutual activation of the focal behavior with the finger-key surface contact via the fingerpad, the wrist flexed and the forearm high is opposite to the behaviors in quadrant III, with the inhibition of the conditioned behavior relating to the finger-key contact with the DP and a neutral wrist position. In quadrant II we can see the shape of the palm area is cupped, indicating that the behavior of the fingers with MJ, PJ, and DJ flexed inhibits the cupped palm area prospectively, at the same time that the cupped hand retrospectively activates the finger action with the MJ, PJ, and DJ flexed. The action of the start of the keystroke from contact with its surface is located in quadrant IV, which means that the focal behavior (DS_DfxMPD) prospectively activates the conditioned behavior (IPT_Dcontsup), at the same time that the conditioned behavior retrospectively inhibits the focal. All this reveals that the motor behavior of the fingers with MJ, PJ and DJ flexed interacts with the finger-key contact of the fingerpad, the high forearm, and wrist flexion, which can be attributed to the fact that, in pressed keystrokes, the wrist anticipates the attack through wrist extension and steadily augments its contribution via wrist flexion ([Oikawa et al., 2011](#); [Goebel et al., 2005](#)). Contact with the fingerpad provides greater tactile feedback, essential for spatial and temporal precision, along with the production of the pianist's sound intentions ([Dalla Bella and Palmer, 2011](#); [Goebel and Palmer, 2008](#); [James, 2012](#); [Robb, 2022](#)); these being motor behaviors characteristic of the pressed touch ([Goebel et al., 2014](#); [Furuya et al., 2010](#); [MacRitchie, 2015](#); [Verdugo et al., 2020](#)).

Participant P1. Motor interactions of the action of thumb in lateral contact (PScT_PcL) with thumb actions (P), shape of the palm area of the hand (MP), hand action (Macc), wrist position (Mca), forearm position (AtBz) and placement of the body in front of the piano (CC).

TABLE 3 Record of visualizations by participant P1.

Dimensions	Behaviors	Visualization frequency	Percentage
Musical extract performed	1st demarcation	6	13.3
	2nd demarcation	3	6.7
	3rd demarcation	3	23.71
	4th demarcation	4	0.79
	5th demarcation	4	8.9
	6th demarcation	4	8.9
	7th demarcation	4	8.9
	8th demarcation	6	13.3
	9th demarcation	11	24.4
Start of keystroke	From contact with the key	21	100.0
	Lifts finger before contact with the key	0	0.0
	Lifts arm before keystroke	0	0.0
Fingers	Flexion M and slight extension P and D	21	37.5
	Flexion M, P and D	6	10.7
	Flexion M and extension P and D	17	30.4
	Extension M and flexion P and D	0	0.0
	Extension M, P and D	12	21.4
Fingers: surface contact with key	Fingerpad	28	60.9
	Distal phalanx	3	6.5
	Distal and proximal phalanx	2	4.3
	Fingertip	1	2.2
	Lateral in supination	0	0.0
	Lateral in pronation	0	0.0
	No contact	12	26.1
Thumb: surface contact	Lateral	25	56.8
	Fingerpad	1	1
	Fingertip	11	11
	No contact	7	15.9
Finger: key release	Sliding over the key	18	100.0
	Lifting over the key	0	0.0
Finger placement	Similar	45	100.0
	Disparate	0	0.0
Thumb: movements	Thumb pass with forearm rotation	0	0.0
	Thumb pivots to allow passage of other fingers	0	0.0
	Thumb slides to allow passage of other fingers	6	100.0
	Lateral thumb movement	0	0.0
Hand: palm area	Cupped	43	95.6
	Flat	2	4.4
Hand: action	Sliding movement	6	13.3
	Movement with pronation turns	0	0.0
	Movement with supination turns	1	2.0
	White keys area	37	82.2
	Back of keyboard	0	0.0
	Away from the keyboard	0	0.0
	Jumping movement	1	2.2

(Continued)

TABLE 3 (Continued)

Dimensions	Behaviors	Visualization frequency	Percentage
Wrist	Neutral position	7	15.6
	Lifted position	38	84.4
	Low position	0	0.0
Forearm	High	42	93.3
	Low	3	6.7
Placement of body in front of keyboard	High	45	100.0
	Low	0	0.0
	In line with the keyboard	0	0.0

The results of the analysis of focal behavior PScT_PcL and the conditioned behaviors expressed in Table 2 for participant P1 were significant, as can be seen in block 3 of Table 5. Third from the left in the corresponding vector map represented in Figure 4, we can see in quadrant I the mutual activation of the focal behavior with the neutral wrist position (Mca_McaN), together with mutual activation, although to a lesser degree but also significant, of the cupped hand shape (MP_Moq) and the action of the hand on the white keys (Macc_MaccBlan). Quadrant III shows the mutual inhibition of the conditioned behaviors relating to the high placement of the body in front of the keyboard (CC_CCa), high placement of the forearm (AtBz_AtBzA), movement of the hand via sliding (Macc_MdlzD) and a high wrist position (Mca_McaF). Quadrant IV shows the prospective activation of sliding the thumb over the key to enable the other fingers to pass over it, allowing lateral movement of the hand without this intervening, as is shown in quadrant III, whilst keeping its position in the white keys area and its cupped shape. Two clearly opposing activation actions are shown (neutral wrist, in quadrant I) and inhibition actions (flexed wrist, in quadrant III), due to the fact that the wrist does not use rotation or flexion for this movement. At the beginning of the sonata where there are six descending consecutive notes (G-F-Eb-D-C-Bb), P1 presses the “D” key with the thumb and allows the middle finger to press the “C” key by sliding over the “D” key. The hand does not change its placement or position, so that it moves laterally towards the left of the keyboard without a pronated turn. On the last beat of the second bar, the group of semiquavers (F-Eb-D-C) ends with the note “C,” on which the thumb carries out the same sliding action to allow the “Bb” at the beginning of the following bar to be played. The results show the interaction of the motor behavior of the thumb in lateral contact, with the thumb sliding over the key, the hand cupped, the hand moving via the thumb sliding over the key and the wrist in neutral position (see Figure 5).

Participant P1. Motor interactions of the action carried out in the musical extract of the 9th demarcation of the fragment of the Mozart sonata (ExMu_Mzt1_9) with the actions of start of keystroke (IPT), finger position (DS), finger-key surface contact (Dsct), thumb surface contact with the key (PScT), key release actions (DlibT), finger placement (DsCol), shape of the palm area of the hand (MP), hand action (Macc), wrist position (Mca), forearm position (AtBz) and the placement of the body in front of the piano (CC).

The results of the analysis of focal behavior ExMu_Mzt1_9 and the conditioned behaviors expressed in Table 2 for participant P1 were significant, as can be observed in block 4 of Table 5, with the exception of DLibT_Ddz and CC_CCa. Fourth from the left in the corresponding

vector map represented in Figure 4, we can see in quadrant I the mutual activation of the focal behavior with the action of the thumb making contact with the tip and the placement of the fingers flexing MJ and extending PJ and DJ. The start of the keystroke with the rest of the fingers is done from contact of the DP and PP with the key surface; the hand is flat and moves via sliding the fingers without modifying its position (Macc_MdlzD). In quadrant II the behavior focal prospectively inhibits the conditioned behaviors of finger position with extension of MJ, PJ and DJ, the wrist flexed and the forearm high, at the same time that the conditioned behaviors retrospectively activate the action of the focal behavior. Quadrant III shows the mutual inhibition of the focal behavior and the conditioned behaviors relating to finger contact via the finger pad (DSct_Dcy), lateral thumb contact (PScT_PcL), cupped palm shape (MP_Moq) and the action of the hand over the white keys (Macc_Blan). Quadrant IV shows the prospective activation of the neutral wrist position, while this retrospectively inhibits the focal behavior.

In focal behavior ExMu_Mzt1_9 we can observe the actions produced in the whole of the 9th bar and the first two beats of the 10th bar of the sonata. At the start of the 9th bar there is a syncope that begins with an octave (F-F), in the strong part of the first beat. The tip of the thumb remains in contact throughout the whole syncope (F, minim figure) due to the distance maintained with the “F” key an octave higher and the following keys “Eb-D” and “D.” Here what is notable is the action of the ring finger sliding over the “Eb” key until the little finger presses the “D” key. This motor action is significant, considering that the hand is moving towards the left of the keyboard, without the ring finger moving to the middle, which is what is immediately to its left, but the ring finger slides over the key to allow the little finger to move, which is on its right, an action which enables the sound continuity of the syncope (Bellman, 2001; Ott, 2003). Finally, a succession of descending sixths is played by sliding the fingers over the keys. The results show the sliding action of the fingers which interact with the rest of the motor behaviors (see Figure 6).

Participant P2. Motor interactions of the fingers that act with extension of the MJ and flexion of the PJ and DJ (DS_DextMfxPD) with the actions of start of keystroke (IPT), finger-key surface contact (Dsct), key release actions (DlibT), finger placement (DsCol), shape of the palm area of the hand (MP), wrist position (Mca), forearm position (AtBz) and the placement of the body in front of the piano (CC).

The results of the analysis of focal behavior DS_DextMfxPD and the conditioned behaviors expressed in Table 2 for participant P2 were significant, with the exception of IPT_DelvectM, DSct_DcfigDP and

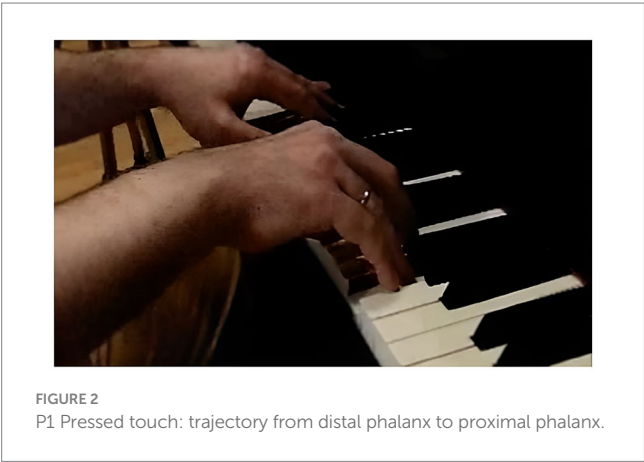
TABLE 4 Record of visualizations by participant P2.

Dimensions	Behaviors	Visualization frequency	Percentage
Musical extract performed	1st demarcation	5	9.8
	2nd demarcation	3	5.9
	3rd demarcation	5	9.8
	4th demarcation	8	15.7
	5th demarcation	4	7.8
	6th demarcation	5	9.8
	7th demarcation	3	5.9
	8th demarcation	6	11.8
	9th demarcation	12	23.5
Start of keystroke	From contact with the key	4	14.8
	Lifts finger before contact with the key	13	48.1
	Lifts arm before keystroke	10	37.0
Fingers	Flexion M and slight extension P and D	1	1.4
	Flexion M, P and D	2	2.7
	Flexion M y extension P and D	2	2.7
	Extension M y Flexion P and D	39	53.4
	Extension M, P and D	29	39.7
Fingers: surface contact with key	Fingerpad	0	0.0
	Distal phalanx	3	5.3
	Distal and proximal phalanx	0	0.0
	Fingertip	25	43.9
	Lateral in supination	0	0.0
	Lateral in pronation	0	0.0
	No contact	29	50.9
Thumb: surface contact	Lateral	21	53.8
	Fingerpad	0	0.0
	Fingertip	7	17.9
	No contact	11	28.2
Finger: key release	Sliding over the key	1	10.0
	Lifting over the key	9	90.0
Finger placement	Similar	25	49.0
	Disparate	26	51.0
Thumb: movements	Thumb pass with forearm rotation	1	20.0
	Thumb pivots to allow passage of other fingers	4	80.0
	Thumb slides to allow passage of other fingers	0	0.0
	Lateral thumb movement	0	0.0
Hand: palm area	Cupped	3	5.9
	Flat	48	94.1
Hand: action	Sliding movement	0	0.0
	Movement with pronation turns	3	5.9
	Movement with supination turns	3	5.9
	White keys area	26	51.0
	Back of keyboard	11	21.6
	Away from the keyboard	1	2.0
	Jumping movement	7	13.7

(Continued)

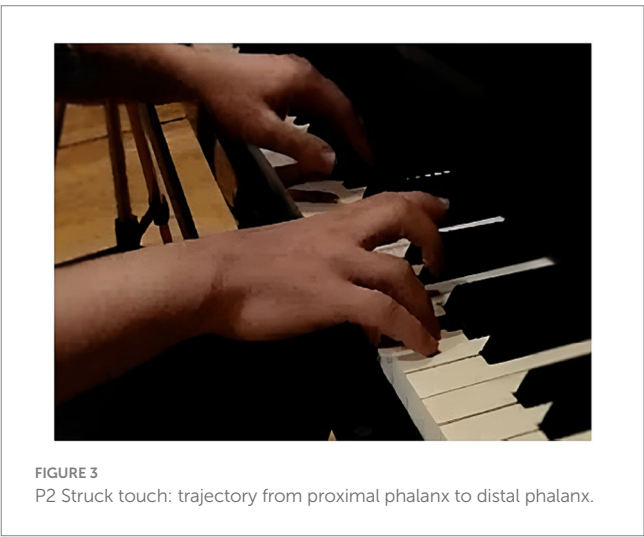
TABLE 4 (Continued)

Dimensions	Behaviors	Visualization frequency	Percentage
Wrist	Neutral position	37	72.5
	Lifted position	13	25.5
	Low position	1	2.0
Forearm	High	36	70.6
	Low	15	29.4
Placement of body in front of keyboard	High	51	100.0
	Low	0	0.0
	In line with the keyboard	0	0.0



Mca_McaEx, as shown in block 1 of Table 6. First on the left in the corresponding vector map represented in Figure 7, we can see the behaviors with the longest vectors in each of the quadrants. Thus, quadrant I shows the mutual activation of the focal behavior with the conditioned behaviors of no finger-key contact (DSct_DNoc), neutral wrist position (Mca_McaN) and low forearm (AtBz_AtBzB). Quadrant III shows the mutual inhibition of the behaviors relating to the start of the keystroke with prior lifting of the arm, along with finger-key contact with the DP, flexed wrist and high forearm. Quadrant II shows the prospective inhibition of the conditioned behavior relating to finger-key contact via the fingertip (DSct_Dcpt), at the same time that this retrospectively activates the action of the fingers with extension of the MJ, and flexion of the PJ and DJ. The key release action via lifting the finger is located in quadrant IV, which means that the focal behavior (DS_DextMfxPD) prospectively activates the conditioned behavior (DLibT_Delv), while the conditioned behavior inhibits the focal retrospectively. These interactions are related to the flattening of the hand arch that occurs with the given focal behavior, necessitating the raising of the fingers or forearm to release or touch the key due to the tension created in the forearm and fingers (Brown, 2000).

The results show the interaction of the motor behavior of fingers with extended MJ and flexed PJ and DJ, with fingertip finger-key contact (Berman, 2002), and key release via lifting the finger and the start of the keystroke from a certain distance from the keys, via the action of no finger-key contact (Furuya et al., 2010); these being behaviors characteristic of the motor behavior of the struck touch (see Figure 8).



Participant P2. Motor interactions of the fingers that act with flexion of the MJ, PJ and DJ, (DS_DfxMPD), with the actions of start of keystroke (IPT), finger-key surface contact (DSct), key release actions (DlibT), finger placement (DsCol), shape of the palm area of the hand (MP), wrist position (Mca), and forearm position (AtBz).

The results of the analysis of focal behavior DS_DfxMPD and the conditioned behaviors expressed in Table 2 for participant P2 were significant, with the exception of behaviors IPT_Dcontsup, IPT_Levprevbz, DSct_Dcpt, DSct_DcfgDP, DSct_DNoc, Mca_McaEx, AtBz_AtBzA and AtBz_AtBzB, which were not significant, as can be seen in block 2 of Table 6. Second from the left in the corresponding vector map, represented in Figure 7, we can see the behaviors with the longest vectors in each of the quadrants. Thus, quadrant I shows the mutual activation of the focal behavior with a similar finger placement (DsCol_DsSim), a behavior opposite to that shown in quadrant III, relating to the inhibition of disparate finger placement (DsCol_DsDisp). Quadrant II shows a flat palm area (MP_Mpl), indicating that the focal behavior prospectively inhibits the conditioned behavior (MP_Mpl), at the same time that the conditioned behavior—i.e., the flat hand—retrospectively activates the focal behavior, that is, the action of the fingers with flexion of the MJ, PJ, and DJ. The flexed wrist position (Mca_McaF) is located in quadrant IV, as opposed to the neutral wrist position (Mca_McaN) of quadrant II, which means that the focal behavior (DS_DfxMPD) prospectively activates the conditioned behavior (Mca_McaF), at the same time that the conditioned behavior inhibits the focal, just the opposite as to what

TABLE 5 Results of the polar coordinate analysis of participant P1.

Behavior	Quadrant	Prospective Zsum	Retrospective Zsum	Ratio	Radius	Significance	Angle
1. Focal behavior: fingers with flexion of the metacarpophalangeal joints and slight extension of the proximal and distal interphalangeal joints (DS_DfxMligextPD).							
IPT_Dcontsup	III	−3.35	−3.81	−0.75	5.07	**	228.72
DSct_Dcy	I	10.36	10.1	0.7	14.47	**	44.29
DSct_DcfgD	III	−3.65	−2.3	−0.53	4.32	**	212.22
DSct_DcfgDP	III	−3.81	−2.63	−0.57	4.63	**	214.66
DSct_DNoc	III	−8.23	−10.11	−0.78	13.04	**	230.86
DLibT_Ddz	I	1.38	2.44	0.87	2.8	**	60.42
MP_Moq	I	3.81	2.63	0.57	4.63	**	34.66
Mca_McaN	II	−1.72	6.77	0.97	6.98	**	104.26
Mca_McaF	IV	1.72	−6.77	−0.97	6.98	**	284.26
AtBz_AtBzA	IV	2.04	−2.2	−0.73	3	**	312.78
CC_CCa	IV	0.37	−2.4	−0.99	2.43	*	278.84
2. Focal behavior: fingers with flexion of the metacarpophalangeal, proximal and distal joints (DS_DfxMPD).							
IPT_Dcontsup	IV	3.07	−1.67	−0.48	3.5	**	331.4
DSct_Dcy	I	1.63	3.12	0.89	3.52	**	62.4
DSct_DcfgD	III	−2.14	−1.96	−0.68	2.9	**	222.55
DSct_DcfgDP	III	−0.82	−1.58	−0.89	1.78		242.47
DSct_DNoc	IV	0.16	−1.33	−0.99	1.33		276.77
DLibT_Ddz	I	0.05	0.16	0.96	0.17		73.14
MP_Moq	II	−5.27	1.58	0.29	5.5	**	163.35
Mca_McaN	III	−0.38	−2.85	−0.99	2.88	**	262.47
Mca_McaF	I	0.38	2.85	0.99	2.88	**	82.47
AtBz_AtBzA	I	1.92	2.06	0.73	2.81	**	47.07
CC_CCa	I	0.9	0.9	0.71	1.27		45
3. Focal behavior: lateral thumb surface contact (PSct_ Pcl).							
P_PdzPsDs	IV	0.33	−1.94	−0.99	1.97	*	279.57
MP_Moq	I	0.64	2.16	0.96	2.25	*	73.6
Macc_MdlzD	III	−1.35	−3.38	−0.93	3.64	**	248.21
Macc_MaccBlan	II	0	2.04	1	2.04	*	90.14
Mca_McaN	I	2.01	442	0.91	4.85	**	65.56

(Continued)

TABLE 5 (Continued)

Behavior	Quadrant	Prospective Zsum	Retrospective Zsum	Ratio	Radius	Significance	Angle
Mca_McaF	III	−2.01	−4.42	−0.91	4.85	**	245.56
AtBz_AtBzA	III	−1.31	−2.69	−0.9	2.99	**	244.06
CC_CCa	III	−1.14	−2.08	−0.88	2.37	*	241.18
4. Focal behavior/elements: musical extract performed whole 9th bar two first beats of 10th bar (ExMu_ Mzt1_9).							
IPT_Dcontsup	I	4.04	6.34	0.84	7.52	**	57.49
DS_DfxMextPD	I	14.56	10.55	0.59	17.98	**	35.92
DS_DextMPD	II	−1.01	5.5	0.98	5.59	**	100.37
DSct_Dcy	III	−15.16	−13.24	−0.66	20.13	**	221.14
DSct_DcfgD	I	6.63	2.56	0.36	7.1	**	21.12
DSct_DcfgDP	I	6.58	3.75	0.5	7.58	**	29.67
PScT_PcL	III	−8.92	−11.78	−0.8	14.78	**	232.88
PScT_PcP	I	15.65	17.14	0.74	23.21	**	47.61
DLibT_Ddz	III	−0.54	−1.07	−0.89	1.2		243.24
MP_Moq	III	−1.58	−3.75	−0.92	4.07	**	247.12
MP_Mpl	I	1.58	3.75	0.92	4.07	**	67.12
Macc_MdlzD	I	5.03	3.45	0.56	6.1	**	34.4
Macc_MaccBlan	III	−3.73	−2	−0.47	4.23	**	208.26
Mca_McaN	IV	0.03	−4.44	−1	4.44	**	270.36
Mca_McaF	II	−0.03	4.44	1	4.44	**	90.36
AtBz_AtBzA	II	−0.02	3	1	3	**	90.38
CC_CCa	I	1.23	1.31	0.73	1.79		46.82

**Means very significant (<0.01).

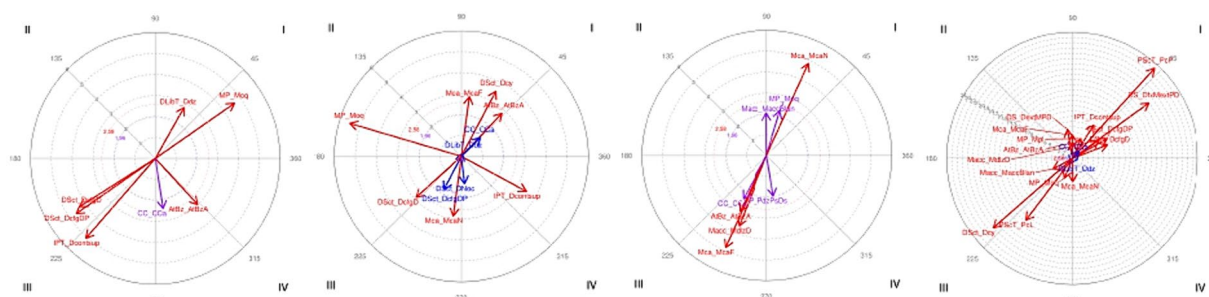


FIGURE 4

P1. Vector representation of the interactions between four given behaviors (focal) and their paired behaviors (conditioned). The panels from right to left correspond to the behaviors indicated in Table 2. Purple vectors represent significant interactions; red vectors represent highly significant interactions; and blue vectors represent slightly significant interactions (corresponding to the values marked with one or two asterisks, according to the significance level in Table 5).



FIGURE 5

P1 Hand movement via thumb sliding.

happens in quadrant II (Mca_McaN). This motor interaction of the wrist can be attributed to the fact that, in struck keystrokes, wrist flexion assists the downward movement of the fingertip prior to the attack. Its contribution diminishes upon finger-key contact and increases towards the end of the attack (Verdugo et al., 2020). Quadrant IV also shows the prospective action of lifting the arm prior to the start of the keystroke (IPT_Levprevbz), along with finger-key contact via the fingertip (DSct_Dcpt), while in quadrant III it inhibits—both prospectively and retrospectively—the behavior that characterizes the pressed touch, i.e., the start of the keystroke from contact with the surface of the key (IPT_Dcontsup).

The results show the interaction of the motor behavior of fingers with flexions MJ, PJ and DJ with a similar finger placement, a flat hand, prior elevation of the arm before the start of the keystroke, and finger-key contact via the fingertip, which are motor behaviors associated with the struck touch (Goebel et al., 2014; Furuya et al., 2010; Verdugo et al., 2020).

Participant P2. Motor interactions of the action of thumb in lateral contact (PScT_PcL) with thumb actions (P), shape of the palm area of the hand (MP), hand action (Macc), wrist position (Mca), forearm position (AtBz) and placement of the body in front of the piano (CC).

The results of the analysis of focal behavior PScT_PcL and the conditioned behaviors expressed in Table 2 for participant P2 were

significant, with the exception of behaviors Mca_McaN and Mca_McaF, that were not significant, as can be observed in block 3 of Table 6. Third from the left in the corresponding vector map represented in Figure 7, we can see the behaviors with the longest vectors in each of the quadrants. Quadrant I shows the mutual activation of the hand action in the white keys area. This behavior is not visible in the vector map due to the long length of the vector (6.62), as can be seen in Table 6. Quadrant III shows the inhibition of the conditioned behaviors Macc_MaccFond, MP_Mpl, Macc_Mgirsup, P_PpsR, AtBz_AtBzA and Macc_MaccSalt. Quadrant IV shows the prospective activation of the hand action with pronated turn (Macc_Mgirpro), the thumb acting as a pivot to allow the movement of the other fingers (P_PpivtPsDs), visible in Table 6 by the long length of its vector (6.34), hand action with the palm away from the keyboard (Macc_MaccFuer) and wrist lowered, via joint extension (Mca_McaEx), while the conditioned behavior inhibits the focal behavior. In movements carried out in the succession of descending sounds by consecutive degrees, the thumb remains fixed on the key and turns in pronation which the hand follows to reposition itself after the fingers have passed. The thumb releases the key via a lifting of the finger, when the rest of the fingers press the next key. The results show the interaction of the lateral thumb contact behavior with motor behaviors related to rotation of the thumb and the hand, together with thumb key release via elevation (Goebel et al., 2005).

Participant P2. Motor interactions of the action carried out in the musical extract of the 9th demarcation of the fragment of the Mozart sonata (ExMu_Mzt1_9) with the actions of start of keystroke (IPT), finger position (DS), finger-key surface contact (Dsct), thumb surface contact with the key (PScT), key release actions (DlibT), finger placement (DsCol), shape of the palm area of the hand (MP), hand action (Macc), wrist position (Mca), forearm position (AtBz) and placement of the body in front of the piano (CC).

The results of the analysis of focal behavior ExMu_Mzt1_9 and the conditioned behaviors expressed in Table 2 for participant P2 were significant, with the exception of DSct_Dcpt, which were not significant, as can be seen in block 4 of Table 6. Fourth from the left in the corresponding vector map represented in Figure 7, we can see the behaviors with the longest vectors in each of the quadrants, where almost all the behaviors are presented in quadrants I and III, which are opposites (mutual activation and mutual inhibition). Thus, quadrant I shows the motor behavior of the fingers with extension of

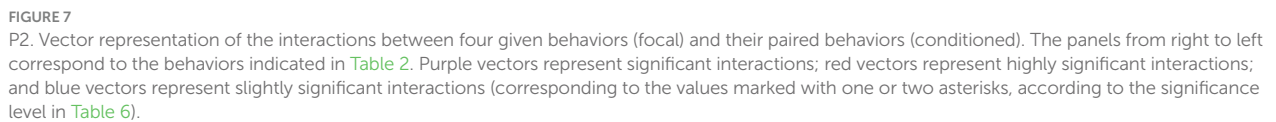
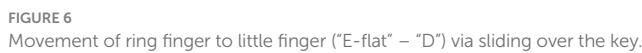


FIGURE 8
P2 Key release via finger elevation and start of keystroke from a certain distance from the keys.

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TABLE 6 Results of the polar coordinate analysis of participant P2.

Behavior	Quadrant	Prospective Zsum	Retrospective Zsum	Ratio	Radius	Significance	Angle
1. Focal behavior: fingers with extension of the metacarpophalangeal joints and flexion of the proximal and distal interphalangeal joints (DS_ DextMfxPD).							
IPT_DelvectM	I	0.94	0.92	0.7	1.32		44.46
IPT_Levprevbz	III	−0.54	−2.48	−0.98	2.54	*	257.64
DSct_Dcpt	II	−2.24	0.27	0.12	2.25	*	173.18
DSct_DcfgD	III	−4.32	−3.65	−0.65	5.66	**	220.21
DSct_DcfgDP	I	1.17	1.19	0.71	1.66		45.52
DSct_DNoc	I	3.44	0.46	0.13	3.47	**	7.68
DLibT_Delv	IV	0.61	−2.89	−0.98	2.95	**	281.95
DsCoL_DsSim	III	−5.3	−4.5	−0.65	6.96	**	220.33
DsCoL_DsDisp	I	5.3	4.5	0.65	6.96	**	40.33
MP_Mpl	I	6.04	1.75	0.28	6.29	**	16.18
Mca_McaN	I	2.48	0.36	0.14	2.5	*	8.25
Mca_McaF	III	−2.83	−0.66	−0.23	2.91	**	193.2
Mca_McaEx	I	0.9	0.93	0.72	1.29		45.96
AtBz_AtBzA	III	−0.53	−4.22	−0.99	4.26	**	262.85
AtBz_AtBzB	I	0.53	4.22	0.99	4.26	**	82.85
2. Focal behavior: fingers with flexion of the metacarpophalangeal, proximal, and distal joints (DS_DfxMPD).							
IPT_Dcontsup	III	−1.17	−0.82	−0.58	1.43		215.13
IPT_DelvectM	II	−2.41	0.35	0.15	2.43	*	171.65
IPT_Levprevbz	IV	1.27	−0.28	−0.22	1.3		347.49
DSct_Dcpt	IV	1.51	−1.05	−0.57	1.84		325.18
DSct_DcfgD	II	−0.91	8.14	0.99	8.19	**	96.36
DSct_DcfgDP	III	−0.4	−0.28	−0.58	0.49		215.16
DSct_DNoc	III	−0.88	−1.57	−0.87	1.8		240.67
DLibT_Delv	II	−1.85	1.5	0.63	2.38	*	141.1
DsCoL_DsSim	I	4.06	2.85	0.58	4.96	**	35.1
DsCoL_DsDisp	III	−4.06	−2.85	−0.58	4.96	**	215.1
MP_Mpl	III	−10.6	−3.24	−0.29	11.08	**	197.02
MP_Moq	I	10.6	3.24	0.29	11.08	**	17.02
Mca_McaN	II	−4.01	1.74	0.4	4.37	**	156.57

(Continued)

TABLE 6 (Continued)

Behavior	Quadrant	Prospective Zsum	Retrospective Zsum	Ratio	Radius	Significance	Angle
Mca_McaF	IV	4.29	−1.65	−0.36	4.6	**	338.95
Mca_McaEx	III	−0.56	−0.4	−0.58	0.69		215.14
AtBz_AtBzA	II	−1.56	0.5	0.3	1.64		162.27
AtBz_AtBzB	IV	1.56	−0.5	−0.3	1.64		342.27
3. Focal behavior: thumb contact surface on the lateral side (PScT_ PCL).							
P_PpsR	III	−2.78	−2.74	−0.7	3.9	**	224.64
P_PpivtPsDs	IV	5.59	−3	−0.47	6.34	**	331.81
MP_Mpl	III	−2.94	−1.4	−0.43	3.26	**	205.5
Macc_Mgirpro	IV	4.6	−1.81	−0.37	4.94	**	338.56
Macc_Mgirsup	III	−3.22	−2.33	−0.59	3.97	**	215.88
Macc_MaccBlan	I	2.45	6.15	0.93	6.62	**	68.23
Macc_MaccFond	III	−4.44	−1.43	−0.31	4.66	**	197.88
Macc_MaccFuer	IV	3.03	−2.74	−0.67	4.09	**	317.87
Macc_MaccSalt	III	−0.57	−3.24	−0.98	3.29	**	259.98
Mca_McaN	IV	0.01	−0.73	−1	0.73		270.7
Mca_McaF	II	−0.98	1.63	0.86	1.9		121.19
Mca_McaEx	IV	3.03	−2.74	−0.67	4.09	**	317.87
AtBz_AtBzA	III	−3.18	−3.7	−0.76	4.88	**	229.3
4. Focal behavior/elements: musical extract performed whole 9 th bar two first beats of 10th bar (ExMu_ Mzt1_9).							
IPT_DelvextM	I	2.44	0.71	0.28	2.54	*	16.16
IPT_Levprevbz	I	2.37	3.85	0.85	4.52	**	58.42
DS_DfxMextPD	II	−1.9	2.74	0.82	3.34	**	124.74
DS_DextMPD	I	10.71	9.45	0.66	14.28	**	41.43
DSct_DcfgD	I	7.14	0.97	0.14	7.21	**	7.77
DSct_DNoc	III	−4.11	−0.07	−0.02	4.11	**	181
DSct_Dcpt	I	1.68	0.33	0.2	1.71		11.28
PSct_PcL	III	−4.73	−8.61	−0.88	9.82	**	241.2
PSct_PcP	I	15.02	14.95	0.71	21.19	**	44.86
PSct_PNoc	II	−0.33	3.59	1	3.61	**	95.2
DLibT_Delv	IV	2.82	−0.04	−0.01	2.82	**	359.21

(Continued)

TABLE 6 (Continued)

Behavior	Quadrant	Prospective Zsum	Retrospective Zsum	Ratio	Radius	Significance	Angle
DsCoL_DsSim	I	5.54	1.64	0.28	5.78	**	16.48
DsCoL_DsDisp	III	−5.54	−1.64	−0.28	5.78	**	196.48
MP_Mpl	II	−0.64	2.9	0.98	2.97	**	102.4
Macc_MaccFond	I	5.07	3.06	0.52	5.92	**	31.06
Macc_MaccSalt	I	1.31	3.17	0.92	3.43	**	67.54
Mca_McaF	I	5.39	6.79	0.78	8.67	**	51.55
Mca_McaEx	III	−1.71	−1.81	−0.73	2.49	*	226.64
AtBz_AtBzA	I	6.34	8.1	0.79	10.29	**	51.94

** Means very significant (<0.01).

The forearm moves forward to press the “D” note of the syncope by placing the finger on the narrow part of the white key, between the two black keys, with the hand acting at the back of the keyboard. This is followed by a succession of descending sixths which are played via jumping hand movements to move from one sixth to the next. The keys are released by lifting the hand, which produces a sound discontinuation in the passage from some sounds to others.

The results show the interaction of the focal behavior with the motor behaviors of the fingers with extension MJ, PJ and DJ, thumb tip contact with the key, hand action at the back of the keyboard, with jumping hand movements, a flexed wrist position and key release via lifting the fingers and the forearm.

The results obtained with respect to frequency in the scrutiny of motor behavior occurrences produced by participants P1 and P2 clearly correspond with the polar coordinate analysis of the motor behaviors that characterize the pressed touch and the struck touch, respectively.

5 Conclusion

The aim of this study was to detect and analyze the interactions of motor behaviors that distinctively characterize pressed and struck touch in piano performance. Additionally, it aimed to show the huge potential offered by research into motor behavior in piano playing from the scientific focus of mixed methods.

Systematic observation is an ideal medium for defining the piano touch procedure and for interpreting the expressive significance of body movement, which goes beyond anatomical and biomechanical knowledge (Goebel, 2017). Observational methodology, which brings a novel perspective to artistic research (Anguera, 2010). The possibility of using computer applications both in the musical research and professional fields, opens up a pathway of innovation and improvement that unites research and practice, implying an effective transfer of knowledge and therefore the evolution towards refinement in the field of musical performance.

Lag sequential analysis was used to examine the strength of association between behaviors using HOISAN software. Polar coordinate analysis, based on adjusted residuals from lag sequential analysis, identified activating or inhibitory relationships between a behavior of interest, known as a focal behavior, and other behaviors, known as conditioned behaviors.

Through observational methodology, this study has extracted relevant defining patterns of motor behavior in piano touch procedure. The findings reveal novel interactions between motor behaviors associated with two types of touch, contributing to the existing literature on motor control in piano performance.

Thus, in the pressed touch, the flexion of the metacarpophalangeal joints (knuckles) and slight extension of the P and D joints interact with the cupped hand and the finger-key contact surface centered on the finger pads. The contact surface of the fleshy part of the finger is larger, which allows for more precise control during performance (Dalla Bella and Palmer, 2011; Goebel and Palmer, 2008; James, 2012; Robb, 2022). The cupped position of the hand interacts with the key release behavior through the sliding of the fingers, which in turn interacts with the raised forearm, facilitating the cupping of the hand while avoiding the heaviness of the arm weight by keeping it in suspension, resulting in an improvement in sound quality. The study has highlighted the importance of sliding the

fingers over the keys towards the palms of the hands in a circular, chained motion that goes from the DP to the PP, and in the case of the thumb, its sliding facilitates the passage of the other fingers. Pressure comes from contact made with the keys before they are pressed. The position of the hand is high, with slightly curved fingers in alignment (Del Pueyo, 1990). The movement is controlled by suspension of the forearm, enabling sound continuity. The position of the hand is not altered by the movements over the keyboard thanks to the sliding motion of the fingers over the keys (Lee, 2005; Ott, 2004). The hand is close to the keyboard, which avoids the noise produced by the contact of the fingers with the keys. At the same time a greater economy of movement is produced since there are no big movements (Goebel et al., 2005).

In the struck touch, the extension of the metacarpophalangeal joints with flexion of the P and D joints interacts with the flat shape of the hand and the finger-key contact surface centered on the fingertip. The keystroke begins with the finger at a certain distance from the key, raised vertically via extension of the MJ before the key is pressed, going from the PP to the DP, or via elevation of the forearm, producing a noise upon contact that affects sound quality. Wrist activity is increased to stabilize the impact of the key's inertia when struck (Verdugo et al., 2020). The finger releases the key vertically, via extension of the MJ or via elevation of the forearm, reducing the time it stays on it (Furuya et al., 2010; Goebel et al., 2014). The key makes contact with the fingertip, the contact surface of which is smaller and so, therefore, is the tactile feedback about sound control (Goebel et al., 2014). Movements across the keyboard are made via thumb, hand and forearm turns. These changes of position alter the sound continuity (Goebel et al., 2005).

The described behavioral interactions were also supported by the descriptive analysis of observed behaviors in both pianists, measured by occurrence frequency, which is relevant in body movements (Anguera, 1982). Through the percentage of response visualization, the most significant behaviors were evidenced in both participants, highlighting behaviors associated with two types of touch, pressed and struck, corresponding to participants P1 and P2, respectively.

The results obtained in this study using observational methodology have successfully addressed the established aims, delving into the analysis of the right upper limb movement in the participating professional pianists. Furthermore, the study introduces new perspectives for supporting piano teachers, showing the effectiveness of systematic observation of pianist motor behavior. Future studies could be based on a bigger sample, along with the direct observation of the whole kinematic chain of piano-playing motion.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Ethics Committee of the University of Barcelona. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was not obtained

from the individual(s) for the publication of any potentially identifiable images or data included in this article because in accordance with the ethical principles and guidelines of the Ethics Committee of the University of Barcelona, the privacy and anonymity of participants in this study were preserved.

Author contributions

IS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. MA: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. JG-V: Conceptualization, Investigation, Supervision, Writing – review & editing. JP-B: Software, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Focus group on conflict management in the classroom in Secondary Education in Costa Rica: mixed methods approach

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Introduction: The educational system in Costa Rica, as regulated by Law #7727, which governs Alternative Conflict Resolution and Promotion of Social Peace must consider the interplay of various factors influencing classroom conflicts and the management strategies employed by teachers. Consequently, it becomes imperative to identify the most effective conflict resolution practices applicable within this context. To achieve this, a thorough procedure based on mixed methods was employed to analyze and interpret both classroom conflict behaviors and teachers' strategic responses.

Method: This study employed an indirect observational methodology, from a mixed methods approach. Data was collected through a focus group comprised of teachers. Following the connect framework, the procedure was conducted in three phases: QUAL-QUAN-QUAL. Two analytical techniques were implemented. A lag sequential analysis was used to explore potential behavioral patterns. The results of this analysis informed a polar coordinate analysis, which generated a visual representation of the relationships between codes.

Results and discussion: A focus group addressed four questions, yielding satisfactory data quality control results (kappa values: 0.80, 0.77, 0.76, 0.82). In polar coordinate analysis, the 37 observational instrument categories were designated as focal behaviors. Each of the 37 analyses treated all categories as conditioned behaviors. The analysis identified 342 activation/inhibition relationships between focal and conditioned behaviors. Of these, 195 were statistically highly significant, distributed across quadrants: Quadrant I (106), Quadrant II (36), Quadrant III (16), Quadrant IV (36). Significant gaps in understanding of conflict were identified, along with disparities in the resources and competencies necessary for successful conflict resolution among the observed educators. Specifically, teachers frequently employed techniques informed by intuition rather than deliberate strategy learned in their training. Consequently, the study advocates for enhancing teachers' cognitive and emotional competencies to optimize conflict management within the classroom and bolster their adaptive coping mechanisms.

KEYWORDS

focus group, observational methodology, observation instrument, mixed methods, conflict management, behavioral relationships

1 Introduction

Costa Rican education faces a deficit in general training and updating, including in the fields of conflict resolution and violence prevention training, for both students and educators (Estado de la Nación, 2023). This stems, in part, from prioritizing the acquisition of functional competencies for specific labor demands, sometimes at the expense of communication skills and values essential for healthy coexistence.

Considering Law #7727 (Procuraduría General de la República (PGR), 2004), which regulates actions for Alternative Dispute Resolution and the Promotion of Social Peace in Costa Rica, Article 1 states that,

Every person has the right to adequate education on peace, in schools and colleges, which have the duty to make their students understand the nature and demands of the ongoing construction of peace... The Higher Education Council will seek to include, in official educational programs, elements that promote the use of dialogue, negotiation, mediation, conciliation, and other similar mechanisms as suitable methods for conflict resolution (p. 1).

Probably the lack of training programs in skills and strategies for conflict management within educational institutions is a contributing factor to the emergence of violence cases in that environment.

Ministerio de Educación Pública (2023) reveals a concerning trend. In the first month of 2022, 30 violent incidents were reported in educational institutions. This number escalated significantly in the first month of 2023, with 77 cases of violence and 24 cases of bullying.

To drive transformative change in educational conflict management, Pineda-Alfonso and García-Pérez (2017) emphasize the necessity of re-examining our understanding of conflict and coexistence. They assert that...

... There is a great deal of parallelism between the causes and consequences of individual and social conflicts, and there is confusion or overlap between personal and social concerns; It is often the case that social interests are conceived only in terms of future personal success (p. 151).

Research demonstrates the essential role teachers have in mediating conflict within classrooms. Pantoja (2005) advocates that educators should have the skillset to shape student behavior, promoting conflict resolution as a naturally acquired competency.

On the other hand, Villalta (2014) underscores the necessity to examine contributing factors to the emergence of conflict, which encompass institutional structures, teacher proficiency, and the overall educational climate.

Addressing deficiencies in both the theoretical and practical understanding of conflict resolution among educators is crucial. A robust body of research on individual, group, and societal influences on conflict exists (Galli, 2004; Luhmann, 2007; Martucelli, 2014; Pineda-Alfonso and García-Pérez, 2017; Redorta, 2019; Stewart and Barrick, 2000).

Furthermore, the Integrated Circular Model of Conflict (Bonilla et al., 2020) facilitates the analysis of the individual, group or social aspects that influence conflicts within educational institutions, supporting the development of essential social, emotional, and cognitive aspects to improve coexistence spaces.

Taking as reference Costa Rican Social Security Fund (2021) data reveals workplace stress as the primary cause of disability among Costa Rican educators in 2019, with a marked rise in neurotic disorders driven by anxiety and depression.

This study's objective was to pinpoint behavioral patterns and the qualitative aspects fueling classroom conflict and the strategies employed by Costa Rican secondary school teachers for their resolution.

A mixed-methods approach, incorporating a focus group to gain insight into teachers' experiences, was utilized. Analysis of indirect observations provided valuable results with the potential to inform future research aimed at enhancing classroom conflict management.

2 Methods

2.1 Mixed methods approach

This study is situated within the framework of mixed methods. While the first authors to mention the term mixed methods were Parkhurst et al. (1972), Newman and Benz (1998), more than a quarter of a century ago, set out to explore the qualitative-quantitative interactive continuum in research (Onwuegbuzie and Hitchcock, 2015; Onwuegbuzie and Johnson, 2021), considering the classical dichotomy that both options respond to opposing paradigms as false and unfounded. In this direction, there are no pure quantitative methods that do not involve qualitative elements in some stages of the process (Chang et al., 2009; Nzabonimpa, 2018; Sandelowski, 2014). The development of mixed methods has been exponential (Anguera, 2022), and it is still in the process of maturation, given the multiple existing methodological sensitivities. However, the current focus is on the integration of qualitative and quantitative elements (Anguera et al., 2017; O'Cathain et al., 2010; Onwuegbuzie, 2012).

We take as a reference the following words of Creswell and Plano Clark (2011, p. 7): "There are three ways in which mixing occurs: merging or converging the two datasets by actually bringing them together, connecting the two datasets by having one build on the other, or embedding one dataset within the other so that one type of data provides a supportive role for the other dataset" (p. 7) [emphasis added]. Taking this quote as a reference, we initiated a rethinking of quantizing, which is a crucial element of mixed methods. "Connecting the two datasets by having one build on the other" means that a qualitative database can be transformed into another qualitative database while maintaining its informative quality but modifying its appearance to make it more organized.

Inspired by this notion, we focus on the re-elaboration and transformation of qualitative data, a process known as quantizing. This involves preserving the essential information within a qualitative dataset while restructuring it for enhanced organization.

Structuring mixed-methods research effectively necessitates a comprehensive framework. To meet this need and based on the via connect approach proposed by Creswell and Plano Clark (2011), we employ the QUAL-QUAN-QUAL macro-stages (Anguera et al., 2020). This approach represents both a conceptual and procedural advancement in mixed-methods research. By applying this process to the focus group, which is entirely innovative, in the first qualitative stage (QUAL), qualitative data are obtained, a customized observation instrument is built, the text is segmented into units, and appropriately coded; in the QUAN stage, data quality control is carried out, and

quantitative analysis is performed; finally, in the second QUAL stage, the results are interpreted. This establishes a bridge between qualitative and quantitative research paradigms.

This study employs indirect observation methodology, gathering data from teachers in a focus group setting. This method is particularly suitable for analyzing classroom conflict and resources for managing conflict, such as emotional regulation and coping mechanisms. Indirect observation is highly valuable in behavioral research as it enables textual analysis of verbal behavior or documents. In this study, it offers a robust framework for observing, systematizing, and analyzing teacher responses within the focus group (Anguera et al., 2018).

2.2 Design

This research aims to study classroom conflicts and the resources teachers utilize for their management, including emotional regulation and coping strategies. Data were obtained from educators participating in a focus group. This approach aligns with Anguera et al. (2018), who advocate for the value of indirect observation value in analyzing everyday behaviors.

Indirect observation analyzes textual material, including verbal transcripts or existing documents. Here, this technique facilitated rigorous observation and systematization of teacher narratives obtained from the focus group.

This study applies observational methodology, specifically indirect observation, always within the framework of mixed methods. In observational studies, there are eight possible designs (Sánchez-Algarra and Anguera, 2013), resulting from combining three dichotomous criteria: units (individual vs. multiple), temporality (single session vs. intersessional following), and dimensionality (single dimension vs. some dimensions). This study employed a nomothetic, punctual, and multidimensional (N/P/M) design. This denotes the involvement of multiple participants (secondary school teachers), data collection within a single session with intrasessional follow-up (following from the beginning to the end of the session), and the existence of some dimensions derived from the study's theoretical framework.

2.3 Focus group and participant profile

In this research project, focus groups were selected as the qualitative data collection method. This approach facilitates the open expression of thoughts and ideas in a conducive group setting (Flynn et al., 2018), providing in-depth insights into teacher reasoning and behaviors (Thofehn et al., 2013).

The inclusion criteria for selecting the 14 participating teachers in the two focus groups were: (1) Teachers with experience levels spanning 2 to 28 years were purposefully recruited. (2) Their professional backgrounds encompassed varied teaching contexts, including rural, urban, urban-rural, and coastal settings. (3) Seven men and seven women were selected. (4) Teachers who demonstrated willingness and commitment to participate in the two previously scheduled work sessions were chosen.

Teachers with less than 2 years of professional experience were excluded, as well as those who had only experienced urban or rural schools, and those who did not demonstrate commitment to participate in the research.

For participant recruitment, permission was obtained through the offices of the Directors of the two schools where the focus groups took

place. A meeting was held with 3 groups of 10 teachers each, with the objective of explaining the research, its scope, and limitations, and to determine their availability to participate in the study.

From there, those who voluntarily decided to participate were asked to sign an informed consent form in which they agreed to be part of the research under strict confidentiality, both regarding their identities and the information they provided.

Both the focus groups and the 8 interviews conducted were moderated and administered by one of the researchers involved in the preparation of this article, and they were conducted in a context of high complexity, considering the enforcement of law #9999 in August 2021 (Asamblea Legislativa, 2021).

2.4 Observation instrument

An *ad hoc* observation instrument was meticulously built to indirectly assess the verbal behaviors of participating teachers. Its design was grounded in both the theoretical framework and emergent themes from the focus group data. Employing a hybrid format combining field notes and category systems (Anguera et al., 2007), the instrument is outlined in Table 1.

This study used a combination of field format and category systems to be advantageous. The category system ensured theoretical alignment, while the field format provided adaptability. This instrument modality reduced the limitations of the category system, which is very rigid, and the field format, which lacks theoretical consistency.

The indirect observation instrument comprises four dimensions: (1) Typology of Conflict, (2) Aspects Influencing Conflict Emergence, (3) Coping Strategies, and (4) Pedagogical Skills for Conflict Management. These dimensions were further refined into sub-dimensions, each with an exhaustive and mutually exclusive system of categories. In total, 38 distinct categories were employed, each assigned a unique code.

2.5 Procedure

These focus groups studies explored the factors influencing classroom conflict and the conflict resolution skills possessed by teachers. Participants were asked:

- 1 What are the primary factors contributing to classroom conflict? Please consider individual, group, and social aspects (e.g., lack of empathy for others' positions, lack of group trust, individual disengagement from the group, inadequate social skills, etc.).
- 2 What skills do you possess to address classroom conflict (e.g., cognitive, emotional, communication, negotiation, reflection, analytical skills, perspective-taking)? Which of these were emphasized during your teacher training?

Focus group dynamics adhered to the guidelines outlined by Hamui-Sutton and Varela-Ruiz (2013). The moderator encouraged open dialogue and equitable participation, fostering a natural conversational flow.

Verbal responses were transcribed and analyzed indirectly. Textual units were segmented and coded, with close attention paid to transcription accuracy, segmentation, and the development of code matrix.

TABLE 1 Direct observation instrument created *ad hoc* for this study.

Dimension	Sub-dimension	Category systems	Codification
1. Typology of the conflict (Coie and Dodge, 1998; Moore, 1995; Muñoz et al., 2007; Underwood et al., 2001)	A. Interpersonal	Verbal Aggression	1A1AV
		Physical Assault	1A2AF
		Irritation	1A3I
		Irrational Communication	1A4ICR
		Repetitive Negative Behaviors	1A5CNR
	B. Structural	Insufficient Coping Resources	1B1DIRAC
		Inter-institutional Disarticulation	1B2FAI
		Power Relations	1B3RP
	C. Interests	Contrasting Objectives	1C1CO
		Disinterest in the other Party in Conflict	1C2NCIOP
		Discourse of the Parties to a Conflict	1C3DPC
		Incompatible Needs	1C4NI
	D. Value	Imposing Beliefs on the other Person	1D1ICOP
		Disregard for the other's Opinion	1D2NCOOP
	E. Information	Poor Information to Make Decisions	1E1EITD
		Different Interpretation of Information	1E2DII
2. Aspects that affect the emergence of conflict (Abbagnano, 1986; Anguera, 1999; Arciniega et al., 2008; Feldman, 1999; Merleau-Ponty, 1975; Owji et al., 2013; Simmel, 1908; Vollmer, 1974)	A. Individuals	Perception of the Conflicting Event	2A1PEC
		Perceptible Behavior in the Natural Environment	2A2CPEN
	B. Groups	Lack of Trust	2B1FC
		Lack of Identity with the Group	2B2FIG
	C. Social	Lack of Social Skills	2C1FHS
		Associative Behavior Tendency	2C2TCA
		Dissociative Behavior Tendency	2C3TCD
3. Coping strategies Dual interest model (Blake and Mouton, 1964; Hall, 1969; Pruitt and Rubin, 1986; Rahim and Bonoma, 1979; Thomas, 1976)	A. Integration	Mutually Friendly Solution	3A1PSFAPC
	B. Domination	Satisfaction of Self-Interest	3B1SIP
	C. Servility	Assignment of One of the Parties	3C1UPCO
	D. Avoidance	Low Intensity to Negotiate	3D1BIPGN
	E. Commitment	Intermediate Solution to the Conflict	3E1APBSI

(Continued)

TABLE 1 (Continued)

Dimension	Sub-dimension	Category systems	Codification
4. Teaching skills to manage conflict (Alves and Pinto da Costa, 2021; Garaigordóbil and Martínez-Valderrey, 2016; Ibarrola-García et al., 2017; Lithoxoidou et al., 2021; Puertas-Molero et al., 2018; Valente and Lourenço, 2020; Zee et al., 2017)	A. Social	Empathy with the other Party in Conflict	4A1EPC
		Prosocial Behavior	4A2CPS
	B. Emotional Issues for Conflict Negotiation	[Auto] Regulates emotions	4B1RE
		Perspective-taking on the Conflict	4B2TPC
		Perception of Effectiveness in Dealing with Conflict	4B3DPEAC
		Awareness of the Conflict Situation	4B4FCSC
	C. Cognitive	Conflict Analysis/Critical Thinking	4C1APCC
	D. Communication	Active Listening	4D1EA
		Proper Tone of Voice	4D2UTVA
		Clear Information	4D3CI

TABLE 2 Kappa coefficients and the assessment of intra-observer agreement for each question.

Kappa coefficients					
Questions	Encodings	Encodings	Encodings	Average	Assessment
	1–2	1–3	2–3		
1	0.72	0.92	0.67	0.77	Enough
2	0.67	1.0	0.80	0.82	Almost Perfect

The rating is indicated according to the criteria established by Landis and Koch (1977): 0.01–0.20 Sligth; 0.21–0.40 Fair; 0.41–0.61 Moderate; 0.61–0.80 Substantial; 0.81–1.00 Almost perfect.

Transcriptions are vital for preserving focus group data. Following Bohle (2013), best practices were employed: (a) careful selection of transcribed content with relevant contextual information, (b) segmentation of text into meaningful units, (c) structuring the text according to participant turns, and (d) incorporation of codes.

Segmenting the transcribed data was complex due to the overlap of different dimensions/sub-dimensions. To resolve this, a taxonomy was used (Anguera, 2021), adhering to Krippendorff's (2013) criteria: (1) orthographic (punctuation-based), (2) syntactic (grammatical sentences), (3) contextual (shifts in topic), and (4) interlocutory (speaker changes). The combined interlocutory-syntactic approach was optimal for this study.

During this stage of the process, quatitizing occurred using a mixed methods approach. To do this, we obtained the parameters of frequency and order or sequence.

Following Anguera et al. (2018), 233 textual units were identified. A mixed-methods approach was used for analysis, obtaining frequency and order/sequence data (Bakeman, 1978). Sequential order was essential for code matrix construction, aligning with Schegloff's (2007, p. 9) definition of sequence as "a course of action implemented through talk."

The record was materialized through code matrices, where the columns represent the subdimensions of the observation instrument and the rows represent the successive textual units. The cells in a row correspond to the different co-occurrences of that textual unit. The coding was done manually using the Excel program.

2.6 Data quality control

Prior to data analysis, the coded observational data matrices must undergo rigorous quality control. This essential step in observational methodology mitigates potential biases inherent in the coding process, a risk that is heightened when using indirect observation techniques. To ensure reliability, a minimum of three records are required for agreement calculations. The Kappa coefficient, introduced by Cohen (1968), was computed using the free GSEQ software¹ (Bakeman and Quera, 2011).

This study employed an intra-observer agreement analysis at three distinct time points, with a minimum one-week interval between assessments. Using indirect observation, three successive records were performed on 15% (approximately 35 textual units each) of the transcriptions derived from both focus group questions. A minimum one-week separation was maintained between records. Partial kappa coefficients were calculated independently for each question and

subsequently averaged to determine intra-observer agreement. Table 2 presents these results.

Following the completion of data quality control, comprehensive data analysis was undertaken.

2.7 Data analysis

The present study employed a mixed-methods approach integrating qualitative and quantitative elements. Within the QUAL-QUAN-QUAL process's second macro-state, lag sequential analysis was performed first, followed by polar coordinate analysis.

Lag sequential analysis (Bakeman, 1978) constitutes a first stage of the polar coordinate analysis. Its purpose was to identify regularities (behavioral patterns) from categorical data records (qualitative data).

The lag sequential analysis allows for the detection of behavior patterns, following the guidelines of Bakeman (1978), and the results it provides are the adjusted residuals resulting from contrasting unconditional and conditional probabilities based on one or several given behaviors and one or several conditioned behaviors, after applying the correction of Allison and Liker (1982). This analysis can be carried out prospectively (forward, with positive lags) or retrospectively (backward, with negative lags). Results are obtained from adjusted residuals. This technique has broad applicability, including focus groups, in-depth interviews, and other text-based sources.

The adjusted residuals enable the second step of the QUAN stage: polar coordinate analysis (Sackett, 1980). This technique maps interrelationships between codes within an observational record and represents these relationships as vectors. Analysis requires a prior record containing sequential code occurrences/co-occurrences. A focal behavior is selected based on the research objective, with other categories serving as conditioned behaviors. This study employed a modified concept of retrospectivity (Anguera, 1997) for enhanced effectiveness (Gorospe and Anguera, 2000; Hernández-Mendo et al., 2012; Tarragó et al., 2017).

After obtaining adjusted residuals from lag sequential analysis, prospective and retrospective Zsum parameters (Cochran, 1954) are calculated for each conditioned behavior across an equal number of positive and negative lags. This step significantly reduces data complexity (Anguera and Losada, 1999). Vector length and angle are then determined, facilitating graphical representation of the relationship between focal and conditioned behaviors. Vector angle (and thus its quadrant) reveals the nature of this relationship (Figure 1), while length indicates statistical significance.

Polar coordinate analysis is conducted using HOISAN software (Hernández-Mendo et al., 2012). The free program R (Rodríguez-Medina et al., 2022) has been used to optimize vector visualization graphically.

1 <https://www.mangold-international.com/en/products/software/gseq.html>

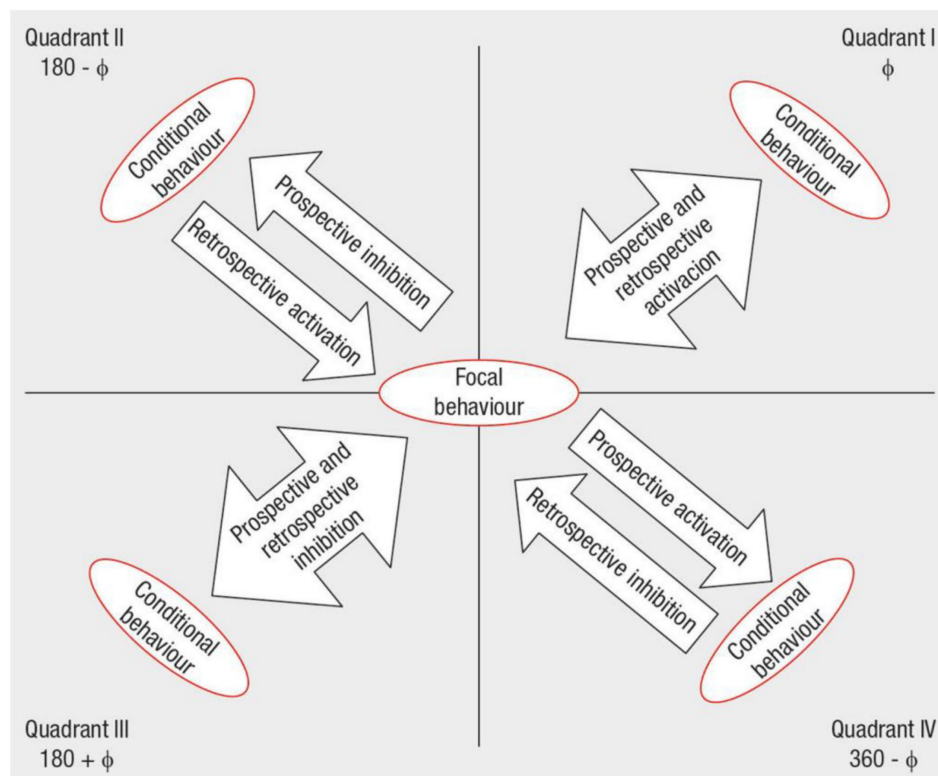


FIGURE 1

Interpretation of the relationships between focal behavior and conditioned behaviors in each. Excerpted from Aragón et al. (2017, p. 30) with permission of the authors.

3 Results

The data analysis aimed to identify behavioral patterns via lag sequential analysis and to map inter-category relationships using polar coordinate analysis.

Due to the extensive results, a detailed commentary focuses on the first category within the first sub-dimension of each of the four dimensions: Dimension 1 (Typology of Conflict), Sub-dimension A (Interpersonal): *Verbal Aggression* (1A1AV). Dimension 2 (Aspects that Affect the Emergence of Conflict), Sub-dimension A (Individuals): *Perception of the Conflictive Event* (2A1PEC). Dimension 3 (Coping Strategies), Sub-dimension A (Integration): *Mutually Friendly Solution* (3A1PSFAPC). Dimension 4 (Teaching Skills to Manage Conflict), Sub-dimension A (Social): *Empathy with the Other Party in Conflict* (4A1EPC).

As outlined in Section 2.7, lag sequential analysis serves to detect behavioral patterns. While primarily instrumental in this study, as the adjusted residuals will form the basis for polar coordinate analysis, it will also provide complementary insights that inform the interpretation of both analyses.

Dimension 1: Focal behavior *Verbal Aggression*

Supplementary Table S1 presents adjusted residuals of the lag sequential analysis (considering 1A1AV as the given behavior and all categories as conditional). Prospective lags (+1 to +5) and retrospective lags (−1 to −5) were assessed.

Supplementary Table S1 emphasizes adjusted residuals exceeding 1.96 (significance level of 0.05), which form the basis for identifying

behavioral patterns. Interpretation follows conventional rules (Anguera et al., 2021), specifically focusing on the second conventional rule: a behavioral pattern ends when two consecutive lags exhibit empty conditional probabilities (i.e., probabilities less than or equal to the unconditioned probability).

The prospective patterns from given behavior 1A1AV are:

1A1AV → 1A1AV →: *Verbal Aggression* then activates another *Verbal Aggression*.

1A1AV → 1A2AF: *Verbal Aggression* activates *Physical Aggression*.

1A1AV → 1A4ICR → 1A4ICR: *Verbal Aggression* activates *Irrational Communication*, which is maintained.

1A1AV → Empty lag → 1C3DPC: *Verbal Aggression*, although not immediately, activates the *Discourse of the parties to a conflict*.

1A1AV → Empty lag → 1E1EITD: *Verbal Aggression*, although not immediately, activates *Poor Information to Make Decisions*.

1A1AV → Empty lag 1E2DII → 1E2DII →: *Verbal Aggression*, though not immediately, activates *Different Interpretation of Information*, which is maintained.

The retrospective patterns before given behavior 1A1AV are:

1A1AV ← 1A1AV: *Verbal Aggression* is usually preceded by *Verbal Aggression*.

1A4ICR ← 1A4ICR ← 1A1AV: *Verbal Aggression* is usually preceded by *Irrational Communication*, which is persistent.

1D2NCOOP ← 1D2NCOOP ← Empty lag → 1A1AV: *Verbal Aggression*, though not immediately, is preceded by a *Disregard for the Other's Opinion*, which is persistent.

1B3RP ← **1A1AV**: *Verbal Aggression* is preceded by *Power Relations*.

2B2FIG ← **1A1AV**: *Verbal aggression* is preceded by *Lack of Identity with the Group*.

1C2NCIOP ← 1C2NCIOP ← Empty lag ← **1A1AV**: *Verbal Aggression*, though not immediately, is preceded by *Disinterest in the other Party in Conflict*, which is persistent.

1E2DII ← Empty lag ← **1A1AV**: *Verbal Aggression*, though not immediately, is preceded by *Different interpretation of Information*.

The parameters of the polar coordinate analysis have been calculated from the adjusted residuals, which are shown in Table 3.

Table 3, in addition to the prospective Zsum and retrospective Zsum values, shows the values corresponding to the length and angle of the vector in all cases where they are significant (length > 1.96, for a significance level of 0.05).

The results indicate the following relationships between focal and conditioned behavior (see Figure 2):

Quadrant I: *Verbal Aggression* is symmetrically activated with *Irrational Communication*, *Discourse of the Parties to a conflict*, *Incompatible Needs*, and *Different interpretation of information*.

Quadrant II: *Verbal Aggression* inhibits *Perception of Effectiveness in Dealing with Conflict* and *Disinterest in the other Party in Conflict*, and these activate *Verbal Aggression*.

Quadrant IV: *Verbal Aggression* activates itself, although it is also inhibited by it at other times.

Dimension 2: Focal behavior *Perception of the Conflictive Event*

Supplementary Table S2 presents the adjusted residuals of the lag sequential analysis, considering 2A1PEC (*Perception of the Conflictive Event*) as given behavior and all categories as conditioned behaviors, and considering prospective lags +1 to +5 and retrospective lags -1 to -5.

Supplementary Table S2 highlights the significantly adjusted residuals (>1.96, for a significance level of 0.05), from which the patterns of behavior are formed, and applies the conventional rules accordingly (Anguera et al., 2021). In all cases, the second rule has been applied.

The prospective patterns from given behavior 2A1PEC are:

2A1PEC → 1B3RP → 1B3RP →: *Perception of the Conflictive Event* activates *Power Relations*, which are maintained.

2A1PEC → Empty lag → 2A1PEC: *Perception of the Conflictive Event*, although not immediately, reinforces the *Perception of the Conflictive Event*.

2A1PEC → Empty lag 2A2CPEN → 2A2CPEN →: *Perception of the Conflictive Event*, although not immediately, activates *Perceptible Behavior in the Natural Environment*.

The retrospective patterns before given behavior 2A1PEC are:

1A5CNR ← 2A1PEC: *Perception of the Conflictive Event* is preceded by *Repetitive Negative Behaviors*.

1D1ICOP ← 1D1ICOP ← 2A1PEC: *Perception of the Conflictive Event* is preceded by *Imposing Beliefs on the Other Person*, which is maintained.

2A1PEC ← Empty lag ← 2A1PEC: *Perception of the Conflictive Event*, although not immediately, is preceded by *Perception of the Conflictive Event*.

2A2CPEN ← 2A1PEC: *Perception of the Conflictive Event* is preceded by *Perceptible Behavior in the Natural Environment*.

3C1UPCO ← 3C1UPCO ← 2A1PEC: *Perception of the Conflictive Event* is preceded by *Assignment of One of the Parties*.

The parameters of the polar coordinate analysis have been calculated from the adjusted residuals, which are shown in Table 4.

Table 4, in addition to the prospective Zsum and retrospective Zsum values, shows the values corresponding to the length and angle of the vector in all cases where they are significant (length > 1.96, for a significance level of 0.05).

The results indicate the following relationships between focal and conditioned behavior (see Figure 3):

Quadrant I: *Perception of the Conflictive Event* is symmetrically activated with *Repetitive Negative Behaviors*, *Power Relations*, *Disinterest in the other Party in the Conflict*, *Imposing Beliefs on the other Person*, *Perception of the Conflictive Event*, and *Perceptible Behavior in the Natural Environment*.

Quadrant II: *Perception of the Conflictive Event* inhibits *Lack of Trust*, and *Lack of Trust* activates it.

Quadrant III: *Perception of the Conflictive Event* is symmetrically inhibited with a *Mutually Friendly Solution*, *Low Intensity to Negotiate*, and *Intermediate Solution to the Conflict*.

Quadrant IV: *Perception of the Conflictive Event* activates *Lack of Identity with the Group*, although it is also inhibited by it at other times.

Dimension 3: Focal behavior *Mutually Friendly Solution*

Supplementary Table S3 presents the adjusted residuals of the lag sequential analysis, considering 3A1PSFAPC (*Mutually Friendly Solutions*) as given behavior and all categories as conditioned

TABLE 3 Values of the parameters corresponding to the analysis of polar coordinate, considering 1A1AV as focal behavior, and all categories as conditioned behaviors.

Category	Quadrant	Prospective Zsum	Retrospective Zsum	Length	Signification	Angle
1A_1A2AF	IV	2.04	-0.75	2.18	*	339.82
1A_1A4ICR	I	2.46	2.46	3.48	**	45
1B_1B1DIRAC	II	-1.94	0.77	2.09	*	158.47
1C_1C3DPC	I	1.22	3.01	3.24	**	67.9
1C_1C4NI	I	3.01	0.45	3.04	**	8.53
1D_1D2NCOOP	II	-0.58	6.59	6.62	**	95.02
1E_1E2DII	I	2.45	0.89	2.61	**	20

Only conditioned behaviors in which significant and very significant values have been obtained are included.

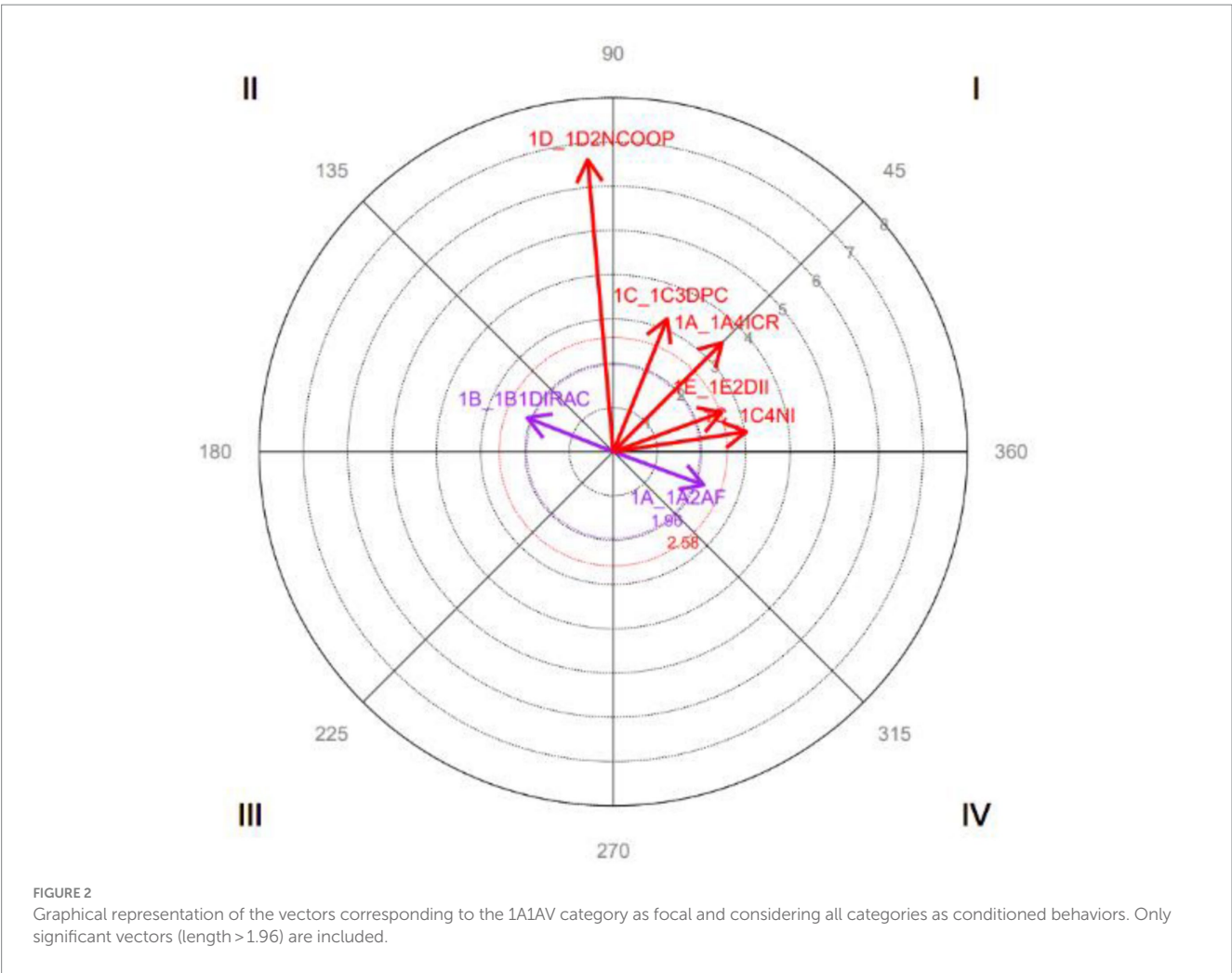


TABLE 4 Values of the parameters corresponding to the analysis of polar coordinate, considering 2A1PEC as focal behavior, and all categories as conditioned behaviors.

Category	Quadrant	Prospective Zsum	Retrospective Zsum	Length	Signification	Angle
1A_1A5CNR	I	1.4	4.17	4.4	**	71.5
1B_1B3RP	I	2.64	2.18	3.42	**	39.57
1C_1C2NCIOP	I	3.66	1.48	3.95	**	22.02
1D_1D1ICOP	I	2.7	4.13	4.93	**	56.85
2A_2A1PEC	I	2.06	2.06	2.92	**	45
2A_2A2CPEN	I	2.98	2.78	4.08	**	43.04
2B_2B1FC	II	−1.84	2.09	2.79	**	131.37
2B_2B2FIG	IV	1.93	−1.51	2.45	*	321.88
3A_3A1PSFAPC	III	−1.13	−2.08	2.37	*	241.44
3D_3D1BIPGN	III	−1.47	−1.72	2.26	*	229.55
3E_3E1APBSI	III	−1.65	−1.53	2.25	*	222.8

Only conditioned behaviors in which significant and very significant values have been obtained are included.

behaviors, and considering prospective lags +1 to +5 and retrospective lags −1 to −5.

Supplementary Table S3 highlights the significantly adjusted residuals (>1.96, for a significance level of 0.05), from which the patterns of behavior are formed, and applying the conventional rules to this effect (Anguera et al., 2021). In all cases, the second has been applied.

The prospective patterns based on given behavior 3A1PSFAPC are:
3A1PSFAPC → 3A1PSFAPC: *Mutually Friendly Solution* activates itself.

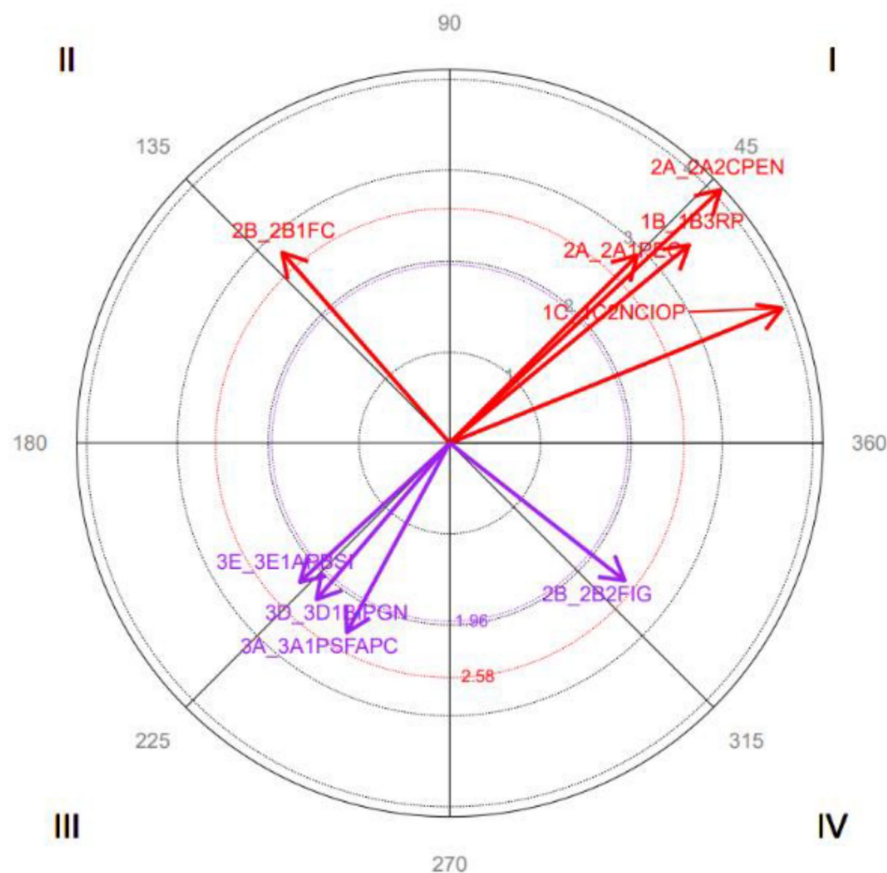


FIGURE 3

Graphical representation of the vectors corresponding to the 2A1PEC category as focal and considering all categories as conditioned behaviors. Only significant vectors (length > 1.96) are included.

3A1PSFAPC → Empty lag → 2C2TCA: *Mutually Friendly Solution*, although not immediately, activates *Associative Behavior Tendency*.

3A1PSFAPC → Empty lag → 3B1SIP → 3B1SIP →: *Mutually Friendly Solution*, but not immediately, activates *Satisfaction of Self-Interest*, which remains.

3A1PSFAPC → 4B3DPEAC: *Mutually Friendly Solution* activates *Perception of effectiveness in dealing with conflict*.

3A1PSFAPC → 4B4FCSC: *Mutually Friendly Solution* activates *Awareness of the Conflict Situation*.

3A1PSFAPC → Empty lag → 4B2TPC → 4B2TPC → 4B2TPC →: *Mutually Friendly Solution*, although not immediately, *Perspective-taking on the Conflict*, which is sustained for a time.

The retrospective patterns before given behavior 3A1PSFAPC are:

3A1PSFAPC ← 3A1PSFAPC: *Mutually Friendly Solution* precedes itself.

3B1SIP ← 3A1PSFAPC: *Mutually Friendly Solution* is preceded by *Satisfaction of Self-Interest*.

4B2TPC ← 3A1PSFAPC: *Mutually Friendly Solution* is preceded by *Perspective-taking on the Conflict*.

1C1CO ← Empty lag ← 3A1PSFAPC: *Mutually Friendly Solution*, although not immediately, is preceded by *Contrasting objectives*.

4A1EPC ← 4A1EPC ← 3A1PSFAPC: *Mutually Friendly Solution* is preceded by *Empathy with the other Party in Conflict*.

4D1EA ← Empty lag ← 3A1PSFAPC: *Mutually Friendly Solution*, although not immediately, is preceded by *Active Listening*.

The parameters of the polar coordinate analysis have been calculated from the adjusted residuals, which are shown in Table 5.

Table 5, in addition to the prospective Zsum and retrospective Zsum values, shows the values corresponding to the length and angle of the vector in all cases where they are significant (length > 1.96, for a significance level of 0.05).

The results indicate the following relationships between focal and conditioned behavior (see Figure 4):

Quadrant I: *Mutually Friendly Solution* is activated symmetrically with *Mutually Friendly Solution*, *Satisfaction of Self-interest*, *Empathy with the other Party in Conflict*, *Prosocial Behavior*, *Perspective-taking on the Conflict*, and *Awareness of the Conflict Situation*.

Quadrant II: *Mutually Friendly Solution* inhibits *Incompatible Needs* and *Proper Tone of Voice*, and these activate it.

Quadrant III: *Mutually Friendly Solution* symmetrically inhibits *Insufficient Coping Resources*, *Inter-Institutional Disarticulation*, *Power Relations*, *Perception of the Conflicting Event*, and *Lack of Identity with the Group*.

Quadrant IV: *Mutually Friendly Solution* activates *Low Intensity to Negotiate* and *Insufficient Coping Resources*, and these inhibit it.

TABLE 5 Values of the parameters corresponding to the polar coordinate analysis, considering 3A1PSFAPC as focal behavior, and all categories as conditioned behaviors.

Category	Quadrant	Prospective Zsum	Retrospective Zsum	Length	Signification	Angle
1B_1B1DIRAC	III	−2.52	−1.92	3.17	**	217.25
1B_1B2FAI	III	−0.31	−1.97	2	*	260.94
1B_1B3RP	III	−1.4	−1.4	1.97	*	225
1C_1C4NI	II	−1.4	1.75	2.24	*	128.58
2A_2A1PEC	III	−2.08	−1.13	2.37	*	208.56
2B_2B2FIG	III	−1.4	−1.4	1.97	*	225
3A_3A1PSFAPC	I	4.56	4.56	6.45	**	45
3B_3B1SIP	I	2.81	1.52	3.19	**	28.43
3D_3D1BIPGN	IV	1.44	−1.46	2.05	*	314.6
3E_3E1APBSI	I	3.38	3.97	5.21	**	49.54
4A_4A1EPC	I	1.74	5.58	5.84	**	72.68
4A_4A2CPS	I	2.81	1.71	3.29	**	31.37
4B_4B2TPC	I	5.14	1.35	5.31	**	14.7
4B_4B3DPEAC	IV	2.33	−0.98	2.53	*	337.25
4B_4B4FCSC	I	4.61	4.61	6.53	**	45
4D_4D2UTVA	II	−0.8	1.89	2.05	*	112.87

Only conditioned behaviors in which significant and very significant values have been obtained are included.

Dimension 4: Focal behavior *Empathy with the Other Party in Conflict*

Supplementary Table S4 presents the adjusted residuals of the sequential analysis of lags, considering 4A1EPC (*Empathy with the Other Party in Conflict*) as given behavior and all categories as conditioned behaviors, and considering prospective lags +1 to +5 and retrospective lags −1 to −5.

Supplementary Table S4 highlights the significantly adjusted residuals (>1.96, for a significance level of 0.05), from which the patterns of behavior are formed, and applies the conventional rules accordingly (Anguera et al., 2021). In all cases, the second rule has been applied.

The prospective patterns based on given 4A1EPC behavior are:

4A1EPC → 1C4NI: *Empathy with the other Party in Conflict* activates *Incompatible Needs*.

4A1EPC → 3A1PSFAPC → 3A1PSFAPC →: *Empathy with the Other Party in the Conflict* activates *Mutually Friendly Solution*, which is maintained.

4A1EPC → Empty lag → 4B1RE: *Empathy with the Other Party in the Conflict*, though not immediately, activates *[Auto] Regulates Emotions*.

4A1EPC → 4B4FCSC → 4B4FCSC →: *Empathy with the other Party in Conflict* activates *Awareness of the conflict situation*, which is maintained.

4A1EPC → 4C1APCC → 4C1APCC →: *Empathy with the other Party in Conflict* activates *Conflict Analysis/Critical Thinking*, which is maintained.

The retrospective patterns before given behavior 4A1EPC are:

1C4NI ← **4A1EPC**: *Empathy with the other Party in Conflict* is preceded by *Incompatible Needs*.

4B2TPC ← Empty lag ← **4A1EPC**: *Empathy with the other Party in the Conflict*, though not immediately, is preceded by *Perspective-taking on the Conflict*.

4B4FCSC ← 4B4FCSC ← **4A1EPC**: *Empathy with the other Party in the Conflict* is preceded by *Awareness of the conflict situation*, which is maintained.

4D1EA ← **4A1EPC**: *Empathy with the other Party in the Conflict* is preceded by *Active Listening*.

4D2UTVA ← **4A1EPC**: *Empathy with the other Party in the Conflict* is preceded by a *Proper Tone of Voice*.

The parameters of the polar coordinate analysis have been calculated from the adjusted residuals, which are shown in Table 6.

Table 6, in addition to the prospective Zsum and retrospective Zsum values, shows the values corresponding to the length and angle of the vector in all cases where they are significant (length > 1.96, for a significance level of 0.05).

The results indicate the following relationships between focal and conditioned behavior (see Figure 5):

Quadrant I: *Empathy with the other Party in the Conflict* is symmetrically activated with *Mutually Friendly Solutions*, *Satisfaction of Self-Interest*, *Prosocial Behavior*, *Perspective-taking on the Conflict*, *Awareness of the Conflict Situation*, and *Conflict Analysis/Critical Thinking*.

Quadrant II: *Empathy with the other Party in Conflict* inhibits *Intermediate Solution to the Conflict*, *Active Listening*, and *Proper Tone of Voice*, and these activate it.

Quadrant III: *Empathy with the other Party in Conflict* reciprocally inhibits *Insufficient Coping Resources*.

Quadrant IV: *Empathy with the other Party in Conflict* activates an *Associative Behavior Tendency*, which in turn inhibits it.

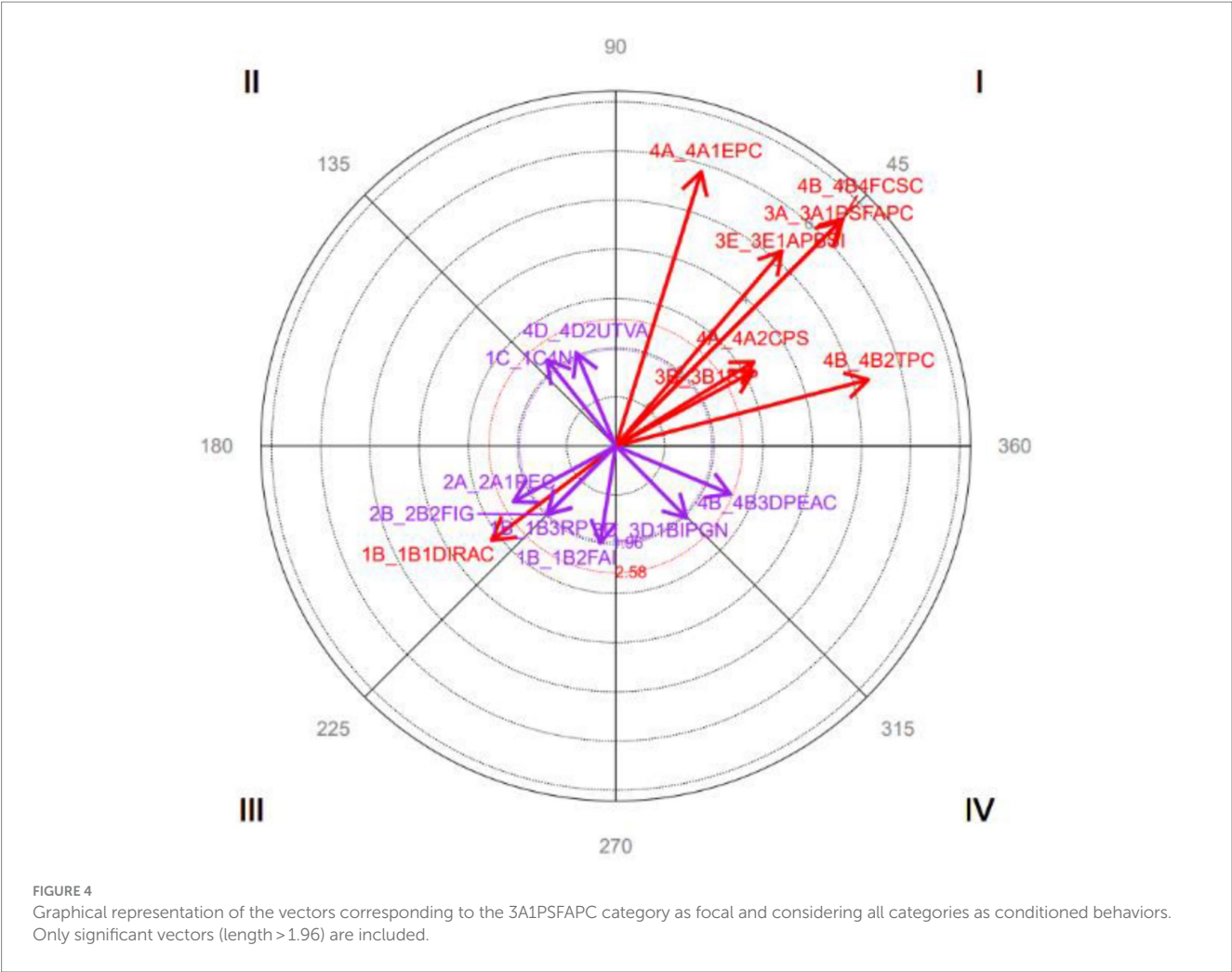


TABLE 6 Parameter values corresponding to polar coordinate analysis, considering 4A1EPC as focal behavior, and all categories as conditioned behaviors.

Category	Quadrant	Prospective Zsum	Retrospective Zsum	Length	Signification	Angle
1B_1B1DIRAC	III	−1.94	−0.54	2.02	*	195.62
2C_2C2TCA	IV	2.76	−0.33	2.78	**	353.13
3A_3A1PSFAPC	I	5.58	1.74	5.84	**	17.32
3B_3B1SIP	I	2.15	0.03	2.15	*	0.76
3E_3E1APBSI	II	−1.13	4.61	4.75	**	103.8
4A_4A2CPS	I	3.19	2.3	3.94	**	35.83
4B_4B2TPC	I	2.75	2.77	3.9	**	45.17
4B_4B4FCSC	I	4.01	4.01	5.67	**	45
4C_4C1APCC	I	1.74	1.73	2.45	*	44.84
4D_4D1EA	II	−0.33	2.77	2.79	**	96.83
4D_4D2UTVA	II	−0.47	3.92	3.95	**	96.86

Only conditioned behaviors in which significant and very significant values have been obtained are included.

4 Discussion

This study investigated behavioral patterns contributing to conflicts within Costa Rican secondary school classrooms and the strategies employed by teachers for conflict management. Two types of

analysis—sequential delay analysis and polar coordinate analysis—were conducted, which helped in identifying 342 relationships between 38 criterion behaviors and their corresponding conditioned behaviors.

(1) The results show how *Verbal Aggression* (1A1AV) activates itself and prospectively generates both *Physical Assault* and *Irrational*

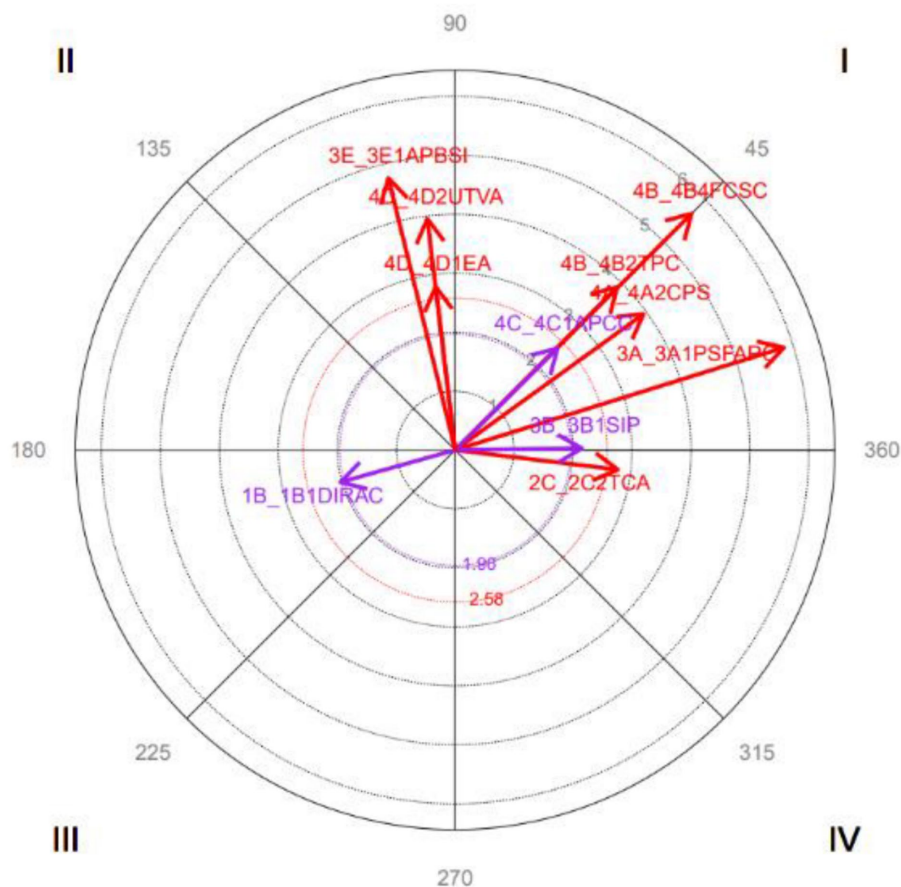


FIGURE 5

Graphical representation of the vectors corresponding to the 4A1EPC category as focal and considering all categories as conditioned behaviors. Only significant vectors (length > 1.96) are included.

Communication, and later triggers the emergence of the *Discourse of the Parties to a Conflict*, based on the *Different Interpretation of Information* they perform. The relationship between *Verbal Aggression* and *Physical Assault* as well as between *Verbal Aggression* and *Irrational Communication* is recurrently clear, both prospectively and retrospectively.

These relational findings contribute to the development of initiatives to strengthen the training processes of teachers in the Costa Rican educational system, as the communication skills they mainly use—according to their own narratives—are not sufficient resources for managing conflicts. Therefore, teachers need to improve both conceptual and practical training in conflict management and develop skills to properly manage the classroom climate, as they lack knowledge about the principles and use of conflict mediation that needs to be addressed (Alves and Pinto da Costa, 2021).

(2) In the results, it is demonstrated how the *Perception of the Conflicting Event* (2A1PEC) activates *Power Relations*, which intensify said *Perception of the Conflicting Event*. In turn, it is preceded by *Repetitive Negative Behaviors* and the *Imposition of Beliefs*, and *Lack of Trust* activates it. The *Perception of the Conflicting Event* activates *Lack of Identity with the Group*, and there is mutual inhibition with the *Mutually Friendly Solution* and *Low Intensity to Negotiate*.

These results, besides showing the negative perception of conflict in the classroom context and the resources teachers must manage them, demonstrate the need for teachers to differentiate the specific

elements—such as perception—that influence the emergence of conflict, to focus the intervention strategy according to the dimension in which it arises.

This is one of the scopes offered by the Integrated Circular Model of Conflict (Bonilla et al., 2020), which enables, through phase analysis and considering teachers' narratives, the recognition and differentiation of individual, group, and social aspects that may be factors influencing the emergence of conflicts in the classroom. In relation to the theoretical framework, the interviews with teachers indicate that, by failing to make such differentiation, it results in a perception of classrooms as environments of complex relationships, which poses new challenges. This supports the role of perceptions in conflict development (Grasa, 1987).

(3) The results indicate that *Mutually Friendly Solutions* (3A1PSFAPC) activate themselves and subsequently generate *Associative Behavior Tendency*, while activating *Satisfaction of Self-Interest*, *Empathy with the Other Party in Conflict*, *Prosocial Behavior*, and *Perspective-Taking on the Conflict*. In turn, they are arrived at after *Perception in Dealing with Conflict*, *Perspective-Taking on the Conflict*, and *Awareness of the Conflict Situation*. Finally, *Mutually Friendly Solutions* inhibit *Insufficient Coping Resources*, *Inter-Institutional Disarticulation*, *Power Relations*, *Perception of the Conflicting Event*, and *Lack of Identity with the Group*, and these factors reciprocally inhibit them.

Another contribution that the research makes to the field of conflict management in Costa Rican education is to show that the

Mutually Friendly Solution behavior represents one of the most effective management strategies according to teachers, confirming that it is within the desirable strategies in mediation processes, according to Montes et al. (2014).

The study's findings regarding criterion behavior activation align with Montes et al. (2014) regarding the commitment strategy, which seeks to reduce perceived differences, maximize gains for all parties, and facilitate swift conflict resolution.

Therefore, training teachers in coping strategies—such as *Mutually Friendly Solution*—also allows for the enhancement of other skills such as associative work, *Awareness of the Conflict Situation*, and perception of one's own resources to manage conflicts, elements that were evidenced as lacking in the previous section.

(4) The results regarding the focal behavior *Empathy with the Other Party in Conflict* (4AIEPC) reveal that it first activates *Incompatible Needs*, *Awareness of the Conflict Situation*, and *Conflict Analysis/Critical Thinking*, which may be followed by *[Auto] Regulates Emotions*. It reciprocally activates with *Mutually Friendly Solution*, *Satisfaction of Self-Interest*, *Prosocial Behavior*, *Perspective-Taking on the Conflict*, *Awareness of the Conflict Solution*, and *Conflict Analysis/Critical Thinking*. Before its occurrence, the categories *Incompatible Needs* and *Active Listening* are detected. Likewise, it reciprocally inhibits with *Insufficient Coping Resources*.

In this regard, although teachers indicated that *Empathy with the Other Party in Conflict* is one of the strategies they use the most, they also pointed out that they do so “intuitively,” without prior knowledge of coping strategies. This confirms the findings of Calderón et al. (2014), regarding teachers' responses to conflict situations that arise in the classroom, which vary according to the specificity of the conflict and the emotional moment but not as a planned or specific strategy.

The results, therefore, can guide actions and policy initiatives for structuring teacher training processes regarding conflict management in the classroom, as they have evidenced both the training gaps and the strategies required to improve teaching-learning dynamics, starting from the pursuit of good coexistence environments.

While this research is methodologically robust, drawing conclusions about how coping strategies, conflict mediation, and emotional regulation influence teachers' perception of conflict requires further investigation. Limitations include the focus group's size, the educational system's historical context, and the Costa Rican Ministry of Public Education's constraints on teacher training participation.

5 Conclusion

This study investigates behavioral relationships influencing the development, emergence, and management of conflicts within the classroom setting. Employing a novel mixed-methods approach for focus group analysis, the research examines both prospective and retrospective behavioral activation relationships. Key findings include:

- (i) *Verbal Aggression* serves as a catalyst for conflict escalation, hindering effective resolution strategies.
- (ii) Individual perception significantly influences conflict emergence and subsequent management by educators. Teachers frequently report a lack of skills and strategies for intervention, leading to behavioral inaction in response to negative student behavior. This inaction risks perpetuating or intensifying conflict dynamics.

(iii) Conversely, the pursuit of solutions benefiting all involved parties positively activates teachers' perceptions of their conflict management efficacy. This leads to heightened *Awareness of the Conflict Situation* and improved perspective-taking.

(iv) Empathy and *Active Listening* exhibit retrospective activation, facilitating critical conflict analysis. Furthermore, these techniques promote emotional regulation through modulated tone of voice, thus enhancing conflict management outcomes.

6 Future lines of research

Future studies could investigate the factors contributing to classroom conflicts, as highlighted in this research. First, additional classroom observations may reveal context-specific behavioral dynamics influencing conflict emergence. Second, research could determine the combined efficacy of coping strategies, conflict mediation, and emotional regulation in enhancing a teacher's conflict resolution abilities. Third, broader teacher participation in studies might illuminate potential deficiencies within current training programs. Informed by these findings, researchers could recommend targeted improvements to teacher development in conflict analysis and management. Finally, expanding the scope of research to encompass individual, group, and social contributors to classroom conflict would facilitate the creation of multi-level conflict management strategies.

Data availability statement

Any anonymized data not published within the article will be shared by request from any qualified investigator.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants.

Author contributions

PR: Writing – original draft, Writing – review & editing, Conceptualization, Investigation. IA: Conceptualization, Supervision, Writing – original draft, Writing – review & editing. MTA: Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1407433/full#supplementary-material>

SUPPLEMENTARY TABLE S1

Adjusted residuals corresponding to the lag sequential analysis considering 1A1AV as given behavior, all categories as conditioned behaviors, prospective lags R + 1 to R + 5, and retrospective lags R-1 to R-5.

SUPPLEMENTARY TABLE S2

Adjusted residuals corresponding to the lag sequential analysis considering 2A1PEC as given behavior, all categories as conditioned behaviors, prospective lags R + 1 to R + 5, and retrospective lags R-1 to R-5.

SUPPLEMENTARY TABLE S3

Adjusted residuals corresponding to the lag sequential analysis considering 3A1PSFAPC as given behavior, all categories as conditioned behaviors, prospective lags R + 1 to R + 5, and retrospective lags R-1 to R-5.

SUPPLEMENTARY TABLE S4

Adjusted residuals corresponding to the lag sequential analysis considering 4A1EPC as given behavior, all categories as conditioned behaviors, prospective lags R + 1 to R + 5, and retrospective lags R-1 to R-5.

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Mixed methods research on reflective writing in teacher education

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In this paper, mixed methods research is presented and discussed in the context of research on reflective writing for the professional development of pre-service teachers. First, we present prominent theoretical frameworks to analyze reflective writings. Second, we review relevant methodological approaches of research on reflective writings in teacher education, such as qualitative, quantitative and mixed methods. Third, we present a study from our research lab combining qualitative content analysis and linguistic analyses as an example for a concurrent mixed method approach. The results of the qualitative content analysis indicated that 198 reflective writings of pre-service teachers were primarily descriptive and on a low level. Computational linguistic analyses revealed that affective and cognitive terminology utilization in reflective writing differed significantly across the different levels of reflection, with a higher frequency of such terms correlating with deeper levels of reflection. Thus, essential challenges and opportunities of implementing such a mixed method study to analyze reflective writings are illustrated and discussed. Finally, we conclude the paper by discussing on how mixed methods approaches might be further advanced in the field of reflective writing research in teacher education.

KEYWORDS

mixed methods, qualitative content analysis, computational linguistics, reflective writing, teacher education

1 Introduction

Reflective practice is widely recognized as a pivotal educational strategy for professional development, especially within higher education (Chan and Lee, 2021; Ryan, 2013). It plays a crucial role in several aspects, such as enhancing the understanding of professional knowledge (Korthagen, 2001), developing metacognitive skills (Desautel, 2009), and increasing self-awareness (Van Beveren et al., 2018). Specifically, within the domain of teacher education, reflection acts as a vital bridge between theoretical knowledge and practical application (Korthagen, 2018).

In research on reflective writing in teacher education, predominantly both quantitative and qualitative approaches are applied (Alsina et al., 2019; Cengiz et al., 2014; Houston, 2016; Lee and Abdul Rabu, 2022; Mena-Marcos et al., 2013). Quantitative methodologies are remarkably esteemed for their replicability, as they implement standardized measurements, enabling the consistent validation of research findings across diverse contexts, thereby

bolstering the reliability of these outcomes. However, the inherent data simplification within quantitative methods might lead to omitting crucial nuances and in-depth information. Qualitative content analysis complements the limitations of quantitative methods. Unlike quantitative approaches that simplify data through numerical conversion, qualitative content analysis leverages detailed narratives to construct a nuanced understanding of educational phenomena. Consequently, the depth of insight qualitative research provides into educational practices and the comprehension of complex pedagogical phenomena offers invaluable perspectives for enhancing teacher education and the learning process. Furthermore, technological advancements offer possibilities for an automated analysis of reflective writing (Chong et al., 2020; Gibson et al., 2016). Automated analytics, encompassing Natural Language Processing (NLP) (Cui et al., 2019; Liu et al., 2020) and Machine Learning (ML) (Fan et al., 2017; Kovanović et al., 2018; Ullmann, 2019), provide a proficient and efficacious means to process and analyze large volumes of textual data. These technologies facilitate the identification of patterns, affective tendencies, conceptual relationships, and the depth and breadth of reflection within texts, thus significantly empowering educational researchers with unprecedented analytical capabilities. Consequently, combining automated analytic techniques with traditional quantitative and qualitative research methodologies represents a mixed methods approach.

This paper presents a mixed-method study from our research lab to bridge the gap in current methodologies for analyzing reflective writings in teacher education. The primary objective of this research was to enhance the depth and breadth of understanding of pre-service teachers' reflective writing by employing qualitative content analysis and computational linguistics techniques. Specifically, we addressed the following research questions:

RQ1: How do qualitative content analysis and computational linguistics methods contribute to understanding reflective writings?

RQ2: In what ways can the integration of findings from these two approaches provide a more comprehensive insight into the quality of reflective writing?

We collected pre-service teachers' reflective writings and applied qualitative content analysis to identify reflection levels. Subsequently, computational linguistics techniques were utilized to assess the complexity and structure of the texts quantitatively. By integrating the insights gained from both methods, our study offers a novel perspective that overcomes the limitations of using a single methodological approach. This dual-analysis framework provides a deeper understanding of the reflective writings.

2 Literature review

2.1 Definition of reflection and theoretical framework

When implementing an innovative and effective professionalization process for teachers, the reflective practitioner is increasingly cited as the target dimension (Argyris and Schön, 2008;

Schön, 1983). Larrivee argues similarly, characterizing teachers as "social mediators, learning facilitators" and, above all, "reflective practitioners" (Larrivee, 2000, p. 293). In this light, reflective thinking is viewed as a relevant part of professional development, lifelong learning, and improving professional learning of (pre-service) teachers (Schön, 1983). However, decades after John Dewey's (1933) important publication „*How We Think*“ reflective thinking has become an umbrella term that encompasses a wide range of approaches and aims but lacking a clear definition, rationale, process, and outcome for pre-service teachers. According to Schön (1983), reflective thinking is the process of actively and critically thinking about one's learning and experiences to understand and learn from them. It involves considering one's thoughts and actions, and the context in which they took place to gain insights and make improvements. In addition to this, Boud et al. (1985, p. 19), Cleary et al. (2013, p. 69), and Gentile (2012, p. 102) have argued that reflection also has an affective component. The concept of reflection (concerning teacher's professional development) has many different meanings and different approaches and directions in terms of its impact and benefits. Schön (1983) claims that education and reflective thinking practices are inseparable, and he introduces the notion of reflection-on-action (a social act) and reflection-in-action (a solitary act). Dewey (1933) and Schön (1983, 1987) argue that (pre-service) teachers learn more deeply when they reflect on experience with practice, and that transformational learning does not necessarily happen without reflective thinking processes. Cochran-Smith and Lytle (2009) focus from a practical perspective on the teacher's professional development role, arguing that teachers must engage in ongoing reflective practice to improve their teaching skills. This approach advocates for teachers to develop as professionals to improve their effectiveness as teachers constantly.

In teacher education programs, numerous attempts were made to encourage pre-service teachers to engage in reflective practice (Borko et al., 1997). In orientation to the frameworks mentioned above, various models of reflection in professional education were developed (Bengtsson, 1995; Calderhead, 1992; Hatton and Smith, 1995). These models aim to reduce the complexity of reflection by representing it, for example through rubrics (Miller-Kuhlmann et al., 2016) or coding systems (Poldner et al., 2014), and to assess reflection levels (Larrivee, 2008). The analytical models commonly used in assessing reflective writings emphasize the depth or breadth of reflection (Ullmann, 2019). For example, the model developed by Hatton and Smith (1995) targeted assessment of depth of reflection, notably in teacher education. The model categorizes reflection into four progressive stages, from basic descriptive writing to descriptive reflection with justifications, dialogic reflection exploring internal dialogs, and culminating in critical reflection that considers broader historical, societal, and political contexts. In addition, the concept of reflection has also been framed as a hierarchical model (e.g., Ip et al., 2012; Kember, 1999; Mezirow, 1991). These models extended from levels of non-reflection to stages characterized by profound and high reflection. Conversely, a more multifaceted and dynamic model of reflection is evident in breadth models (e.g., Jung and Wise, 2020). An example is Gibbs's (1988) Reflective Cycle, which outlines a six-stage framework for examining reflective texts. This cycle begins with a "description" stage, briefly summarizing the event, followed by "feelings," where emotional reactions are articulated. The "evaluation" stage involves assessing the positives and negatives of the response.

This leads to “analysis,” where understanding and interpretation of the event occur. The cycle then moves to “conclusions,” drawing general or specific lessons, and concludes with an “action plan,” outlining future responses in similar situations. Additionally, the breadth model has been utilized in research by various scholars, including, for example, Kolb (1984), Mansvelder-Longayroux et al. (2007), and Poldner et al. (2014).

2.2 Benefits and challenges of reflection in teacher education

The systematic review study by Van Beveren et al. (2018) demonstrates the significant role of reflection in contributing to learners’ professional development. As Korthagen (2001) highlighted, reflection enables (pre-service) teachers to connect their practical experiences with theoretical teaching knowledge. To support professional development, various strategies, such as reflective writing have been used in teacher education to facilitate pre-service teachers’ reflection during their professionalization. Reflective writing in teacher education typically focuses on the one hand on professional knowledge, linking learned theory to practice, and on the other hand on personal development, reflecting on learning achievements and planning for future actions. However, engaging in reflection about one’s learning and the teaching profession can be particularly challenging for pre-service teachers, and studies illustrate that the level of reflection among pre-service teachers is relatively low (Fütterer et al., 2024; Zhang et al., 2023). For example, reflections from less experienced teachers tend to be superficial and predominantly descriptive (Nguyen et al., 2014). Körkkö et al. (2016) noted that student reflections were more detailed after related practice but often lacked critical reflective thinking. Therefore, fostering reflection, especially in pre-service teachers, presents a challenge (Saric and Steh, 2017).

Furthermore, evaluation and research methods for reflective writing are problematic in various ways (Boud, 2010; Sumsion and Fleet, 1996). Assignments to levels of reflection or dimensions of reflection depend, among other aspects, on the research question, the sample or the existing data material, and the research methods applied. Consequently, evaluating reflections is not an absolute statement, mainly if only a specific research method is used (Kember et al., 2008). In order to analyze reflections from different perspectives and in both their depth and width and as accurately as possible, a combination of different methods is required (Whyss, 2013). Finally, when assessing the reflective skills of (pre-service) teachers, the research trend is clearly toward mixed methods approaches (Waag, 2017).

2.3 Methodological approaches of research on reflective writings

As described, the analysis of reflective writings is a highly challenging task. Qualitative and quantitative methods are applied in research in higher education and teacher education. In terms of qualitative methods, case studies are a strategy of inquiry in which the researcher explores in depth an event, activity, or process of one or more individuals. Well-known analysis methods in qualitative

research are the documentary method (Bohnsack, 2013; Payne and Payne, 2004) and grounded theory (Glaser and Strauss, 1999). For example, based on a grounded theory coding system, Jumpakate et al. (2021) developed a typology of reflective writings to investigate novice teachers’ reflective acts to support their professional development. But to analyze reflective writings, predominantly qualitative content analysis is used (Krippendorff, 2004; Mayring, 2022; Mayring, 2000; cf. Gläser-Zikuda et al., 2020). Qualitative content analysis offers several coding strategies that are more or less theory-guided for a deductive or inductive coding process (Mayring, 2022). The object of qualitative content analysis can be any recorded or written communication, i.e., transcripts of interviews, protocols of observation, and written documents, in general. Not only the manifest content of the material is analyzed, but also the so-called latent content by an interpretative procedure, as well as formal aspects of the material, such as length, structure, etc. (Mayring, 2000). Three distinct analytical strategies (summary, structuring, and explication) may be carried out independently or in combination, depending on the research question (Mayring, 2000).

For the analysis of reflective writings, numerous studies applied qualitative content analysis. For instance, Dunne (2019) used qualitative content analysis and focused on analyzing the depth of reflection in their studies on reflective writings, providing valuable insights into the complexity of reflective thinking. Alt et al. (2022) and Bowman (2021) made substantial contributions by exploring the elements that make up reflective writing, shedding light on its constituent parts. Moreover, Prymachuk et al. (2019) identified emergent topics within reflective writings by using a qualitative content analysis. For example, Van Leeuwen et al. (2009) studied students’ personal experiences, emotions, and cognitive transformations by qualitatively examining their reflective writings. This method focuses intently on the nuanced interpretation of textual data, uncovering internal motivations, emotional variances, and cognitive transitions within the students’ reflective journeys. The potential of qualitative content analysis in research on reflective writings is related to identifying topics of reflection, the description of situations and experiences, individuals’ thoughts and feelings related to reflection, and the description and interpretation of the broadness and depth of reflection.

Not only qualitative methods but also quantitative methods are used in research on reflective thinking and practice. For instance, Poldner et al. (2014) devised a quantitative analysis framework based on existing literature and applied this framework to conduct quantitative content analysis. Additionally, they utilized statistical techniques to investigate various characteristics and patterns within reflective writing. This approach did not merely facilitate the comparison of reflection levels among individuals or groups but also delved into potential correlations between the depth of reflection and other pedagogical variables, such as teaching effectiveness (Azimi et al., 2019). Quantitative methods are generally applied for testing objective theories by examining the relationship among variables using statistical procedures, for example, based on questionnaires, e.g., Reflective Practice Questionnaire (RPQ) (Priddis and Rogers, 2018), Reflective Teaching Inventory (RTI) (Akbari et al., 2010) or Teacher’s Reflective Thinking Questionnaire (RTTO) (Choy and San Oo, 2012). The RPQ, represents an instrument promoting reflection processes, provides the results of a reflection, and, through the

processing and the results, stimulates further and deeper reflections (Priddis and Rogers, 2018). In sum, an instrument was designed that can be applied for promoting reflection processes in different subjects and domains without an adaptation. Results from previous studies have shown that the implementation of the RPQ supports reflective practice and fosters confidence and further a desire for self-improvement (Priddis and Rogers, 2018). The Reflective Teaching Inventory (Akbari et al., 2010) and the Teacher's Reflective Thinking Questionnaire (Choy and San Oo, 2012) were designed differently: Both questionnaires were specifically developed as a teacher reflection instrument and, in addition to cognitive, also for metacognitive, affective, critical and moral dimensions of reflection. In the RTI, several items are specifically aiming at didactic topics, as the instrument primarily focuses on teaching English. In contrast, the RTTQ may be used for different subjects and grades, as well as at different types of schools. The RTTQ has been proven to be a reliable and valid instrument for the assessment of reflective thoughts and it can contribute to improve students' reflections (Choy and San Oo, 2012).

Quantitative methods, such as the mentioned questionnaires, are basically related to statistical analyses with many variables, including complex analyses that allow causal interpretation of data. This type of research provides a quantitative description of opinions or actions related to reflection and reflective writings of a sample with the intent of generalizing from a sample to a population (Creswell, 2015). But there is a lack of research on reflective writing in teacher education utilizing mixed methods research, as mentioned for example by Hayden and Chiu (2015). Therefore, in order to take the potential of both qualitative and quantitative methods for the analysis of reflective writings into account, we argue to combine qualitative content analysis with quantitative methods, which offer possibilities to investigate especially linguistic features playing an essential role in the analysis of reflective writings (Ullmann, 2019). Natural Language Processing and Machine Learning allow the analysis of a large amount of linguistic data and, beyond, a rapid analysis. For NLP, the Linguistic Inquiry and Word Count (LIWC) tool is a popular choice for methodology in research on reflective writing, as shown in studies by Cui et al. (2019), Savicki and Price (2015, 2021), and Springer and Yinger (2019). LIWC's ability to analyze various linguistic attributes has made it valuable in these investigations.

A meanwhile well-known approach that systematically combines qualitative and quantitative methods is mixed methods research (Creswell, 2015; Tashakkori and Teddlie, 2010). Mixed methods research aims to leverage the strengths of both quantitative and qualitative methods to offer a more comprehensive understanding of complex phenomena, such as reflective writings in teacher education. In the last years, mixed methods research has been conducted in numerous studies in research in education and instruction, as well as teacher education (for an overview, e.g., Gläser-Zikuda et al., 2012; Hagenauer and Gläser-Zikuda, 2019; Mejeu et al., 2023).

2.4 Potential strengths of mixed methods research

Mixed methods research is more than simply collecting and analyzing both kinds of data; it also involves using both approaches together so that the overall strength of a study is more significant than

just qualitative or quantitative research (Creswell and Plano-Clark, 2007). Different procedures for mixed methods inquiry strategies have been developed (Creswell and Plano-Clark, 2007). The following three main strategies are often applied. First, the sequential exploratory strategy involves a first phase of qualitative data collection and analysis, followed by a second phase of quantitative data collection and analysis that builds on the results of the first qualitative phase. The first qualitative phase is an exploratory step in a new research field to gain relevant aspects for a theoretical perspective to be developed. The purpose of this strategy is to use quantitative data and results to quantify the qualitative results and to support the interpretation of qualitative findings together with the quantitative results. Another example of this strategy is using qualitative findings to develop quantitative research instruments, such as questionnaires (Creswell and Plano-Clark, 2007).

Second, the sequential explanatory strategy goes in the opposite direction. It is a strategy for mixed methods design often applied by researchers with a strong quantitative focus. It is characterized by the collection and analysis of quantitative data in the first phase of research, followed by the collection and analysis of qualitative data in the second phase. This second phase aims to get deeper insight or interpret the, e.g., not expected quantitative results in more detail. Thus, the two data types are separate but connected concerning the research conclusions. This strategy often has a theoretical perspective, and in the first phase, quantitative methods are applied to test hypotheses.

The third strategy is the concurrent mixed methods approach; the researcher collects both quantitative and qualitative data concurrently, and then the two databases are compared to determine if there is convergence, differences, or at least some combination for interpretation of the data. This comparison may be seen as confirmation, disconfirmation, cross-validation, or corroboration (Greene et al., 1989). In this model, quantitative and qualitative methods are used to address the weaknesses inherent within one method with the strengths of the other. In this model, the quantitative and qualitative data collection are concurrent, meaning they are done in the same research study phase. The qualitative and quantitative parts and steps are equal. The mixing in this model is usually applied in the interpretation and discussion section in merging the data or integrating or comparing the results of two databases side by side in a discussion, for example, with quantitative statistical results and qualitative case studies that support or disconfirm the quantitative results (Creswell and Plano-Clark, 2007).

In this study, we employed mixed methods research to analyze the reflective writing of pre-service teachers. Our choice was primarily based on three factors: the complexity of reflective writing, the complementarity of qualitative and quantitative methods, and the state of the art in the research field. Firstly, reflective writing is a complex and multi-layered process involving pre-service teachers' self-examination and critical thinking about their learning and teaching practices (e.g., Körkkö et al., 2016). This type of writing goes beyond merely narrating learning and teaching experiences; it delves deeply into reflections on beliefs about learning and teaching, instructional methods, and outcomes. Secondly, using mixed methods gave us a more comprehensive understanding and explanation of the research phenomenon in this situation. In this study, through qualitative content analysis, we detailed and categorized the reflective writings of pre-service teachers. This analysis helped us to construct a

preliminary framework of reflective writing, which served as a foundation for subsequent quantitative analysis. We then used the LIWC2015 software to analyze these writings focusing on linguistic characteristics quantitatively. This step enabled us to statistically analyze a large volume of text data, revealing patterns in reflective writing. Finally, existing research indicates that mixed methods research are widely applied in education research. However, there is a lack of research on reflective writing in teacher education utilizing mixed methods research.

3 Method and results

3.1 Participants and data corpus

To analyze pre-service teachers' reflective writing, we applied the concurrent mixed methods approach. In our study, we examined reflective writings of pre-service teachers in different teacher education programs (primary school, lower and higher secondary school) at one German university (Zhang et al., 2023). The reflective writings focused on core teacher education topics, namely pedagogical diagnostics (one week) and classroom management (three weeks). In total, 100 pre-service teachers participated in the study. Regarding the demographic composition of the sample, a significant majority, 71.90%, were female students, and 87.83% of the participants were in their first to third semesters ($M=1.71$; $SD=1.68$) of their respective teacher education programs. The students received a task with a case study for each topic and were asked to reflect upon these and to write one text for each topic.

Figure 1 shows the mini-portfolio applications.

For reflective writing assignments, students were required to reflect first on the professional content they had learned and second on their individual learning process. To guide and support students' reflection process, structured prompts were designed. The prompts provided students with timely and focused information. The design of the prompts was based on Narciss' (2006) framework, starting from the lowest level, KTC (knowledge of task constraints), to KH (knowledge of how to proceed). The prompts were primarily cognitive, and they were also very concrete because prompts with too abstract representations are difficult to achieve any effect (Berthold et al., 2009; Table 1).

A random sample of 200 reflective writings of 100 pre-service teachers (each student had to write a reflective text for two topics) was initially selected for analysis. However, after excluding an outlier (One students did not write reflective writing.), the final dataset comprised 198 reflective texts. Our analysis revealed that the average word count of these 198 texts was 230 words ($M=229.85$; $SD=148.99$). The number of words differed because there were no specifications regarding the length: The most extended reflection consisted of 806, the shortest of just 30 words.

3.2 Reflective level classification using qualitative content analysis

In a first step, reflective writings were analyzed using qualitative content analysis (Gläser-Zikuda et al., 2020). More specifically, we carried out a structured content analysis. The theoretical framework established by Hatton and Smith (1995) and adapted by Fütterer (2019) served as the theoretical background. Hatton and Smith's framework for levels of reflection provides a systematic approach to categorizing and assessing the various levels of teacher reflection. This framework allows to accurately identifying and describing the specific characteristics and levels within (pre-service) teachers' reflective writing. Many studies have used this model to evaluate reflective practices in (pre-service) teachers' professional development, confirming its effectiveness and applicability. The coding system, and the deductive analysis procedure including coding rules and anchor examples are described in more detail by Zhang et al. (2023).

Each text was coded focusing on sentences and sections presenting relevant information about reflection based on the coding system presented. Depending on the overall coding result (in terms of representation of reflection level based on most of the codings in the different parts of the text), we rated each text at the end one of the four levels of reflection. Coders were members of the project team and were trained prior to formal coding. The intercoder reliability was checked by two coders who analyzed 198 reflective writings independently. The summative agreement between the coders was measured using Cohen's Kappa, and the results indicate a very high level of agreement, with a Cohen's Kappa score of 0.97 for pedagogical diagnostics and 0.96 for classroom management. Agreement was

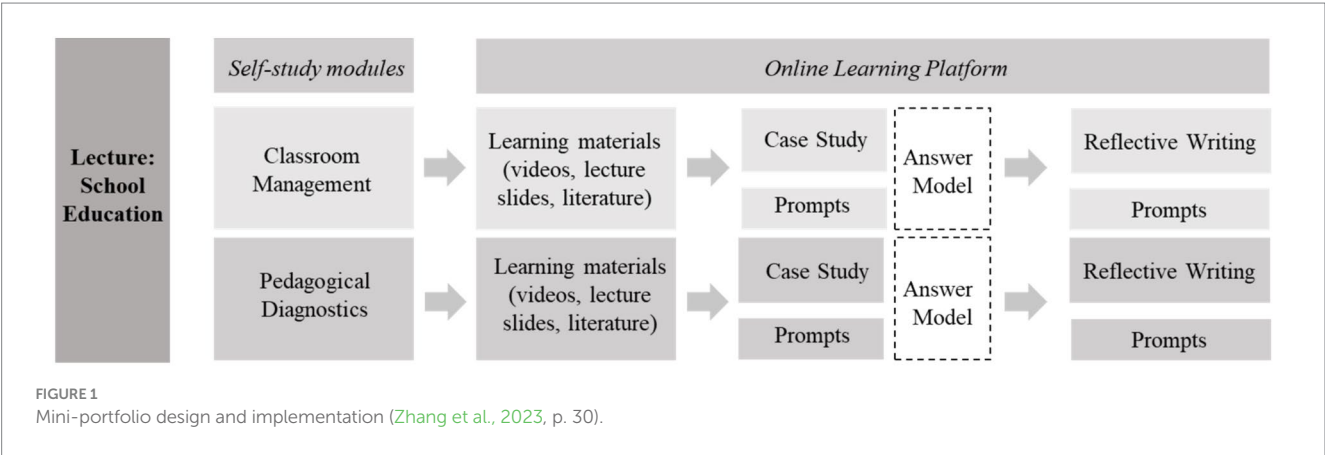


TABLE 1 Illustrates examples of the prompts (for the topic classroom management) designed for this study.

Prompt 1 KTC – Knowledge on task constraints Notes on subtasks and task requirements	“I need a little food for thought...” The topic of classroom management and dealing with disruptions can be divided into two large sub-areas: After clarifying what constitutes a teaching disruption (definition), it can be structured as to what happens before (preventive measures) and what happens after (intervention measures) of a possible disruption. The first part of the question (How do you analyze the following situation?) refers to prevention measures and situation analysis, the second part of the question (How do you react?) to intervention measures.
Prompt 2 KC – Knowledge about concepts Notes on technical terms and context of terms, explanations of terms	“I need a little tip regarding content...” For example, relevant definitions and classifications for the terms “teaching disorders” and “conflicts” come from Becker (2006) . To prevent conflicts, different actions can be taken; according to Osher et al. (2010) can be differentiated into three different categories. A well-known preventive approach comes from Kounin (1970) , for example. On the intervention side, Becker’s (2006) action matrix is often used for conflict analysis and resolution.
Prompt 3 KH – Knowledge on how to proceed Task-specific solution tips	“I need more concrete advice...” On the StudOn learning platform • The folder for topic area 4 “Class management and dealing with disruptions” is located next to the slides for the lecture. • A video recording of the lecture on the topic can also be viewed under the “Useful information and materials” tab (path: “Lecture recordings” ♦ “Videos on topic area 4: Class management and dealing with disruptions”). • Further information can be found in the “Literature” folder. The following book excerpts are particularly recommended: • Becker (2006): Action matrix for conflict analysis and teachers solve conflicts. • Lohmann (2011): Getting along with students. • Ophardt and Thiel (2013): Classroom management.

They were offered to the students via the learning platform of the university.

achieved when both researchers rated the whole the text on the same level of reflection. Disagreement occurred only in a few cases due to ratings on different levels of reflection. The codings of sentences and sections itself were not part of the intercoder reliability check. For further details of coding agreement and disagreement respectively, we described an example shown in the attachment. The theoretically derived category system used in our study is shown in [Table 2](#). See [Table A1](#) in the [Appendix](#).

The main results of the qualitative content analysis of pre-service teachers’ reflective writings show that most of the reflective writings were on the descriptive level. Specifically, 37 reflective writings were categorized at the descriptive level, while a more significant number of 129 reflective writings were found to be at the descriptive reflection level, as detailed in [Table 3](#). Among the 198 analyzed reflective writings of pre-service teachers, only 31 reflective writings were identified as engaging in dialogic reflection, indicating a more interactive and in-depth level of reflection. Notably, just one reflective writing text was coded at the highest level of reflection (critical reflection), which involves deep analytical and critical thinking.

3.3 Psycholinguistic features in reflective writings

To extract psycholinguistic features in the reflective writings, we employed the LIWC2015 method, a dictionary-based approach outlined by [Pennebaker et al. \(2015\)](#) in the German adaptation, DE-LIWC 2015, developed by [Meier et al. \(2018\)](#). This adaptation includes over 80 dictionary categories and encompasses a comprehensive list of 18,711 words, word stems, and various linguistic features tailored to the German language context.

We tested the differences in psycholinguistic features across the levels of reflection coded with qualitative content analysis in the reflective writings, as described in chapter 3.2. Affective processes,

negative emotions, and the use of the term “feel” were more prevalent in writings with higher reflective performance (see [Table 4](#)). These attributes under affective attributes and perception categories showed a slight but significant impact. The results were $F_{\text{affective processes}}(1, 91) = 4.43, p = 0.038$, $F_{\text{negative emotion}}(1, 91) = 4.28, p = 0.029$, and $F_{\text{feel}}(1, 91) = 4.91, p = 0.016$, respectively. Lastly, we differentiated between the levels of reflection by examining the linguistic features associated with cognitive attributes. Specifically, indicators of cognitive processing, including terms related to discrepancy, certainty, differentiation, negations, and comparisons, were found to be vital in distinguishing between different levels of reflection. The presence and relevance of these cognitive process words were positively correlated with the level of reflection in the writings.

4 Discussion

This paper addressed the potential of mixed methods in research on reflective writings in teacher education. This has been explored in three steps: firstly, with a theoretical and empirical overview of research on reflective writing in teacher education; secondly, the description and explanation of qualitative and quantitative research methods (and mixed methods) on reflective writings in teacher education with a specific focus on qualitative content analysis and computer-linguistic methods, and thirdly, the presentation and discussion of the potential of a concurrent mixed method study on reflective writings of pre-service teachers from our lab.

Research on reflective writings represents a theoretically and methodologically multifaceted and interdisciplinary research field. Therefore, the concurrent mixed method approach in our study helped provide a comprehensive analysis of reflective writings. The qualitative content analysis and the computational linguistics methods contributed to analyze reflective writings. Different forms of data were collected simultaneously and then integrated into interpreting the

TABLE 2 Coding system of levels of reflection based on a structured content analysis (translated from the original German coding system applied in the study).

Category	Theoretical description	Anchor examples (from reflective writings)
Level 0: Descriptive writing	A situation (action, behavior...) is described. No efforts to classify or explain exist. Because reflective processes were defined as metacognitive, a mere description does not represent a reflective process.	"I have addressed the attributes of educational diagnostics and ways of classifying diagnostic instruments, but not the aspects of 'types of performance assessment,' 'evaluation research,' and the different forms of performance measurement." (Topic: Pedagogical diagnostics)
Level 1: Descriptive reflection	Situations are either justified (personal judgment, perspective), or feelings, optional perspectives, or influential variables are reported, but without connecting them or considering their contextual embedding. Personal assumptions are presented.	"I found some diagnostic approaches, but should have created a better future perspective for the students and the teacher. For this purpose, specific examples, such as an observation matrix or a reference to the learning development diagnostic tools would have been good." (Topic: Pedagogical diagnostics)
Level 2: Dialogic reflection	Different perspectives, influencing factors, and justifications for situations are identified. Perspectives are weighed in an interpersonal dialog. For this to happen, subjective theories and beliefs must become conscious. Competing perspectives are weighed up, leading to judgment.	"The scheme represents a well-structured approach to dealing with conflicts in everyday school life, but it seems to be designed mainly for conflicts among students. A model specifically for class – teacher conflicts might be more suitable for the task." (Topics: Classroom management)
Level 3: Critical reflection	It is recognized that both situations and the identified perspectives, influential factors, and rationales are embedded in and influenced by a broader context (including historical, social, and political). Values and norms of the profession's goals are also challenged, and institutional expectations are included.	"In addition, mathematics is a particular case here; the diagnostics must be different than in my subjects of study English, Geography, and Social Studies." (Topics: Classroom management)

TABLE 3 Distribution of pre-service teachers' reflective writings to the reflection levels by learning topics.

	Description	Descriptive reflection	Dialogic reflection	Critical reflection
Pedagogical diagnostics	20	61	18	1
Classroom management	17	68	13	0
Total	37	129	31	1

overall results regarding levels of reflection and linguistic features to describe these levels. Furthermore, in this study, we used and analyzed with qualitative content analysis a smaller amount of data (reflective writings of 198 pre-service students) and a more extensive data collection (different linguistic features in those reflective writings) in order to address the different types of research questions. The qualitative content analysis addresses the three levels of reflection while the quantitative analyses are used to test for statistical differences of linguistic features between these three levels of reflection. The integration of findings from the two methods applied provided a more comprehensive insight into the quality of reflective writing. By integrating the methods it was possible to analyze not only the level of reflection in pre-service students' reflective writings but also how saturated they are and to what extent the level of reflection are related to the linguistic means used in the quantitative analyses. Given these results, suggestions can be derived on which linguistic means increase the likelihood of writing a successful reflection. Based on the linguistic means also assessment of reflective writings may be provided more systematically and economically. Finally, the qualitative and

quantitative data may be used for validating purposes. The paper contributes to the broader literature on mixed methods research by offering an illustrative example of how such a combination and integration can occur at the paradigmatic, theoretical, analytical, and interpretative levels. Therefore, as explained in this article and illustrated in our research example, mixed-methods designs have a particular potential for researching the complex field of reflective writing in teacher education. Mixed methods approaches are increasingly used in educational research to obtain the most comprehensive and valid picture of the research subject by combining qualitative and quantitative methods in the sense of complementarity (Hagenauer et al., 2023; Mejeh et al., 2023).

The combination of qualitative and quantitative methods is often justified by the aim to achieve generalization with the quantitative part of the study, while the qualitative part is used to have a deeper insight into single cases or the context of the research subject for a better understanding (Creswell, 2015; Hagenauer et al., 2023). The study presented in this paper illustrates these principles. Specifically, we showed that reflective writing is a complex phenomenon that can

TABLE 4 ANOVA comparing the psycholinguistic attributes of reflective writing at different reflection levels.

Linguistic category	Description	Descriptive reflection	Dialogical reflection	F
	M/SD	M/SD	M/SD	
Affective attributes				
Affective processes	5.04/2.32	5.79/2.47	6.21/1.74	4.43*
Negative emotion	1.06/0.77	1.30/1.06	1.63/1.17	4.91*
Perception				
Feel	0.23/0.41	0.51/0.72	0.62/0.69	6.08*
Cognitive attributes				
Cognitive processes	21.05/3.97	23.12/4.21	25.65/3.44	21.92***
Discrepancy	1.88/1.18	2.51/1.40	3.38/1.47	19.25***
Certainty	3.09/2.27	2.95/1.46	4.16/1.88	4.89*
Differentiation	3.69/1.99	4.19/1.72	5.83/2.19	17.93***
Negations	0.72/0.92	0.86/0.80	1.61/1.06	13.70***
Comparisons	2.08/1.22	2.67/1.03	2.97/1.10	9.71**

Statistical significance was reported after subsampling for class imbalance; each group was 31 samples (*** $p < 0.001$, ** $0.001 < p < 0.01$, * $0.01 < p < 0.05$).

only be depicted using several partially intertwined theoretical models (Bengtsson, 1995; Calderhead, 1992; Hatton and Smith, 1995) and, consequently, multiple methods (Whyss, 2013). Qualitative content analysis (Gläser-Zikuda et al., 2020; Mayring, 2022), which is predominantly used in the analysis of reflection, has also been proven to be adequate in our study to determine different levels of reflection. As a limitation, the relatively small number of reflective writings from just one teacher-education course at one single university has to be critically mentioned. The quantitative method applied in our study for analyzing linguistic features (LIWC2015) (Pennebaker et al., 2015) also delivered relevant results, especially in combination with the levels of reflection determined with qualitative content analysis. Therefore, it was possible to identify linguistic attributes that may be assigned to different levels of reflection and to test how the linguistic means differ between the levels of reflection.

One of the main challenges in mixed method research is to draw a common conclusion from the results obtained from the different parts of the mixed methods study at the end of data collection and data analysis – the integration takes place at the level of common interpretation and conclusion. It should be mentioned that the aim is not to report and interpret the results from each part one after the other in the sense of a mere addition, but rather to relate the qualitative and quantitative results and their interpretations to one another in order to conclude from the possibly controversial and conflicting results (Schoonenboom, 2019) to gain a deeper understanding of a particular phenomenon (Greene, 2007). In our study, the levels of reflection determined by using a qualitative content analysis were used in a second step to assign the linguistic attributes to these levels. The combination of the two methods applied in this study was therefore carried out one after the other, i.e., the first step (qualitative analysis) represents a necessary pre-condition for the second step (quantitative linguistic analysis).

As described, reflection is an essential concept for the professional development of teachers (Korthagen, 2001). There is a growing

application of approaches to support reflection in teacher education, such as reflective writings, and it is challenging to analyze and adequately assess reflective writing from the viewpoint of teacher educators (Poldner et al., 2014; Ryan, 2013). Up to now, most of the studies have predominantly relied on the one hand on qualitative content analysis and, on the other hand, on quantitative word counts or automated evaluation methods, leaving a gap in covering larger samples or focusing on reflection from a subjective perspective, respectively. Addressing this gap, our study shows, based on a mixed-method approach, that the integration of these different research methods is powerful in analyzing the relationship among different levels of pre-service teachers' reflection and linguistic features. Finally, by incorporating a mixed-method approach, this study contributes to the future development of evaluation methods to capture, at the same time, analytical depth and multiperspectivity of reflective writing. It becomes clear that research on reflective writing in teacher education – and in the study presented in this paper – gains from applying mixed methods. However, researchers need to understand when and how to use quantitative, qualitative, and mixed methods research designs to fully benefit from their potential (Hagenauer et al., 2023; Teddlie and Tashakkori, 2009).

Next, to methodological considerations, implications for implementing and fostering reflective writing in teacher education can finally be drawn. In line with other studies (Fütterer, 2019; Fütterer et al., 2024; Kember, 1999), the results of our research show that most reflective writings lack quality. Therefore, it is necessary to revisit and improve teacher education programs by incorporating specific training to support pre-service teachers in gaining and deepening reflective skills for a higher quality of reflection concerning their professional development.

5 Conclusion

Reflection connects theoretical knowledge with practical experience, which is essential for the professional development of

(pre-service) teachers. However, effectively facilitating pre-service teachers' reflective abilities poses substantial challenges within teacher education, notably the difficulties in precisely analyzing and in a second step evaluating reflective writing. Research on pre-service teachers' reflective writing has focused on qualitative content analysis or quantitative methods. This study introduces a concurrent mixed method approach to afford a more comprehensive investigation into the levels of reflection, linguistic features of representation, and their interconnections, aiming to bridge the gaps identified in existing research. The findings indicate that pre-service teachers generally exhibited low levels of reflection. However, the cognitive and affective linguistic features in their reflective writing emerged as significant indicators of the reflection level. By employing a mixed method approach, this study not only reveals the substantial methodological benefits but also significantly enriches the body of research on reflective writing in teacher education.

Data availability statement

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients/participants or patients/participants legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

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MG-Z: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. CZ: Writing – original draft, Methodology, Investigation, Data curation. FH: Writing – review & editing, Writing – original draft, Investigation, Conceptualization. LPL: Writing – review & editing, Methodology, Investigation, Data curation. LPö: Writing – review & editing. MA: Writing – review & editing, Methodology.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

TABLE A1 Example for disagreement and agreement for inter-coder reliability check (translated from German).

Example 1: Disagreement Rater 1 (overall rating on level 2) Finally, in contrast to the feedback form, my justification for the diagnostic methods to be used was very brief. While I had included my explanations in a continuous text, the justifications in the feedback were listed as a separate point and differed greatly from my results. (2×1) Overall, it can be said that my answers differed greatly from those on the feedback form. In my opinion, this is possibly due to the fact that I had difficulties with the task in this subject area, which I only really realized when I compared them with the feedback sheet. As I was still able to give my own answers to the questions, I did not use the tips on the assignments, which would have been useful in hindsight. (3×2) In addition, the self-study made it difficult for me to fully grasp the content of this subject area. This also explains why my answers differed from those on the feedback sheet. (2×2)	Rater 2 (overall rating on level 1) Finally, in contrast to the feedback form, my justification for the diagnostic methods to be used was very brief. While I had included my explanations in a continuous text, the justifications in the feedback were listed as a separate point and differed greatly from my results. (2×0) Overall, it can be said that my answers differed greatly from those on the feedback form. In my opinion, this is possibly due to the fact that I had difficulties with the task in this subject area, which I only really realized when I compared them with the feedback sheet. As I was still able to give my own answers to the questions, I did not use the tips on the assignments, which would have been useful in hindsight. (3×2) In addition, the self-study made it difficult for me to fully grasp the content of this subject area. This also explains why my answers differed from those on the feedback sheet. (2×1)
Example 2: Agreement Rater 1 (overall rating on level 1) The learning modules were easy to understand and good for learning, there were a few problems with the videos, which is why I only read through the slides and did without the videos. Nevertheless, I got on well with the learning material (2×1) I was able to complete the tasks well. For the first task, I still had to look briefly at my notes as I had worked on the slides a long time ago. (2×1)	Rater 2 (overall rating on level 1) The learning modules were easy to understand and good for learning, there were a few problems with the videos, which is why I only read through the slides and did without the videos. Nevertheless, I got on well with the learning material (2×1) I was able to complete the tasks well. For the first task, I still had to look briefly at my notes as I had worked on the slides a long time ago. (2×1)



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Systematic observation of participatory interaction in university lectures: a multiple case study with a mixed methods approach

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Introduction: In order to improve and innovate the face-to-face instructional task in postgraduate and doctoral university teaching encompasses different formats of participatory interaction (PI), considered to be social medium facilitators of deep learning, including the development of autonomous expert activity. The purpose of this article is to establish the use of systematic observation and lag sequential analysis as a conceptual-methodological choice to base the review of social-constructivist instructional practice that is taught in an expository format prepared by the teacher.

Method: The systematic observation of the expert's expository session from its inception to its conclusion was approached from a mixed methods perspective as a subject of multiple case studies. A total of four postgraduate teachers were selected. A purpose-built observational instrument was constructed. The data quality was evaluated with intra-observer agreement tests by calculating Cohen's kappa coefficient (k). After the data matrices for each case were obtained, all possible file aggregations of the data were performed to detect the existence of common structures in the patterns through lag sequential analysis.

Results: The sequential patterns of replicated and common lags of the multiple cases describe the chaining of the observed events, which characterizes the participatory interaction. Twelve lag sequential patterns have been identified that function as dialogical links, generated by the probability that the category "question" is linked to the conditioned events of "speech direction" and "exchange orientation."

Discussion: Having constructed a theoretical interpretative scheme of the replicated patterns, we discuss the results. First, the significant results of the lag sequential analysis as examples of basic patterns extracted from their way of conducting expert expository sessions. As such, they can be reviewed with the formative purpose of reflecting on their potential for change when they are understood as dialogical links of participatory interaction committed to deep learning and the development of expert autonomy. Second, there is a training step consisting of the use of self-observation and the observation that teachers can make of the expert expository task. Finally, we conclude that non-intrusive systematic observation is a good choice when channeling the gradual and renewed improvement of participatory interaction with an expert expository format (SEF) and a mixed methods methodology.

KEYWORDS

participatory interaction, mixed methods, multiple case study, systematic observation, university lectures

1 Introduction

Despite not overlooking the issue of the conceptualization and measurement of student learning throughout academic education in the countries of Organisation for Economic Co-operation and Development (2008), it is of great interest to education centers and their professional teams to come up with novel ideas to help create educational experiences that provoke deep or expert learning (Hattie, 2015; Houser and Hosek, 2018; Stobart, 2014).

This article, which complements previous publications on instructional communication by employing an expert expository format derived from the university lecture (Tronchoni et al., 2018b; Tronchoni, 2019; Tronchoni et al., 2021, 2022), falls within the chain of joint efforts made by an education center and its teaching staff to enhance their teaching practice, firmly committed to an active social-constructivist vision of the learning process (Chi, 2009).

Within the framework of participatory action research (Elliot, 1991), our research commitment with the center and participating lecturers consisted of analyzing how the teachers—in their interactions with the attending students—gave expert expository lessons. These lessons were designed as a mode of participatory interaction (PI) based on a kind of listening (Barker, 1971; Rogers, 1984) that entails the recognition of the dialogic experience (Bakhtin, 1981) of the overlapping, nested, crossed, or defined alternation of speaking-speaking turns, together with confirmatory sympathy (Watzlawick and Weakland, 1977), and the sharing of the active-comprehensive state of the interlocution (Pérez Fernández, 2008; Van Dijk and Kintsch, 1983) initiated, maintained, and closed by the expert format.

The research-educational focus of the improvement of participatory interaction with an expert expository format (from now on PI\$EF) was designed in accordance with the possibilities offered by observational methodology within the framework of the mixed methods paradigm (Bazeley, 2018). The challenge of integrating qualitative and quantitative processes in data extraction and analysis is inherent in non-intrusive observational methodologies, preferably based on systematic methods of diachronic analysis of the continuous stream of behavior events in context (Alvarado-Álvarez et al., 2021). The categories to be observed and coded for later quantitative and qualitative analysis must be well defined and accessible to external observers in order for the study of them to be replicated (Anguera et al., 2021; Izquierdo and Anguera, 2021).

It should be noted that the systematic framework of observation—conceived as a specific way to access the quantification of behavior—is distinguished from other quantitative methodological options present in psychological research in that it incorporates, controls, and verifies the shared criteria of scientific rigor and its connections with the objective of the study. Therefore, it is imperative to consider the sensitivity and conditions that impact the process of obtaining, measuring, and analyzing situated behavior, which must be taken into account, preferably from a sequential perspective (Bakeman and Gottman, 1986). In the Method section, the necessary indications are incorporated step by step to enable understanding of how the research

was conducted and to be able to offer a sufficient degree of precision and replicability, although it is not without limitations (*Vide*, Section 4).

Thus, in the methodological context of systematic observation, we carried out a multiple case study in accordance with the case aggregation procedure (Anguera, 2018) that incorporates the suggestions of Stake (2006) and Yin (2014). Our objective of conducting an intensive inquiry focuses on the momentary and dynamic aspects of PI\$EF, with the idiographic aim of exploring the existence of patterned regularities in the multimodal instructional processes shared by the participants (*Vide*, Section 2.3).

The educational task of teaching and supporting learning (Wertsch, 1988) implies guiding the process of content acquisition via student-teacher interaction in order to achieve the goals of the activity (Van Dijk et al., 2020). In the expert expository task, the instructional communication pivots between “giving” information about what is known and “asking questions”¹ about how it is known. The presence or absence in the participants—total or partial—of this two-fold game of intentions will leave a mark on both verbal and non-verbal modes of activating the lecturer’s expository plan from both extremes of the interaction. In effect, both actions foster the planning and execution of the lecturer’s explanation, and both actions connect with the constructive activity of the students’ active-comprehending listening (Pérez Fernández, 2008; Van Dijk and Kintsch, 1983). It can be inferred that the educational objectives put into circulation by “give” and “question” are spontaneously shared and anticipated by the mere act of executing out the assigned task in the classroom (Goffman, 1974; Poyatos, 1983). It is imperative to be adequately prepared for the PI\$EF challenge, given the potential risks and obstacles that may result in a demoralizing outcome.

Our research focuses on the systematic observation of PI\$EF on the cognitive and socio-affective processes of active-comprehending listening, which is stimulated by the acts of speaking and discursive and semiotic strategies (Coll and Onrubia, 2001; Sperber and Wilson, 2004; Van Dijk, 1985, 2000; Van Dijk and Kintsch, 1983). This dialogued expository mode is expressed in the verbal and non-verbal behavior of the observable exchanges within the expert’s speaking turn (Duncan, 1973; McCarthy, 2003) and, to a lesser extent, in the rotation between turns (Duncan and Fiske, 1977; Poyatos, 1983).

In accordance with our conceptualization (Tronchoni et al., 2018b), the invitation to dialogical cooperation stemming from active-comprehending listening implies something more than mere factual recognition (Kilby, 2021) of the acknowledgement of the information provided at each point in time. The communicating actors observe, listen, write, ask, answer, etc., and these observable actions can be interpreted within the framework of the declared intentions plan and/or performed by the participants as the tip of the iceberg of the non-mechanical deep

1 From now on we will use “question” to refer to ask for, ask questions, request, demand, invite, etc.

processing (Ausubel et al., 1978; Bruner, 1960) of interactive minds (Staudinger and Baltes, 1996). These externalize the internal dialogue manifested in the *auditor back channels* activities (Duncan, 1973) and in the brief alternate couplings—secondary alternating, alternation filling in, or overlapping—between the students and the teacher, employing verbal and non-verbal language that is almost like shorthand and unique to the group to communicate what is being understood and, therefore, consequently shared (Schön, 1987).

Our vision of the role played by PI\$EF is rooted in the educational principles of social-constructivist psychological development (Coll and Onrubia, 2001; Wertsch, 1988); in addition, we are also concerned about universal design for learning (UDL) principles (Mottet, 2015; Novak, 2016). When we talk about the construction of expert knowledge, we refer to the socio-affective/cognitive learning changes and the micro changes or small steps that the actors experience and express as dispositional movements and/or instrumental tools. These changes contribute to the growth of autonomous expertise. We have identified the involved mechanisms of educational support as fluid or sequential scaffolding (Bruner, 1978), depending on the contribution of both extremes in the interaction, and as teacher-planned scaffolding aided by high or low technology (Yelland and Masters, 2007). In the context of co-constructive (Monereo, 2009) step-by-step improvement, diachronic systematic observation provides us with consistent lag sequential analysis results, enabling us to advance—in our case—in the formation of fluid scaffolding and the preparation and execution of planned scaffolding.

To be more precise, and by way of summary, so far we have referred to: (a) the fluid otherness sustained by the motives and baggage of previous experiences and knowledge that nurture cooperation in the organization of active-comprehending listening shared by both extremes of the interaction; and (b) the collaboration via the use of strategies and abilities linked to the problems anticipated by the teacher and those that arise that shake the socio-cognitive/emotional adjustments of the PI\$EF (Tronchoni et al., 2021).

The scientific and professional interest that this approach to PI\$EF—based on expert learning with global and dynamic social-constructivist modeling—might have for university lecturers (Mandl et al., 1996) has been subjected to a process of systematic review (Tronchoni et al., 2022).

The results obtained are unfavorable, despite the fact that the framework of systematic evidence employed verified the scientific visibility of the existence of a determination to renew the expository lecture format prevalent across different continents. This is supported by higher education institutions and educational research centers, and it is recognized and demanded by a wide range of existing fields of knowledge. The suggestion for this renovation is limited to Incorporating ICTs (Information and Communication Technologies) and the use of strategies, techniques, and practices that foster motivation, commitment, and active learning. These are certainly improvements, but they are also at risk of reducing the expert expository format to a mere anecdote since no value is placed on the dialogued condition of active-comprehending listening.

Hence, it can be asserted that despite having established the existence of a widespread interest among universities over the five continents in transforming the expository format inherited from the lecture class, no specific formative treatment has been identified for the comprehensive, in-depth development of the principle of activity

linked to the processes of construction and interaction of learning (Chi, 2009) with an expert expository format (§EF). This vacuum is what has driven us to develop and obtain evidence about PI\$EF.

Finally, we conclude this section by establishing the prerequisites of the expert expository format and furnishing PI\$EF with an operational definition. The §EF rules that we have taken into consideration are: R1, the rule of shared commitment between both extremes of the interaction, with active-comprehending listening; R2, the rule of “give-receive/receive-give” in accordance with the expert’s fundamental actions of give/question; and R3, the rule of the asymmetric constriction of the speaking time in the students’ turns.

We conceive the expert expository moment—independently of the duration of the explanation—as a PI experience lived and relayed by the listeners with these words: *speak, speak, and do not stop* (S), *because we follow you* (F) *and you understand us* (C) *and also follow us* (G)... *In this way, together we will learn to be experts* (PI\$EF).² By using the algebra of sets, we have:

$$\text{PI\$EF} = S \cap F \cap C \cap G$$

where, $\text{PI\$EF} = x/x \in S \wedge x \in F \wedge x \in C \wedge x \in G$. In accordance with this expression, we define participatory interaction (PI), made up of the rules of the expert expository format (§EF), as a set of values assigned to the properties or attributes common to the four components: (1) *the teacher speaks* (S), (2) *the students follow* (F), (3) *the actors feel the confirmation of the relationship* (C), and (4) *the actors share the help that guides the learning* (G). The intersection of the four components encompasses the following attributes: the direction of the speech (K), the illocutionary action of the intervention (I), the modality of the response (M), and the orientation of the exchange (N) (Vide; Figure 1).

Finally, from the point of view of union (U), the disjunctive attributes (∗) include the specific and distinctive elements of each component in accordance with the situations covered (Vide, Section 2.2).

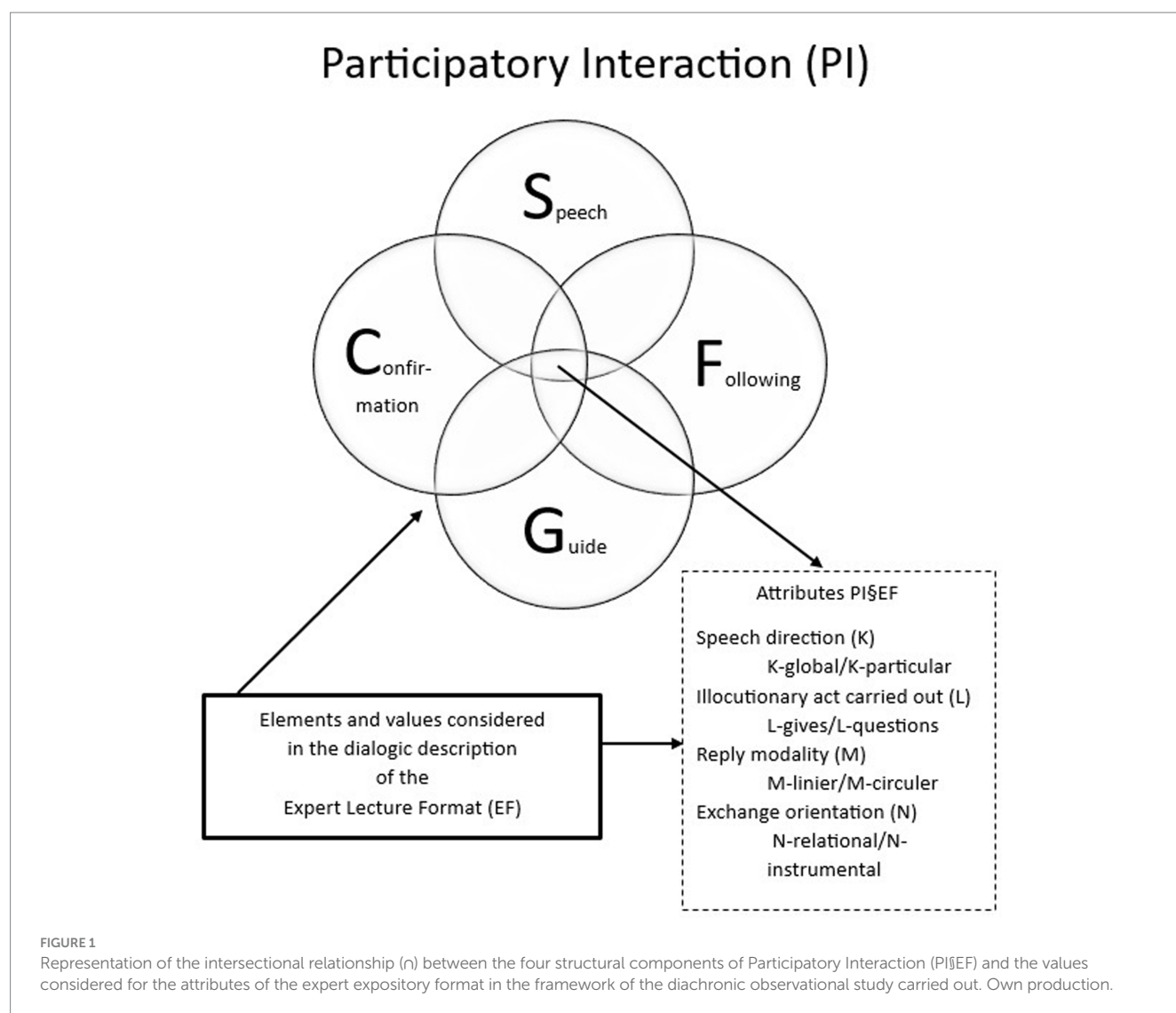
2 Method

The existence of systematic observation in the disciplinary field of analysis of social interaction involving multimodal human communication is due to important methodological advances tied to conceptual, statistical, and computer aspects (Anguera and Izquierdo, 2006; Sackett, 1980).

In this section, we incorporate, on the one hand, the advantage of having bridged the gap between the qualitative and the quantitative by allowing the observational records of interactive behavior—that are categorical in nature—to undergo a quantitative treatment through the construction of an organized data matrix in accordance with certain parameters. This is made possible through the use of novel robust techniques of quantitative analysis applicable to social interaction (Anguera et al., 2021).

On the other hand, the incorporation of a multiple case study as a methodological aim (Anguera, 2018) has allowed us to go deeper

² § specific rules for implementing the expert expository format (EF).



into the proposed observational problem without losing intensity; i.e., lag sequential analysis (Sackett, 1980) applied to the data matrix of each lecturer participating in this research ($n=A, B, C$, and D) is completed by verifying the existence of identical structures in the behavioral patterns detected via the aggregation of data from the four participating lecturers: A, B, C , and D ; AB, AC, AD, BC, BD , and CD ; ABC, ABD, ACD, BCD ; and $ABCD$ (Anguera, 2018; Yin, 2014).

2.1 Design

An applied observational design is N-I/P/M (Anguera et al., 2001). The study is characterized as nomothetic on a primary level of analysis due to the presence of four lecturers, idiographic on a secondary level due to the presence of multiple cases, punctual with intra-session follow-up due to the recording of a single session per teacher from the start to the finish of the class, and multidimensional due to its theoretical framework and its structure in two macro dimensions.

This study conforms to the characteristics that establish the profile of observational methodology: (1) the study of spontaneous

and perceptible behavior is studied, in the usual contexts where it occurs; (2) the subsequent stages that follow on from the establishment of the design consist of the construction of an *ad hoc* instrument, computerized registration, data quality control, and data analysis; (3) the custom-built instrument is non-standard, and its laborious preparation necessitates the proposal of certain dimensions based on the theoretical framework and reality that can be deployed in sub-dimensions, each of which produces a comprehensive and mutually exclusive system of categories; (4) the computerized record is tailored to the categorical nature of the data; (5) data quality control ensures the agreement of the records of different observers (inter-observer) or of the same observer at different moments in time (intra-observer); and (6) the data analysis is tailored to the stated objective, taking into consideration the categorical nature of the data.

2.2 Participants, context, and setting of the multiple case study

The context of the multiple case observation is a Mexican university that conceives learning as significant at the base of the

TABLE 1 Description of the observed situations.

Case	Number of students	Rank of student's age	Subject type	Academic period	Master
A	9	26–53	Theory Practice	5th	Mathematics
B	26	25–56	Theory	2nd	Pedagogy
C	10	25–40	Theory	2nd	Pedagogy
D	25	23–48	Theory Practice	5th	Mathematics

TABLE 2 Aspects framing the observation in each case.

Case	Duration	Number of contributions	Frequency of category PE	Frequency of category DA
A	2 h. 41' 11"	871	99	723
B	1 h. 56'	609	41	551
C	2 h. 20'	582	85	490
D	2 h. 7' 25'	567	89	466
Total	9 h. 6' 36"	2.629	314	2.230

PE (QUESTION) and DA (GIVE).

processes of teaching, learning, and assessment processes. The department responsible for teacher training has expressed concern regarding the instructional communication between teachers and students via the offer of training that includes different workshops and a diploma in communicative competence. The institution's informed idea about the expository class reveals the apprehension about the effectiveness of teaching with this prevalent format at the Master's Degree level.

The participants in the observed class sessions included 4 teachers and 70 students from urban and semi-urban districts, aged between 23 and 56 (mean 39.5). The teaching staff has an average age of 51.5 (between 40 and 63), is committed to the university education project, and is familiar with instructional communication via basic theoretical training. Furthermore, the lecturers have broad professional teaching trajectories and, in particular, are interested in the effectiveness of teaching about student learning. They are willing to achieve effective encounters.

The work plan was developed in front of the group in an ordinary classroom on a Saturday, with each class session lasting 3 h each. The classrooms are equipped with basic technology, including a computer, projector, and one digital whiteboard. There are between 20 and 30 desks in each classroom—both individual and longer for two or three students—and normal seats or stools. The chalkboard or whiteboard occupies a significant portion of one wall of the classroom, covering various meters, and the arrangement of seats, in general, is traditional.

The observed situations introduced new concepts belonging to two different fields of knowledge within the Master's Degree. Cases A and D were from two 4-month subjects from the fifth year, theoretical-practical in nature from the Master's Degree in Mathematical Education. The Mathematical Education lecturers emphasize the value of the expository class with the aim of presenting and developing a great quantity of content progressively in a demonstrative way. In this way, the board and

screen play a fundamental role. Cases B and C pertain to two second-year subjects that mainly comprise theoretical material from the Master's Degree in Pedagogy. The pedagogy lecturers employ new methods of distributing the students in the classroom and activities in an expert expository format. Table 1 summarizes the main heterogeneous characteristics of the four cases³.

From a perspective of class session observation, Table 2 synthesizes the aspects of each case: the duration of video recordings, the number of contributions, and frequencies by category.

The recordings required technical material that was installed in each classroom: an omnidirectional microphone, a Sony Action camera with a wide-angle lens, and a Canon camera with a fixed-focus lens. Sound and image editing and montage were carried out by specialized technicians with the Quicktime reproducer and the Final Cut X program, as shown in Figure 2.

2.3 Systematic observation instrument

Based on the theoretical conceptualization of the object of study in instructional contexts and in systematic observational methodology (Tronchoni et al., 2018b; Tronchoni, 2019; Tronchoni et al., 2021), the instrument LUniMex-2017 was developed (Vide; Figure 3). This approach combines field format with category systems that meet the conditions of exhaustivity and mutual exclusivity for the study of the two macro dimensions: (I) the organizational contributions of the interaction, and (II) the regulation of participation in the construction of knowledge.

³ For more information about the participants, the context, and the scene, consult the following references: Tronchoni, 2019; Tronchoni et al., 2021.



FIGURE 2
Example of filmed images in Case D.

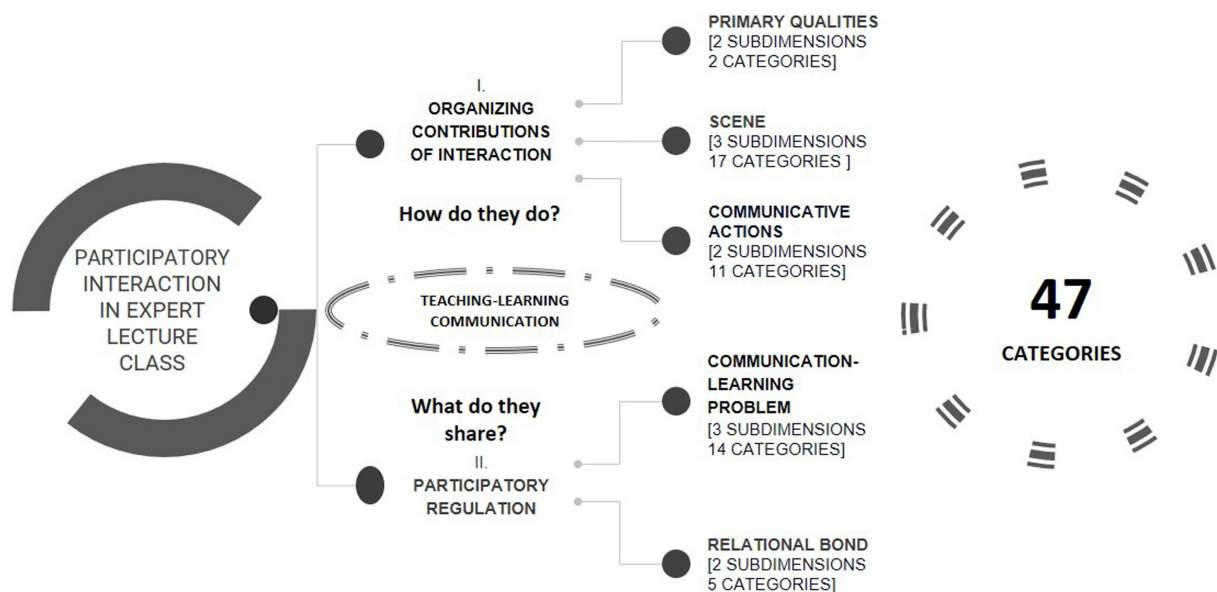


FIGURE 3
Multidimensional conceptualization and category systems of the systematic observation instrument LUniMex-2017 (Tronchoni et al., 2018a). Own production.

2.4 Procedure

First of all, authorization to develop the study was sought from the Dean of Social Sciences of the university, and written informed consent was obtained from the lecturers and students in order to carry out the video recordings. The study received the necessary ethical permission for it to be carried out by the institution. The issue of observation was the lecturers' interactive

behavior during a class session with an expository format. The unit of record was the alternating intra- or inter-turn contribution (Duncan and Fiske, 1977), with a minimum duration of 1 s per turn. A passive observation, sampling, transcription, and systematic record of the filmed sessions were executed. Class sessions were coded using the observation instrument LUniMex-2017. The data matrix derives from the systematic record of the categorical coding within the open-access program LINCÉ (<http://>

TABLE 3 Illustrative example of the recording and coding processes.

Recording			Coding						
Moment	Duration seconds	Segmentation unit: contribution	Who-to-Whom	Role	Mode	Act	Task	Strategy	Relational bond
0:05–0:07	2	#D: On that date, Freire was also going to be presented, and the colleague who is going to present is on the SEP courses*G	DG	HA	MPR	DA	CI	CEC	IPC
0:08–0:09	1	#G [visual contact]*D	GD	OA	MPR	DA	CI	CEC	IPC
0:10–0:14	4	#D: Although we are going to be lagging behind with the times (...) *G	DG	HA	MPR	DA	CI	UPL	IPC
0:15–0:17	3	#E [directed look]*D	ED	OA	MPR	DA	CI	UPL	IPC
0:18–0:19	2	#D: So they aren't going to present Freire then, right? *G	DG	HA	MPR	DA	CI	CEC	IPC
0:20–0:21	2	#E [they fiddle with notebooks]*D	ED	OA	MPR	DA	CI	CEC	IPC
0:22–0:25	4	#D: Although chronologically we are going to be jumping around (...) *G	DG	HA	MPR	DA	CI	UPL	IPC
0:26–0:27	2	#E [they smile or laugh]*D	ED	OA	MPR	DA	CI	UPL	IPC
0:28–0:29	2	#D: You already know Freire, so there's no problem (...) *G	DG	HA	MPR	DA	CI	CCO	IPC
0:30–0:33	4	#E [visual contact or directed look]*D	ED	OA	MPR	DA	CI	CCO	IPC

Codes: DG (Teacher-Group), GD (Group-Teacher), ED (Students-Teacher), HA (Main Speaker), OA (Active Listener), MPR (Proposal-Response Mode), DA (Give), CI (Share Information), CEC (Current Content or Procedures), UPL (Use of the 1st Person Plural), CCO (Knowledge Shared in Class), IPC (Proximal-Warm Exchange).

observesport.com/; [Gabin et al., 2012](#); [Table 3](#)). The concordance calculation and lag sequential analysis were performed using the open-access program GSEQ (<https://www.mangold-international.com/en/products/software/gseq.html>; [Bakeman and Quera, 2011](#)). We then examined the records of the four cases in conjunction with the aggregation of files into 15 groups and through four aggregation levels in order to carry out a lag sequential analysis and detect the possible existence of common patterns PI\$EF.

To guarantee the quality control of the observational records, initially, a consensus agreement was carried out by two researchers possessing extensive knowledge in the subject matter in order to ensure that the content of each category was precisely established and comprehended. During the recording, Cohen's kappa coefficient (1960) was used to obtain a satisfactory intra-observer agreement of 0.90.

2.5 Data analysis

In accordance with the previously outlined observation instrument (*Vide*, Section 2.3), we coded the multiple events observed in each of the episodes that make up the sequential chain of the development of the observed PI\$EF sessions.

In order to analyze the transitional probabilities of the multi-event data and verify their significance, we utilized lag sequential analysis ([Anguera, 1997](#); [Sackett, 1980](#)). According to the indications of [Bakeman and Gottman \(1986\)](#) and the user instructions for the GSEQ program for the construction of the lag contingency association tables ([Bakeman and Quera, 1996, 2011](#)), it is a good idea to limit the number of conditioned behaviors, adjusting them to the aim, and, in addition, to also limit the

number of lags. Thus, we have selected 12 categories of interest that have been proposed as conditioned behaviors ([Table 4](#)). Each one of these codes belongs to one of the four basic dimensions of the coded observation, and as a given behavior (GB), we focused on the illocutionary action of the QUESTION (*Vide*, Section 1). The given behavior “question” is defined as a verbal and nonverbal message that communicates the need to carry out an action linked to the moment of active comprehension. This is an act of demand or exhortation about something with the possibility of being received or not as answers and replies (ask, ask for, demand, request, invite, etc.).

In terms of the chaining *Lag [L]* of pairs of events (antecedent-criterion [*c*] with subsequent events [*s*]), expressed as $p(s_{t+1}/c_t)$, it was fixed at five lags ([Bakeman and Gottman, 1986](#)). The perspectives analyzed are both prospective ([Sackett, 1980](#)) and genuine retrospective ([Anguera, 1997](#)).

The rules used to determine when a sequential pattern of behavior conventionally ends were: (a) when there are no more lags with significant behaviors, (b) when there are two consecutive empty lags, and (c) when there are various significant behaviors in two consecutive lags. In this case, the initial of the lags is considered MAX LAG, which marks the interpretative end of the obtained structure ([Anguera et al., 2021](#); [Sackett, 1979](#)).

3 Results

The results of the file aggregation are presented in table format. The category-given behavior is located in the central column, and the patterns PI\$EF are classified in accordance with their structural characteristics: temporal orientation (retrospective/prospective),

TABLE 4 Codes used in the lag sequential analysis with Given Behavior and conditioned behaviors.

Dimension SCENE		
Sub-dimensions	Category systems	Codes
Who-to-Whom	Teacher-Group	DG
	Group-Teacher	GD
	Teacher-Students	DE
	Students-Teacher	ED
Dimension communicative acts		
Verbal basicacts	Question (Given Behavior)	PE
	Give	DA
	Show	MO
	Ignore or Reject	IR
Dimension communication-learning problem		
Support strategies to connect with previous knowledge	Previous knowledge of the social framework	CIN
	Knowledge shared in class	CCO
	Individual experience of the social framework	EIN
	Shared experience in class	ECO
Dimension relational bond		
Sociocognitive and emotional regulation	Proximal-Warm Exchange	IPC
	Proximal-Cold Exchange	IPF
	Distant-Warm Exchange	IDC
	Distant-Cold Exchange	IDF

The codes have been maintained according to Spanish nomenclature (Tronchoni et al., 2018b).

temporal position of the link of the event conditioned for GB (the five lag positions), nature of the link associative to the event conditioned with GB, and type of conditioned event (positive/negative). Each table contains an interpretative description of the patterns found, based on the positive and negative associations identified.

3.1 Lag sequential analysis

3.1.1 Aggregation of the files corresponding to ABC, ABD, ACD, and BCD

Twelve significant sequential patterns were selected ($p < 0.01$). We identified four retrospective positives, two retrospective negatives, four prospective positives, and two prospective negatives. Out of 12 sequential patterns, 8 patterns (2 retrospective positive, 2 retrospective negative, 2 prospective positive, and 2 prospective negative) were replicated in the 4 groups of 3, and the 4 remaining were replicated following this distribution: one prospective positive in the case of ABD; one prospective in the cases ABC, ACD, and BCD; one retrospective positive in the case of ABC; and one retrospective positive in the cases ABD, ACD, and BCD (Table 5).

Positive sequential associations are developed in exchanges that mobilize the global attention of the class group and relational and instrumental strategies (prospective) in the four cases. There exists a possibility of being able to observe the illocutionary PE action subsequent to having observed a global communicative moment and relational and instrumental strategies (retrospective).

Negative sequential associations are the values “global/particular” of the speech direction event that were observed much fewer times than expected by chance in alternate positions for each value.

3.1.2 Aggregation of files corresponding to ABCD

The search for replicated patterns culminated with the aggregation of the data obtained in A, B, C, and D. Once again, 12 significant sequential patterns were obtained: 3 retrospective positive, 3 retrospective negative, 3 prospective positive, and 3 prospective negative (Table 6).

Positive sequential associations: the action “question” is developed in exchanges that mobilize the global attention of the class group, and relational and instrumental strategies (prospective) in the four cases. There exists the possibility of observing the illocutionary PE action in R0 when lag-positive associations have previously been observed before (-R1 a -R5) between PE and DG, PE and IPC, and PE and CCO.

Negative sequential associations: the values “global/particular” of the speech direction event were observed much fewer times than expected by chance in alternate positions for each value. The same thing happens with the “prior knowledge” instrumental strategy of the social framework.

3.2 Theoretical interpretation of the replicated patterns in the aggregation of files ABCD

If the social and scientific commitment derived from the analysis is to establish the level of intervention understood as a

TABLE 5 Classification of PIJEF patterns ($p < 0.01$) for each case: ABC, ABD, ACD, and BCD.

Classification of PIJEF patterns in the ABC Case												
Lag Type	Nature of event	Retrospective					GB	Prospective				
		-R5	-R4	-R3	-R2	-R1	R0	R1	R2	R3	R4	R5
Positive	Global		DG		DG		PE		DG			
	Particular						PE					
	Relational			IPC		IPC	PE	IPC				
	Instrumental	CCO		CCO		CCO	PE	CCO				
Negative	Global	DG	GD	DG		DG	PE	DG		DG		DG
	Particular				ED		PE		ED		ED	
	Relational						PE					
	Instrumental						PE					
Classification of PIJEF patterns in the ABD Case												
Positive	Global		DG		DG		PE		DG			
	Particular						PE					
	Relational	IPC		IPC		IPC	PE	IDC				
	Instrumental	ECO		ECO		ECO	PE	CCO				
Negative	Global	DG		DG		DG	PE	DG		DG		DG
	Particular		ED		ED		PE		ED		ED	
	Relational						PE					
	Instrumental						PE					
Classification of PIJEF patterns in the ACD Case												
Positive	Global		DG		DG		PE		DG			
	Particular						PE					
	Relational	IPC		IPC		IPC	PE	IPC				
	Instrumental			ECO		ECO	PE	CCO				
Negative	Global	DG		DG		DG	PE	DG		DG		DG
	Particular		ED		ED		PE		ED		ED	
	Relational						PE					
	Instrumental						PE					
Classification of PIJEF patterns in the BCD Case												
Positive	Global		DG		DG		PE		DG			
	Particular						PE					
	Relational	IPC		IPC		IPC	PE	IPC				
	Instrumental			ECO		ECO	PE	CCO				
Negative	Global	DG		DG		DG	PE	DG		DG		DG
	Particular		ED		ED		PE		ED		ED	
	Relational						PE					
	Instrumental						PE					

co-constructive method, it is imperative to summarize—without omitting any pertinent information—the adjustment model found among the most replicated patterns (*Vide*; Table 4) shared by the four observed cases (*Vide*; Table 5), within the restriction of limiting: (a) the associations conditioned by PE to the positions -R2 or -R1 and +R1 or +R2, (b) the relationships of inhibition to those values that did not obtain retrospective or prospective

positive presence in other lagged positions, and (c) the unnecessary repetition of events.

The adjustment issuer-receiver/expert-learner is related to different categories of instrumental and relational content that, in order to be received or taken with a view to being negotiated and shared at different comprehension levels, need to be provided in accordance with the discursive moment of the exchanges and

TABLE 6 Classification of the PI§EF patterns ($p < 0.01$) in the ABCD file aggregation.

Lag type nature of event		Retrospective					GB	Prospective				
		-R5	-R4	-R3	-R2	-R1	R0	R1	R2	R3	R4	R5
Positive	Global		DG		DG		PE		DG			
	Particular						PE					
	Relational	IPC		IPC		IPC	PE	IPC				
	Instrumental			ECO		ECO	PE	CCO				
Negative	Global	DG		DG		DG	PE	DG		DG		DG
	Particular		ED		ED		PE		ED		ED	
	Relational						PE					
	Instrumental		CIN		CIN		PE		CIN		CIN	

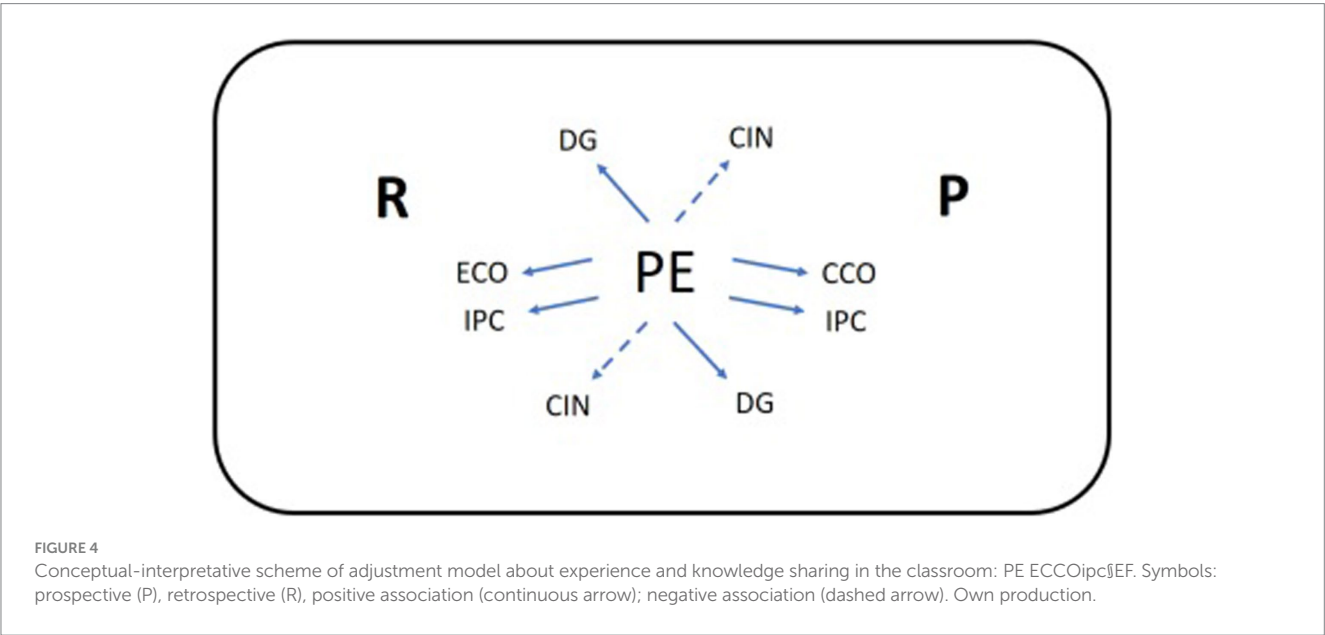


FIGURE 4
Conceptual-interpretative scheme of adjustment model about experience and knowledge sharing in the classroom: PE ECCOipc§EF. Symbols: prospective (P), retrospective (R), positive association (continuous arrow); negative association (dashed arrow). Own production.

their combinations: establish bridges, give meaning, and elaborate relationship networks (Tronchoni et al., 2018b).

The discoveries from the aggregations of the files ABC, ACD, and BCD coincide in incorporating the prospective pattern PE IPC, and the retrospective pattern PE ECO forms part of the cases ABD, ACD, and BCD. The prospective pattern PE CCO is shared in the four cases. On examining the sequential patterns, taking into account the aforementioned restrictive rules, we discover (Figure 4):

- a. The reflectivity-continuity before/after a mode of IPC relationship that guides the CCO exchanges.
- b. The prospective positive association of PE with CCO which provides the IPC relationship with instrumental content.
- c. The retrospective positive association of PE with ECO which provides the IPC relationship with instrumental content.
- d. The global preceding-consequence DG contribution is positively associated with the category PE.

- e. The diminution or blocking of both the retrospective and prospective negative association of CIN PE CIN.

4 Discussion and conclusions

The evaluative-formative objective of this research into instructional communication situates the discussion of the presented outcomes with the realm of educational intervention. In line with a relational vision of the communication that takes place via languages and psychosocial relationships, the interactive process has been designed to recognize the speakers' participation, i.e., both extremes of the interaction listen and transact (Anguera and Izquierdo, 2006; Izquierdo, 1996; Izquierdo and Anguera, 2021; Izquierdo and Perinat, 2010; Watzlawick and Jackson, 2010; Winkin, 1981).

The principles of communication (Grice, 1975; Marc and Picard, 1989; van Dijk and Kintsch, 1983; Watzlawick and Weakland, 1977) that support the instrument of systematic

observation, LUniMex-2017, are (Tronchoni et al., 2018b): (a) the concept of feedback and its various functions, (b) the dialogism inherent in verbal interaction, (c) the situation and the activity's objectives, (d) the exchange of meanings, (e) the multimodal construction of meaning, (f) the reciprocity or recognition of the other as a valid interlocutor, and (g) mutual influence.

The reading of the PI\$EF process was contextualized from the educational viewpoint in the principles of social constructivism, which structure the educational discourse (Coll, 1996; Coll and Onrubia, 2001; Coll et al., 1992; García-Fariña et al., 2018; Prados and Cubero, 2005; Rogoff, 1990) around the teacher-student shared task of adjusting the expert explanation and the activity of active-comprehending listening as a process of guided and conscious dialogical inquiry (Ur, 1994; Fernández and Cuadrado, 2008).

The detection by aggregation of cases (Anguera, 2018) of shared significant patterns in the analyzed combinations of triples and quaternary (see other examples, Alarcón-Espinoza et al., 2024; García-Fariña et al., 2018) has enabled us to concentrate the descriptive return of the observed instructional behavior into a theoretical-interpretative diagram showing the complexity of the exchanges motivated by the illocutionary action “question” (PE). The educational assistance identified in the significant and replicated link between PE and the categories “speech direction” and “exchange orientation” includes: (a) regulatory dialogical sequences of how we communicate and what we share, (b) dialogical sequences of attention opening and subject advancement, and (c) dialogical sequences of closure with significance.

The communicative mode PE is further complemented by the communicative mode “give” (DA). Both modes of communication attempt to identify both instrumental and relational issues of adjustment between the attending students and the expert teacher (Figure 5).

We comprehend that these two distinct movements of educational support pertaining to language are generated in

different ways. Maintenance of the fluid deployment of the sequential or planned educational support in PE mode is fed by the lecturer's (D) search for information about the course of the interaction to assess what questions to ask in order to reinforce and channel the students' active-comprehending listening (E). However, when the teacher executes action DA, the search for information is centered on the evaluative behavior displayed by the students (E) minute by minute throughout the explanation. It is noteworthy that the critical position of D in DA is not altered by educational support; it does not modify the course of the instructional communication dialogue until the lecturer incorporates the listeners' message received in DA.

The instructional intervention, supported by a systematic observation study and envisaged as a constructivist learning environment via the viewing of the produced digital videos, involves (Jonassen and Rohrer-Murphy, 1999) returning the results incorporated into the theoretical-interpretative diagram, exposing the filming to dialogued self-observation, and establishing a plan of improvement. The use of video analysis in education and in sports training (Chicote et al., 2009; Cushion, 2006; Hernández-Mendo and Anguera, 2000; Lemyre et al., 2007) provides evidence about the benefits it can bring. In our case, it is worth mentioning that self-observation and the discussion of the video recordings connect with the expectations and interests of the teachers involved.

Four examples are presented, one for each case, interpreted according to the theoretical interpretative diagram of the adjustment model PE ECCOipc\$EF (Vide; Figure 4). The examples are accompanied by: (i) the adjustment model of experience and shared knowledge in class (ECCO) based on feedback, (ii) the scaffolding mode—sequential or planned, and (iii) a descriptive framework that places each example in the temporal phase of the class session (start, middle, or end), the didactic moment it corresponds to (introduction, development, or closure) and the subject, followed by the subject.

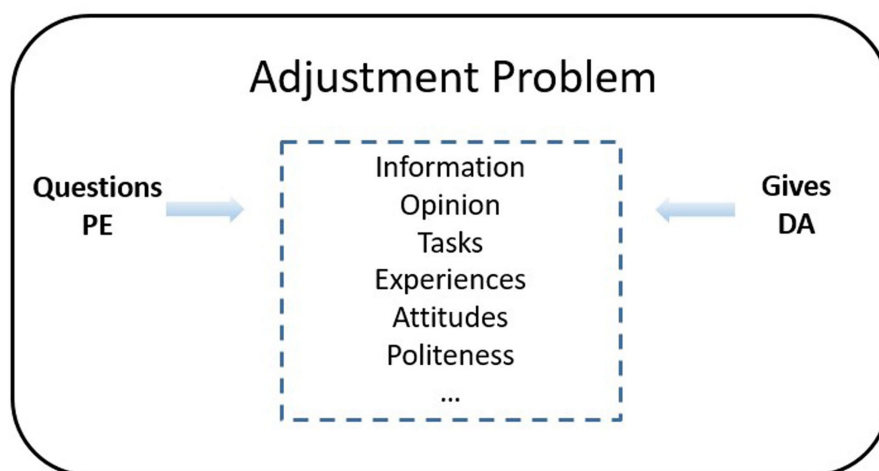


FIGURE 5

Adjustment problem between the communicative acts *Questions* and *Gives*. Own production.

Case A:

Adjustment model of experience and shared knowledge in class which describes an accumulative confirmatory feedback of work rules or regulations.

Planned scaffolding.

The teacher is a lecturer, the example takes place during the final temporal phase of the class session, the didactic moment is of closure and the subject Mathematics of Change.

Student: *Excuse me, err... when do we have to hand in the portfolios?*

Teacher: *I suggest that if we don't see each other again in eight days time, that there is some activity online (...) I propose that you hand it in by the following week, we agreed that it would in a Word file, didn't we?* [PE: Support requirement]

Student: Yes

Teacher: *I think that would be the last week, I will be opening a link in the first few days.*

Case B:

Adjustment model of experience and shared knowledge in class which describes an accumulative dynamic feedback.

Planned scaffolding.

The teacher is a lecturer, the example takes place during the initial temporal phase, the didactic moment corresponds to the introduction and the subject is Educational Currents.

Teacher: *We have to discuss the Renaissance. Last week we talked about the Middle Ages, how it starts and how it ends, the importance of monastic groups (...), how universities come into being there, right?* [PE: Invitation to the subject]

Student: *(the students are in preparation mode, taking things out of their bags and placing them on the tables; visual contact is being initiated between the students and the lecturer.)*

Case C:

Adjustment model of experience and shared knowledge in class which describes a feedback of correct reception.

Sequential scaffolding.

The teacher is a lecturer, the example takes place during the initial temporal phase, the didactic moment corresponds to the introduction and the subject is the Foundations of Educational Orientation.

Teacher: *And I was saying that it was associated to which type of model? Do you remember? (pause) From the models we reviewed at the beginning. (pause) (the lecturer is sitting in the oval formed by the distribution of the group, her gaze sweeps around the group of students and her tone of voice is linear with confirmation modulations: aha / right?)*

Student: *To the consulting [model]*

Teacher: *To the consulting and clinical [model], right?* [PE: Joint negotiation-action]

Case D:

Adjustment model of experience and shared knowledge in class which describes a dynamic-sequential/planned feedback.

Sequential scaffolding.

The teacher is a lecturer, the example takes place in the initial temporal phase, the didactic moment is that of development, and the subject is Information Analysis Processes.

Teacher: *What is statistical correlation? (...) (gaze directed towards the PPT alternating with directionality towards the group at the front of the class) Do you know why? Because it could be a rule of mathematical correspondence (...) we can do a (inaudible) geometric, draw it, either in second or third dimension.* [PE: Joint negotiation-action]

Student: *(two students join the class session; others are taking notes on their laptops and in their notebooks)*

Teacher: *(addressing the group) We had already seen it too. When I have an experiment that gives me many points (writing on the board)*

These examples of the adjustment model PE ECCOipc\$EF are reflected in the different realities lived and experienced by the four lecturers and embody the interpretative diagram based on the knowledge adjustment shared in class and the analysis of the multiple cases. Therefore, within the framework of participatory action research (Vide, Section 1), the professional educational task requires the teacher to self-observe via the viewing of filmed sessions, moving backward and forward, and stopping in exemplifying situations to describe feedback management and the sequential and planned structure of PI\$EF.

The instance of Case A takes place within a scenario that seeks the confirmation (*when do we have to hand in the portfolios?*) of established rules regarding the study and autonomous development of the work. The situation in Case B corresponds to a dynamic feedback that connects and mobilizes the thematic plan of the course (*Last week we talked about the Middle Ages*), and it is anticipated that active listening will be established (*the students are in preparation mode, taking out material*) on what follows and commences the session. Both accumulative examples, owing to their sedimentation of the ongoing work, correspond to a planned scaffolding that guides the conduct of the exposition.

Case C is within a scenario that seeks to ensure the correct reception (*to the consulting and clinical [model], right?*) of thematic content (models of educational orientation) studied prior to the filmed class session. The situation in the Case D example corresponds to revitalizing feedback mobilized through the act of questioning (*Do you know why?*), in which the lecturer knows the difficulties the students might have in the action of listening-comprehending, reducing the cognitive distance (*because it could be a rule of mathematical correspondence*). Both examples—Cases C and D—correspond to a sequential structure plan derived from an *in situ* interactive sequence between the lecturer and the students.

In terms of the four examples provided here, there are some advanced guidelines to assist the teacher to address basic and important issues, such as: the need to plan autonomous work and study together with the students (Case A); the importance of preparing the necessary resources that affect attention from the beginning of the session, and adopting WE BEGIN mode (Case B); to strengthen objectivism about the circumstances, conditions, and consequences related to learning consolidation (Case C); and mediate cognitive distance with the incorporation of longer pauses following a question that permit the students to establish connections between their prior knowledge through oral contributions (Case D).

The work of teacher self-observation is guided by the discussion of the results from the practiced systematic observation and used as a support of the lived experience in viewing the filmed sessions. This training exercise process involves the conscious, deep, and reflexive vision of the teacher, channeled toward a plan of improvement of what is being done and how it is being done in terms of educational support. As previously stated in the introduction, the objective of PI\$EF is to generate and cultivate the expertise of the listener as a communicative actor and as a learner of academic content.

In light of the above, it can be concluded that there exist two key moments in the pursuit of improving the preparation of the expert expository class. These are the updated, substantial, and well-documented moments of assembling the expository plan of curricular content and the moment of preparing communicative interaction, i.e., how to communicate it in the face of the communication-learning problem (Vide; Figure 2), via mechanisms of feedback and the discursive strategies on which the asymmetric commitment of the actors relies.

By way of conclusion, the above examples of the PE ECCOipc\$EF adjustment model demonstrate the instructive potential of revealing what was previously hidden from the participants because they did not have the conceptual and analytical tools to objectively deal with the complexity of PI\$EF. The four examples form a narrative of the captured images. The results of the observational research conducted are presented to the professional forum responsible for assessing the efficacy of the instructive proposal based on video analysis, backed by a previous systematic

observation study conducted within the framework of the mixed methods approach with a multi-case study.

The limitations of this study are twofold: first, it is imperative to augment the number of trained observers; second, it is imperative to adhere to the training and consensus guidelines of the work and evaluate the agreement between observers until the application of the statistics specific to observational methodology. However, the instrument is clear and transparent and therefore has great potential for communication with the scientific and professional community. Furthermore, the laborious work of delimiting, naming, and defining the categories means that it is adaptable to different educational contexts. Furthermore, it allows us to progress through the molecularization of category systems in the morphology of comprehensive attention of the interpretative parts of the expository class, for the benefit of teacher training.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation (Spain: Art. 11 of RD 99/2011, published in BOE 10/2/201) and institutional requirements (University of Barcelona: 21/7/2014). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any identifiable images or data included in this article.

Author contributions

HT: Writing – review & editing, Writing – original draft. CI: Writing – review & editing, Writing – original draft. MA: Writing – review & editing, Writing – original draft.

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Conflict of interest

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1410486/full#supplementary-material>

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Leadership practices of physical education teachers and student-related outcomes: a systematic mixed method review and analysis

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Introduction: This study systematically reviewed and analyzed both qualitative and quantitative studies that focused on the relationship between physical education (PE) teachers' leadership and student outcomes using data mining and meta-analysis.

Methods: Using the Scopus, PsycINFO, PubMed, and SPORTDiscus databases, text data from the included 150 relevant articles were examined through a text data mining approach. Quantitative and mixed-method studies were then further evaluated, yielding 49 articles eligible for inclusion in the meta-analysis.

Results: Findings from the data-mining analysis using Leximancer revealed eight major themes associated with PE teacher leadership, emphasizing motivation, education, support, and teaching. Results from the meta-analysis using the Comprehensive Meta-Analysis software showed that autonomy-supporting behaviors showed strong positive effects on student satisfaction, motivation, competence, and engagement. Regional differences in research focus were observed, with health being less emphasized in Asian and European studies. Student sex emerged as a moderating factor.

Conclusion: The study highlights the role of PE teacher leadership and the convergence/divergence among research findings. Moreover, applying the HDST approach to synthesize both qualitative and quantitative articles provided a deeper and more comprehensive understanding of leadership within the PE field.

KEYWORDS

teacher leadership, data mining, sports curriculum, autonomy-support behavior, motivation, student sex differences, regional differences, meta-analysis

1 Introduction

Leaders are regarded as important individuals in any organization, as they are generally described as those who influence or guide members or followers to accomplish goals. Leaders are designated in various organizations or institutions, such as businesses, governments, and educational institutions. In physical education (PE) for instance, teachers are delegated classroom leaders during PE class. They teach and demonstrate fundamental motor skills, sports, and other physical activities. They also educate students about health-related topics, such as stress management, nutrition, health conditioning, safety, and prevention. In addition to developing motor skills and fitness competencies, PE teachers also promote students' life skills, including teamwork, persistence, and sportsmanship, through PE activities and programs (Cronin et al., 2023). To fulfill these teaching roles, effective teaching and leadership behaviors are crucial for teachers when conveying PE-related knowledge and skills to students.

A teacher who demonstrates positive behaviors while delivering class lessons is likely to enhance student motivation, class participation, and perceptions of PE, and more importantly, encourage students to regularly engage in active and sustainable healthy lifestyles. In contrast, a teacher who lacks organization, delivers unstimulating lessons, and is indifferent to students' needs, may negatively impact students' attitudes (Cruz et al., 2021), feelings (Van den Berghe et al., 2015), and engagement in PE and other physical activities (Hassandra et al., 2003). Therefore, it is paramount for PE teachers to possess the appropriate teaching skills and leadership behaviors that foster positive experiences for students in PE, which in turn can influence the adoption of healthy active lifestyle. By doing so, PE teachers not only achieve the learning goals of PE but also effectively fulfill their roles as classroom leaders.

Currently, approximately 81% of adolescent students (11–17 years old) of the world's population do not meet the required physical activity recommendations of the World Health Organization (WHO) (Guthold et al., 2020). This high level of physical inactivity in school-aged populations can lead to future adverse health-related repercussions (Katzmarzyk et al., 2022) unless opportunities to actively involve students in physical activities are implemented. Studies revealed that students' motivational and emotional experiences in PE can promote either physical inactivity (Beltrán-Carrillo et al., 2012; Cardinal et al., 2013; Fierro-Suero et al., 2022) or participation in leisure time physical activity (PA) (Castillo et al., 2020; Chen et al., 2014; Fierro-Suero et al., 2022). In this case, given that PE teachers have direct contact with students during PE classes, they possess the capacity to create a classroom climate and learning culture that can affect students' responses through their interactions when teaching PE curriculum content and physical activities. The way PE teachers instruct, inspire, support, and provide feedback can either negatively or positively affect students' feelings, attitudes, and behaviors resulting from their PE experiences. Thus, it is crucial for PE teachers to acquire and demonstrate effective leadership traits, skills, and behaviors when interacting with students during PE class, as their teaching and leadership approaches and strategies can have an influential role in shaping students' affective, cognitive, and behavioral outcomes. Physical education teachers who practice appropriate and positive leadership during class can effectively enhance student motivation to engage in PE and lifelong physical activity participation, thereby contributing to achieving PE objectives as well as supporting Sustainable Development Goals (e.g., SDG3 good health and well-being) (World Health Organization, 2018).

Although various approaches can be used to understand the influential role of PE teachers as leaders in education, the transformational leadership approach (Bass, 1998) has recently emerged as a promising framework. This framework is widely used to study leadership behaviors in occupational settings, but has recently been extended to the field of education and conceptualized as transformational teaching (Beauchamp and Morton, 2011). According to Beauchamp and Morton (2011), who advocate for using transformational leadership theory in the PE domain, effective leadership and teaching are quite similar because both involve the

process of influencing others in a social context to achieve established goals. They also contend that while transformational teaching is grounded from transformational leadership, it also share similar theoretical concepts from several common teaching and behavior change models such as social learning theory (Bandura, 1977), self-determination theory (Deci and Ryan, 2012), and pygmalion effect (Rosenthal and Jacobson, 1968). Transformational teaching is described as inspiring, motivating, and building students' confidence to achieve higher levels of functioning, as well as transcending the teacher's own self-interests by exhibiting transformational behaviors. These transformational behaviors include individualized consideration, intellectual stimulation, inspirational motivation, and idealized influence. Individualized consideration refers to the degree to which a teacher supports students' needs and desires and a concept which conforms with psychological need satisfaction within the self-determination theory (Beauchamp and Morton, 2011; Deci and Ryan, 2012). Intellectual stimulation is the degree to which a teacher encourages students to be creative, critical thinkers, and problem solvers and considered to offer a unique view in understanding the effects of transformational behaviors of teachers in physical education (Beauchamp and Morton, 2011). Inspirational motivation is the degree to which a teacher communicates task objectives clearly and meaningfully, which matches the idea of the Pygmalion effect that high and clear expectations can affect performance (Rosenthal and Jacobson, 1968). Idealized influence is the degree to which a teacher resonates with charisma and acts ethically and with integrity among students and a concept similar to role modeling within the social learning theory (Bandura, 1977). Showing these transformational leadership qualities and characteristics to students tends to create a teacher-student connection built on trust, respect, and loyalty, thereby inspiring students to achieve established individual and group class goals. Based on these assumptions, for students to enhance their motivation to participate in PE and their commitment to achieve the desired PE outcomes, PE teachers should demonstrate a high degree of transformational behaviors that consider students' physical strengths and weaknesses, encourage the development of students' creativity and higher-order cognition through sports and games, build students' passion to pursue health and fitness objectives, and set a good example for students by maintaining a healthy weight and practicing active living and healthy behaviors. Therefore, finding the right balance of teaching behaviors that elicits positive outcomes in students is vital for becoming effective PE teachers.

Numerous studies have shown that PE teachers' teaching behaviors can have a profound influence on student outcomes. It was found that PE teachers who provide positive verbal feedback (Koka, 2010; Koka and Hein, 2003), cultivate student autonomy (Van den Berghe et al., 2015; Lewis, 2014), display supportive teaching (Van Doren et al., 2021; Tilga et al., 2020) and practice democratic (Kokkonen et al., 2013; Koka, 2010), and transformational teaching behaviors (Verma et al., 2019; Castillo et al., 2020; Hernández-Martos et al., 2023) affected students' positive affect (Beauchamp et al., 2010), satisfaction (Hsu et al., 2022), motivation (Koka and Hein, 2003; Castillo et al., 2020), and engagement (Van den Berghe et al., 2015; Verma et al., 2019) in PE.

In contrast, findings also revealed that PE teachers who demonstrate uncaring and controlling behaviors (Hein et al., 2015; Koka et al., 2019; Timken et al., 2019) can lead to students' disengagement (Leo et al., 2022; Van den Berghe et al., 2015),

Abbreviations: CI, Confidence interval; CMA, Comprehensive Meta-Analysis; ES, Effect size; LSS, Leadership Scale for Sports; MMSL, Multidimensional Model of Sports Leadership.

demotivation (De Meyer et al., 2014; Koka et al., 2019), boredom (Sanchez-Oliva et al., 2014), and dissatisfaction (Van den Bergh et al., 2015) in PE classes, which in turn are related to decrease in class performance (Behzadnia et al., 2018) and even decreased intention to participate in physical activities outside of PE class (Behzadnia et al., 2018; Koka et al., 2019; Viksi and Tilga, 2022) due to the unfavorable experiences toward PE.

With existing studies on PE teachers' teaching styles and behaviors, researchers have attempted to summarize qualitative (White et al., 2021) and quantitative studies (Guo et al., 2023; Lochbaum and Jean-Noel, 2016; Tao et al., 2022; Vasconcellos et al., 2020). For instance, a review of qualitative studies has revealed the emergence of various themes related to PE teachers. Specifically, PE teachers who are friendly, enthusiastic, and actively engaged with students during class positively influenced students' intrinsic motivation and participation in PE. Moreover, PE teachers who provide students with novel tasks or different options in terms of activities and roles, emphasize fun, challenge, and teamwork, and personally involved in class lessons and activities with students resulted in students reporting enhanced motivation, perceived competence, self-efficacy, and PE participation (White et al., 2021). PE teachers who emphasize competition and performance scores, only pay attention to physically talented students, publicly choose teams without any student consultation, and allow students to perform individually in front of others have been found to undermine students' motivation and perceived competence (White et al., 2021). On the other hand, findings from quantitative studies using a meta-analysis revealed that PE teachers who provided autonomy support instruction showed large effects on students' motivation and positive emotions during PE and leisure time. However, the influence of PE teacher autonomy support on students' physical activity motivation is weak (Lochbaum and Jean-Noel, 2016).

Indeed, a systematic review of qualitative and quantitative studies has provided better insights into the critical role of PE teachers' behaviors in shaping students' learning outcomes. However, because of the vast number of textual documents that were manually checked and evaluated during data synthesis in a previous qualitative review (White et al., 2021), it is likely that other concepts or themes related to PE teacher leadership and student outcomes were omitted and thereby remain open for further exploration. The use of a more sophisticated, automatic, unbiased, and faster approach to synthesizing and summarizing content from large collections of documents may provide new and more in-depth insights into the key concepts associated with this topic. Whereas previous meta-analyses often encountered large variations in student outcomes (Lochbaum and Jean-Noel, 2016; Vasconcellos et al., 2020), researchers tend to combine these variables, leading to potential challenges in understanding the nuances or distinct consequences of the phenomenon under investigation. Additionally, because meta-analysis studies are generally concerned with statistical values to calculate and summarize relevant variables, studies with or without insufficient quantitative data are often excluded (almost 90%) from the assessment process, thereby losing considerable information that may be vital for researchers. It would therefore be noteworthy to first explore the content of these related studies by systematically analyzing these documents to identify prospective distinct variables prior to summarizing the statistical data of quantitative studies. Thus, it is likely to draw better conclusions about the overall impact of PE

teachers' leadership styles and behaviors on students' learning outcomes.

Recently, a novel mixed-method approach has been developed, called the Hybrid Data Synthesis Technique (HDST) (Kim and Cruz, 2022), which synthesizes relevant studies on a given topic and evaluates both lexical and numerical data via content analysis and meta-analysis. The advantage of the HDST approach is that researchers can gain an overall and more robust perspective on a certain topic by examining both qualitative and quantitative studies for potential concepts and themes using data mining and analyzing numerical information via meta-analysis. The outcomes are then used to determine whether the lexical and statistical findings converge or diverge from one another. With these summative findings, researchers and/or practitioners can gain more meaningful insights into the research topic being investigated, which can be potentially overlooked using conventional systematic review approaches and, in turn, provide appropriate practical and/or theoretical recommendations on how to solve a problem and/or advance a research field. For example, when using the HDST to examine the relationship between transformational leadership and well-being in the service industry, the authors found convergence between themes, concepts, and statistical results related to leadership and well-being. However, they also identified findings that were either unique or inconsistent with the results from separate qualitative and quantitative analyses, highlighting both the limitations of each research methodology and potential directions for future studies. Notably, they encourage other researchers to consider using this approach when exploring data from both qualitative and quantitative studies (Kim and Cruz, 2022). Hence, adopting the HDST approach in collecting, synthesizing, and evaluating both qualitative and quantitative studies on PE teacher leadership and student outcomes may reveal new themes and concepts associated with this research area coming from all available textual documents as well as determine the magnitude of the relationship between the predictor and outcome variables based on relevant statistical data, thereby offering a more robust and comprehensive understanding of the research landscape of leadership in PE in general and the impact of the leadership styles and behaviors of the PE teacher on various learning outcomes in particular.

Therefore, the purpose of this investigation was to systematically review and analyze both qualitative and quantitative studies that focused on the relationship between PE teachers' leadership and student outcomes in the field of PE using the HDST approach (Kim and Cruz, 2022). The following research questions are explored in this study:

- 1 What major themes and concepts would emerge from the synthesized lexical data related to the leadership of PE teachers and student outcomes?
- 2 What major themes and concepts would emerge from the synthesized lexical data related to PE teachers' leadership and student outcomes based on regional affiliations?
- 3 What is the overall effect size (ES) of the relationship between PE teacher leadership and pertinent student outcomes?
- 4 Will the leadership behaviors of PE teachers affect student outcomes differently for male and female students?
- 5 Will there be convergence or divergence between the results of qualitative and quantitative studies?

2 Method

This study employed a mixed-method approach to answer its research objectives, consistent with the critical appraisal methodologies proposed by Heyvaert et al. (2013) and Kim and Cruz (2022). The mixed-methods approach integrated both textual (qualitative) and numerical (quantitative) data, acknowledging the significance of combining these forms of evidence to produce thorough insights (Pluye and Hong, 2014; Schoonenboom and Johnson, 2017).

The methodological technique for data synthesis in this study was delineated into two separate phases. The initial phase involved the collection and preliminary analysis of both qualitative and quantitative data, ensuring that each data type was meticulously assessed for its possible themes and concepts. The second phase, adhering to the recommendations of Kim and Cruz (2022), assessed the effect size scores concerning potential linkages among underlying factors and moderators for a comprehensive interpretation. The Hybrid Data Synthesis Technique (HDST) combines the strengths of narrative (qualitative) and numerical (quantitative) data, adhering to the guidelines established by Pluye and Hong (2014) and Kim and Cruz (2022) to leverage the “power of stories and numbers” in formulating robust conclusions.

2.1 Phase 1: systematic review and data mining

2.1.1 Phase 1 text-data source selection

For the initial analysis of Phase 1, the data sources utilized were the Scopus, PsycINFO, PubMed, and SPORTDiscus databases. The authors simultaneously performed the initial search across these databases using a combination of interconnected keywords, including terms like “physical education teacher,” “leadership,” “leadership styles,” “teacher behavior,” “student outcomes,” “student satisfaction,” “student engagement,” and “learning outcomes.” Inclusion criteria for studies required that they: (1) written in English and available in full text, (2) focus on physical education context and its influence over students at various levels, and (3) be published in peer-reviewed journals prior to June 3, 2023, with the relevant scope range regarding the keywords listed above.

The initial literature search yielded 19,597 articles. After further filtering according to the specified inclusion parameters and removing duplicates, 285 published articles were eligible for additional screening. The authors conducted individual screening searches and obtained pertinent documents by carefully evaluating the content based on predetermined inclusion criteria. Eligible documents were subjected to a rigorous review process and were subsequently excluded based on the following criteria: (1) not within the context of physical education ($n = 118$), (2) unavailability of the full text for each article ($n = 3$), (3) non research articles ($n = 6$), (4) physical education topic unrelated to teacher leadership/student outcomes ($n = 4$), or (5) dispute regarding the article's relevance and selection ($n = 4$). The authors extensively examined whether an article met the selection criteria, but failed to reach a consensus of 80%. Of the initial collection of articles ($n = 285$), 52.6% ($n = 150$) were deemed pertinent for Phase 1 of the analysis, as determined by the selection criteria and by incorporating both qualitative and quantitative approaches. To prepare for additional data synthesis and analysis, the incorporated

articles were converted into an analyzable format. Additional information regarding the techniques used for synthesizing and analyzing the data is shown in Figure 1.

2.1.2 Data-mining analysis

The text data from the initial set of 150 articles were examined through a text data mining approach employing Leximancer (version 5.0; Leximancer Pty Ltd). This software facilitates the visualization of text data by validating and presenting thematic and conceptual maps. It can uncover and highlight interconnections or groupings of themes and concepts. An essential advantage of this data mining technique is its proficiency in visualizing the central topics within text data. This visualization aids in comprehending the inherent structure of the text data (Angus et al., 2013; Hyndman and Pill, 2018). Leximancer is widely recognized as a text analytic tool that automatically generates a thesaurus of words and phrases based on contextual similarities as well as semantic and relational extraction (Thomas, 2014).

Based on the theoretical framework of the Bayesian decision theory (Bühlhoff and Yuille, 1996), this analytical tool generates a graphical representation using its conceptual and thematic mapping algorithms. Forming equivalent thematic and conceptual networks (Hyndman and Pill, 2018; Thomas, 2014), the concept map of Leximancer depicts the relative co-occurrence of words and phrases. Leximancer generates bubble-shaped clusters representing “concepts” that have been transformed or classified into “themes” according to their associated keywords (Angus et al., 2013; Thomas, 2014), after the analysis of the data. To comprehend Leximancer's concept map, the following characteristics must be considered. (1) The clusters are depicted by colors that indicate the degree of importance for each subject. Warm shades such as red and orange signal a higher level of connectivity to the theme, while cool colors like blue and green signify a lesser level of connectedness to the theme. Further details can be found in Leximancer user guide release 5.0, where the magnitude of a theme's circle signifies its degree of interconnection within the program's concept map (Lemon and Hayes, 2020).

2.2 Phase 2: meta-analytic review

2.2.1 Phase 2 coding data for meta-analytic review

A comprehensive examination of the textual data obtained in phase 1 was conducted in phase 2 through a meta-analysis of the selected articles. During phase 2 of the analysis, we adhered to the fundamental procedures recommended by the Preferred Reporting Items for Meta-Analysis (PRISMA) standards (Panic et al., 2013). Out of the original set of 150 articles, studies employing a qualitative design were automatically eliminated (28 studies), whereas the remaining mixed-method and quantitative studies underwent further evaluation. Of the 122 studies examined, 49 with a combined sample size of 13,779 were considered eligible for inclusion in the meta-analysis because these studies contained correlation matrices with adequate statistical information to compute ES (Figure 2). The selected articles were grouped according to gender ratios (i.e., the proportion of different sexes in the PE Programs) to determine the potential moderating effect of student gender on the relationship between PE teachers and student outcomes, as proposed in a previous study (Guo et al., 2023). The specific processes of Phases 1 and 2 are outlined in Figure 2.

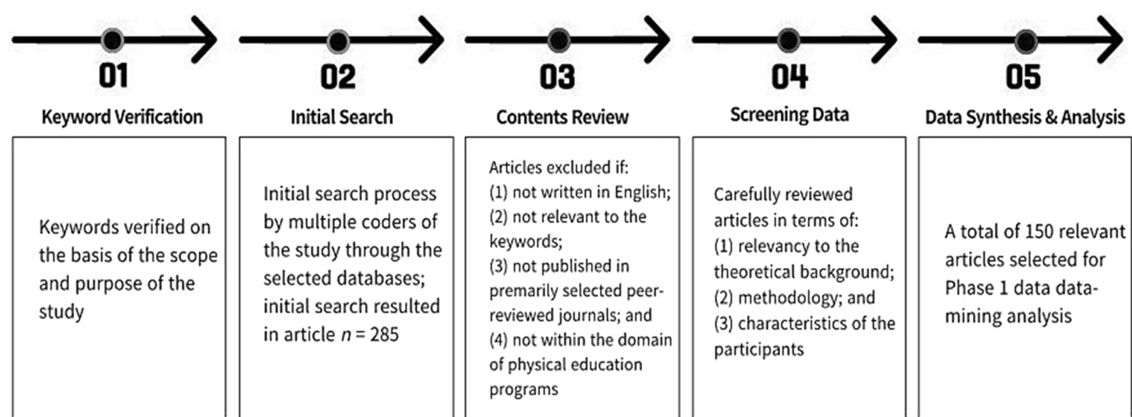


FIGURE 1
Procedural details of text-data coding and analysis.

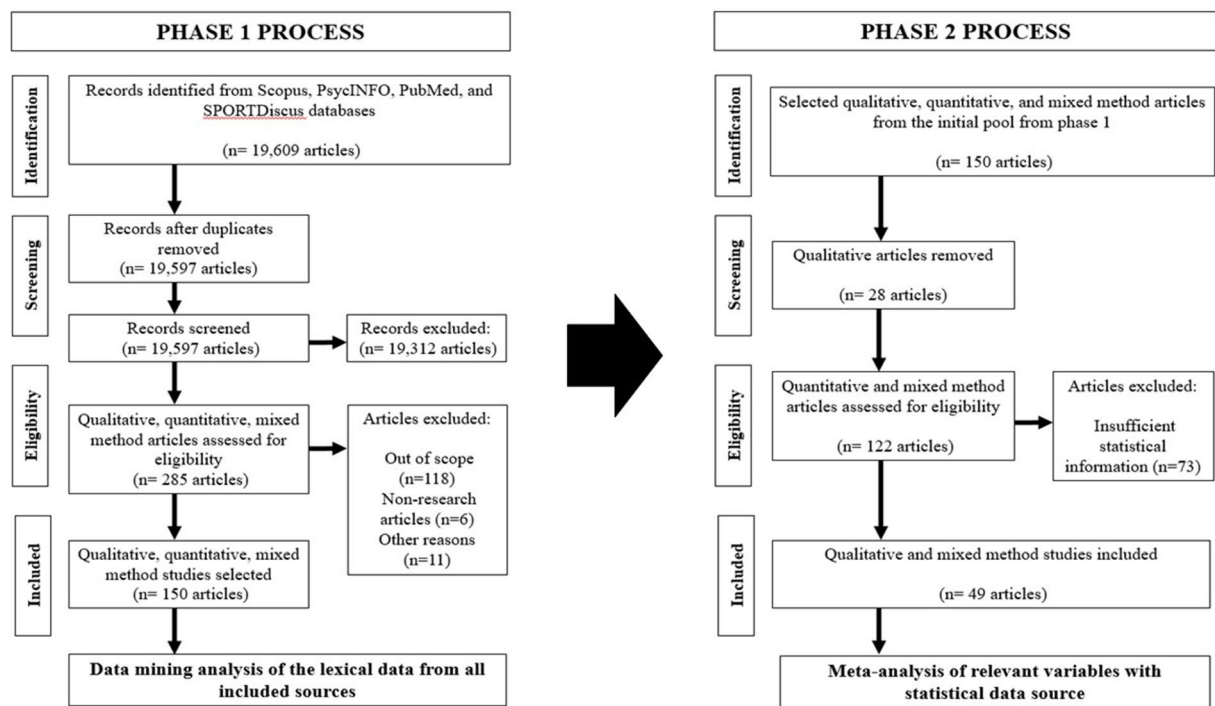


FIGURE 2
Flow diagram of the Hybrid Data Synthesis Technique for phase 1 and phase 2 processes.

Possible publication bias for the studies accepted in this study were assessed by the funnel plot of Hedges's g values based on their standard errors. It is important to gain insights into potential presence of publication bias for further meta analytic analyses. Studies accepted with larger sample sizes (i.e., therefore more precise estimates) tend to be plotted symmetrically and also toward the top of the funnel plot graph, indicating no publication bias (see [Supplementary Figure 1](#)-funnel plot). Based on the funnel plot of PAS and PO variables, the distribution of plot showed symmetry of points on both sides, suggesting no indication of publication bias. Moreover, the Hedges's g values was .5057, $p > 0.05$ which also confirms no publication bias.

A statistical model utilizing random effects was chosen for the analysis of the data ([Petitti, 2001](#)) based on the assumption of heterogeneity. A random-effects meta-analysis was conducted according to the guidelines provided by [Hunter and Schmidt \(2004\)](#).

Comprehensive meta-analysis software (CMA) was used to compute pertinent statistical data, including sample sizes and correlations, acquired from quantitative studies. These data were used to estimate 95% confidence intervals and the extent of certainty ([Borenstein et al., 2009](#)). A value of ES equal to or greater than 0.5 is considered to be a large effect size, while a value between 0.30 and .49

is considered to be a moderate effect size. A value less than 0.30 is considered to be a small effect size (Fritz et al., 2012; Cohen, 1988).

3 Results

3.1 General results

Overall, the included articles related to PE leadership were published from 2003 to 2023. Majority (84%) were conducted from 2011 to 2023 and with the highest number of studies observed in 2021 (23 articles). In terms of region, 47% of the articles were conducted in Europe, followed by North America (25%), Asia (17%), and Oceania and others (11%). The research method used was mostly quantitative studies (71%), while the remainder employed qualitative methods (19%) and mixed methods (10%). The summary information of all articles can be found in the [Supplementary Table](#)-summary of articles.

3.2 Results of the data-mining analysis

The analyses for this research were conducted in two distinct phases, as described in the methodology section. Using data mining technology, the initial phase entailed an examination of selected articles concerning PE teacher leadership and student-related outcomes. The objective of this procedure is to authenticate common themes and ideas extracted from the textual data of the selected articles.

The graphical representation generated by Leximancer data-mining software is known as a “concept/cluster map,” which illustrates the concepts and themes prevalent in a given text data source. The relevance of a theme or concept as well as the degree of mathematical interconnection among words is discernibly indicated on the concept map through variations in the size and color of the words (Thomas, 2014). The ability to generate conceptual maps throughout the production of meaningful outputs is the most distinctive characteristic of this analytical instrument. In terms of the capacity to handle substantial amounts of data and resistance to human bias, this characteristic establishes this analytical instrument is more effective than conventional qualitative analysis approaches (Sotiriadou et al., 2014). The key characteristics of the Leximancer conceptual map include the following: (1) colors, which represent the significance of each theme (e.g., the least connected theme is purple, and the most significant is red) and (2) the magnitude of the theme, which signifies the degree to which a concept appears to cluster with other concepts in a single text-mining analysis. The terms “themes” are used to denote clusters of concepts that range in temperature from warm (red, orange) to cold (blue, green).

Overall, eight major themes were confirmed by the data mining analysis conducted in Phase 1 throughout the selected articles (see [Table 1](#)). The theme education had the highest significance in terms of hit count and connectedness, followed by motivation, teaching, support, group, engagement, values, and exercise. The education theme contains word concepts such as “sport,” “physical,” and “Physical Education” while the motivation theme contains several word concepts including “classroom,” “development,” “performance,” “climate,” “academic,” “process,” and “participation.” The support theme contains word concepts such as “autonomy,” “perceived,” “positive,” “outcomes,” “content” and “satisfaction,” while the teaching

theme comprises word concepts such as “learning,” “social,” “competence,” “personal” and “multiple” ([Figure 3](#)).

For the themes and concepts generated from all studies categorized according to continent, the results showed that, for Asian studies, the most prominent theme that emerged was autonomy, followed by performance, teaching, and experimental. The autonomy theme contains the word concepts such as “engagement,” “agentic,” “support,” “perceived,” “controlling,” and “supportive.” The performance theme includes word concepts such as “motivation,” “positive,” “negative,” “academic,” “knowledge,” and “individual.” The teaching theme contains word concepts such as “development,” “beliefs,” “physical,” “change,” and “intentions,” while the experimental theme has word concepts such as “condition” and “control” ([Figure 4](#)).

In European studies, only five major themes have been generated by text-mining analysis. These themes are support, motivation, education, values, and teachers themes. The support theme emerged as the highest theme with word concepts such as “autonomy,” “physical,” “teaching,” “competence,” “satisfaction,” “positive,” “frustration,” and “differences.” The motivation theme contains word concepts such as “quality,” “relationship,” “life,” “engagement,” “climate,” and “autonomy-supportive,” and “questionnaires.” The education theme includes word concepts such as “physical” sport and “physical education” ([Figure 5](#)).

In North American studies, the most prominent theme is learning, followed by climate, physical education, and health. The learning theme contains word concepts such as “teaching,” “development,” “social,” “classroom,” “interest,” “practice,” “caring,” “role,” and “process.” The climate theme includes word concepts such as “motivation,” “performance,” “engagement,” “relatedness,” “goals,” “perceptions,” and “different.” The physical education theme only contains the word concept “sport” whereas the health theme includes only has its own word concept ([Figure 6](#)).

Five themes were assessed as being relevant to Oceania and other studies. The theme that emerged was teaching, followed by motivation, physical education, primary education and health. The teaching theme includes word concepts such as “learning,” “knowledge,” “skills,” “social,” “process,” “participants,” “student-centered,” “development,” and “strategies.” The motivation theme contains word concepts such as “control,” “group,” “support,” “interventions,” “positive,” and “autonomy.” The remaining three themes only included their own word concepts ([Figure 7](#)).

3.3 Findings from the meta-analysis

This study incorporated the following student-related outcome variables: (1) satisfaction; (2) amotivation; (3) engagement; (4) motivation; (5) frustration; and (6) competence. When examining the themes and word concepts generated from Phase 1, as well as the common dependent variables measured in the included quantitative studies related to PE teacher leadership, these outcome variables have consistently held considerable importance ([Table 2](#)).

Regardless of gender, the meta-analysis revealed that the relationship between the autonomy-supportive behavior of physical education instructors and student satisfaction had moderate to substantial effects (ES ranged from .456 to .582; 95% CIs = 0.461, 0.572; $k = 59$; $p < 0.05$). Based on student sex, male students exhibited a greater degree of satisfaction (ES: male = 0.582; 95% CIs = 0.538, 0.622; $k = 28$; $p < 0.05$) compared to female students.

TABLE 1 Thematic and conceptual analysis findings resulted from the selected articles by the origins of subjects.

Overall PETL studies	Theme (HC)	Motivator (488)	Education (615)	Support (275)	Teaching (318)
		Group (247)	Engagement (203)	Values (180)	Exercise (383)
		Teaching (176)			
	Concepts (HC/RP)	Motivation (196/66%), teaching (126/43%), support (91/31%), learning (75/25%), engagement (75/25%), autonomy (71/24%), reliability (67/23%), group (67/23%), social (58/20%), values (51/17%), motivational (46/16%), perceived (46/16%), development (45/15%), competence (39/13%), controlling (39/13%), fit (39/13%), validity (37/12%), different (36/12%), knowledge (36/12%), leadership (36/12%), performance (35/12%), classroom (34/11%), intervention (34/11%), climate (32/11%), positive (32/11%)			
ASIAN PETL studies	Theme (HC)	Autonomy (62)	Performance (64)	Teaching (52)	Experiment (52)
		Exercise (80)	Leadership (25)	Autonomy (15)	Group (11)
		Questionnaire (13)	Instruction (3)		
	Concepts (HC/RP)	Autonomy (30/47%), agentic (22/34), support (21/33%), engagement (19/30%), positive (18/28%), leadership (17/27%), performance (16/25%), physical (16/25%), factor (14/22%), motivation (10/16%), teaching (10/16%), fit (10/16%), negative (9/14%), questionnaire (9/14%), belief (8/12%), perceived (7/11%), experimental (7/11%), condition (7/11%), knowledge (7/11%), controlling (6/9%), development (6/9%), control (6/9%), group (6/9%), social (6/9%), change (6/9%)			
North American PETL studies	Theme (HC)	Learning (209)	Climate (132)	Physical Education (151)	Health (4)
	Concepts (HC/RP)	Teaching (50/100%), motivation (40/43%), social (30/33%), development (26/28%), learning (25/27%), interest (25/27%), practice (25/27%), personal (24/26%), climate (22/24%), engagement (15/16%), performance (14/15%), classroom (14/15%), caring (14/15%), support (14/15%), variables (14/15%), children (13/14%), participants (13/14%), play (13/14%), evaluation (12/13%), reliability (12/13%), others (11/12%), relatedness (11/12%), positive (11/12%), different (11/12%), task (10/11%)			
European PETL studies	Theme (HC)	Support (589)	Motivation (338)	Education (348)	Values (146)
		Teachers (149)			
	Concepts (HC/RP)	Motivator (141/97%), physical (97/66%), teaching (87/60%), support (82/56%), autonomy (59/40%), competence (53/36%), group (44/30%), relationship (41/28%), frustration (41/28%), values (41/28%), sport (40/27%), different (38/26%), lesson (38/26%), differences (37/25%), quality (36/25%), skills (36/25%), satisfaction (36/25%), learning (35/24%), engagement (32/22%), controlling (31/21%), intervention (30/21%), life (29/20%), social (29/20%), motivational (27/18%), factor (27/18%)			
Oceania PETL studies	Theme (HC)	Teaching (132)	Motivation(76)	Physical Education (34)	Primary(4)
		Health(9)			
	Concepts (HC/RP)	Motivation (37/88%), teaching (32/76%), learning (32/76%), social (16/38%), knowledge (14/33%), group (14/33%), relatedness (12/29%), work (11/26%), cultural (11/26%), skills (10/24%), support (10/24%), intervention (10/24%), student-centered (9/21%), development (9/21%), critical (9/21%), program (9/21%), health (9/21%), process (8/19%), control (8/19%), content (8/19%), participants (7/17%), controlled (7/17%), role (7/17%), educational (7/17%), curriculum (7/17%)			

PETL, physical education teacher leadership; HC, hit count; RP, relevancy percentage. The relevancy percentage is the percentage frequency of text segments coded with that concept from the origins of the participants sector; all themes analyzed by the Leximancer program are presented in the row, “Theme”; top 25 concepts are listed in the row.

The relationship between student amotivation and supportive behaviors of physical education teachers exhibited negative effect sizes, with values ranging from -0.00788 to -0.252 (95% CIs = -0.239 , -0.034 ; $k = 15$; $p < 0.05$). Based on student sex, the ES value for the relationship was more negative for the female student group (ES female = -0.254 ; 95% CIs = -0.123 , -0.377 ; $k = 8$; $p < 0.05$).

The effect sizes for the correlation between supportive behaviors of physical education instructors and student engagement were predominantly positive (ES ranged from $.346$ to $.400$; 95% CIs = 0.239 , 0.453 ; $k = 23$; $p < 0.05$). Based on student sex, male students exhibited a greater degree of engagement (ES male = 0.400 ; 95% CIs = 0.360 , 0.438 ; $k = 2$; $p < 0.05$) compared to female students.

The effect sizes ranging from $.434$ to $.522$ (95% CIs = 0.404 , 0.541 ; $k = 24$; $p < 0.05$) for the association between PE teachers’ supportive behavior and student motivation were also within the positive range. Based on student sex, this relationship was associated with a relatively higher ES value among female students (ES female = 0.522 ; 95% CIs = 0.428 – 0.606 ; $k = 11$; $p < 0.05$).

The relationship between supportive behaviors of physical education teachers and student frustration exhibited negative effect sizes, with values ranging from -0.00712 to -0.205 (95% CIs = -0.190 , 0.005 ; $k = 15$; $p < 0.05$). Based on student sex, the ES value for the relationship was more negative for the female students (ES female = -0.00712 ; 95% CIs = -0.190 , 0.005 ; $k = 8$; $p < 0.05$).

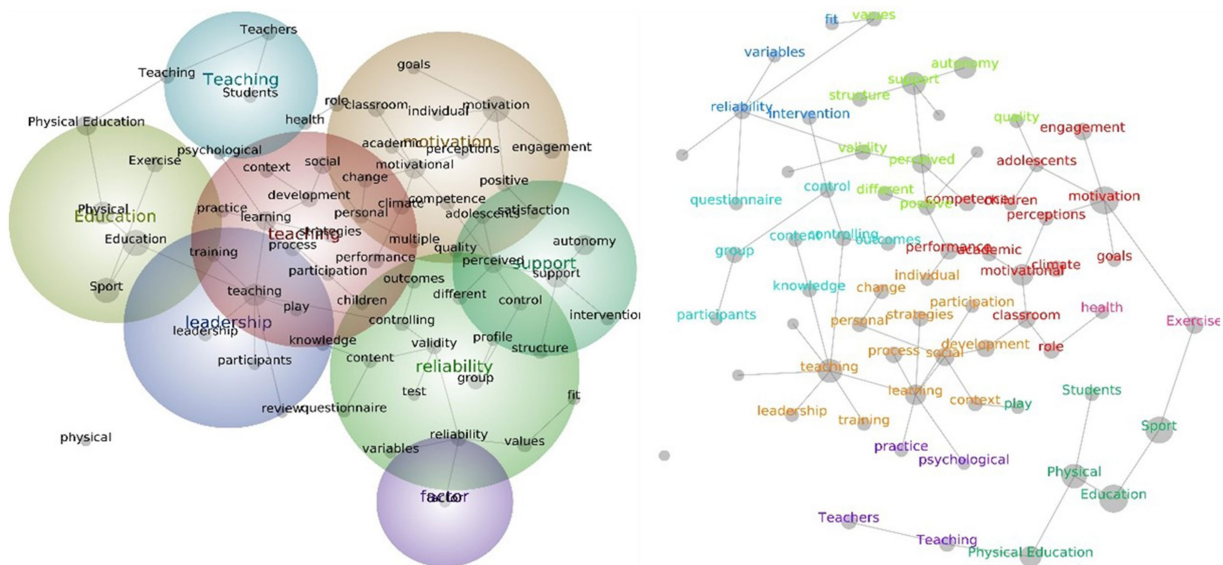


FIGURE 3

Social network and concept map views for the overall PE teacher leadership studies. The relative size of each theme circle is the boundary of clustered concepts; hot colors (red, orange) indicate the most important themes and cool colors (blue, green) denote those less important.

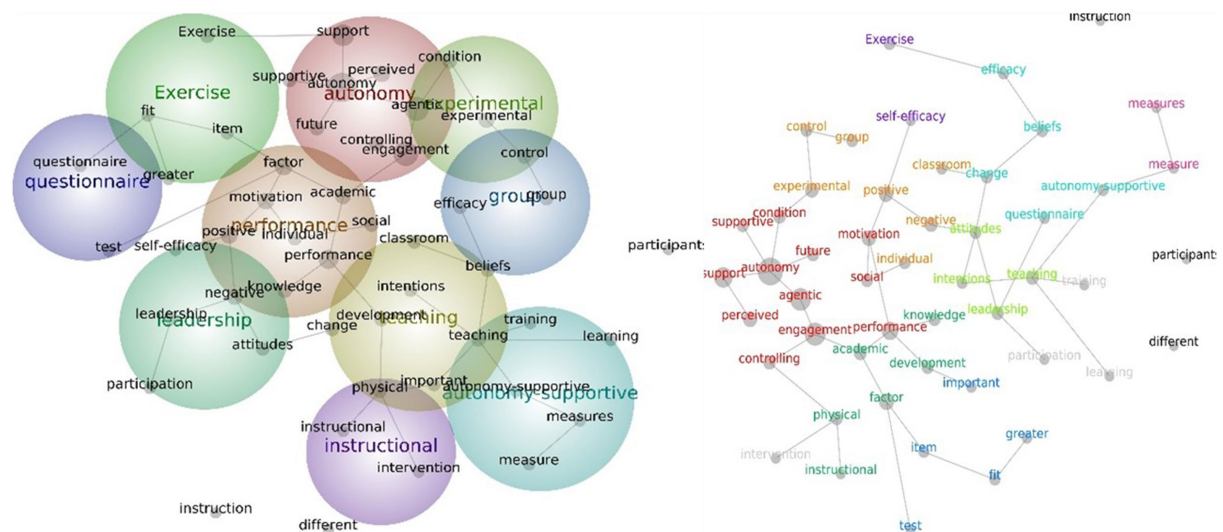


FIGURE 4

Social network and concept map views for the Asian PE teacher leadership studies. The relative size of each theme circle is the boundary of clustered concepts; hot colors (red, orange) indicate the most important themes and cool colors (blue, green) denote those less important.

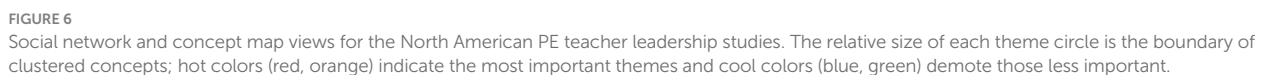
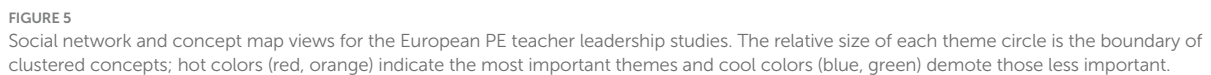
The effect sizes ranging from .198 to .440 (95% CIs = .0171, 0.459; $k = 14$; $p < 0.05$) for the relationship between the supportive behavior of PE instructors and student competence were moderate. Based on student sex, male students ($ES = 0.440$) exhibited a greater degree of competence compared to female students ($ES = 0.198$).

4 Discussion

This study systematically synthesized and evaluated pertinent qualitative and quantitative literature on PE teachers' leadership styles

and behaviors and their associations with student outcomes using a mixed methods (HDST) approach to examine both lexical and statistical data through data mining and meta-analyses, respectively.

Based on the findings in the first phase of the HDST technique, we found that overall, eight (8) themes emerged to be associated with PE teacher leadership. Motivation, education, support and teaching themes were identified as major themes with connectivity scores of 931, 593, 511, and 461, respectively, indicating their relative importance. Primary concepts contained within these major themes include: "classroom," "development," "performance," "climate," "process," "strategies," "adolescents," "academic," "play" and



leading to positive outcomes such as motivation, competence, satisfaction, and learning in PE. This finding substantiates the idea that PE teachers are important educational leaders who can facilitate motivation and other PE-related outcomes of students by demonstrating positive leadership styles and teaching behaviors, creating fun and meaningful PE class settings, and providing additional support for the transformational leadership approach. In addition, the relevant themes and concepts connected with these themes are in line with the Self-Determination Theory (SDT) (Deci

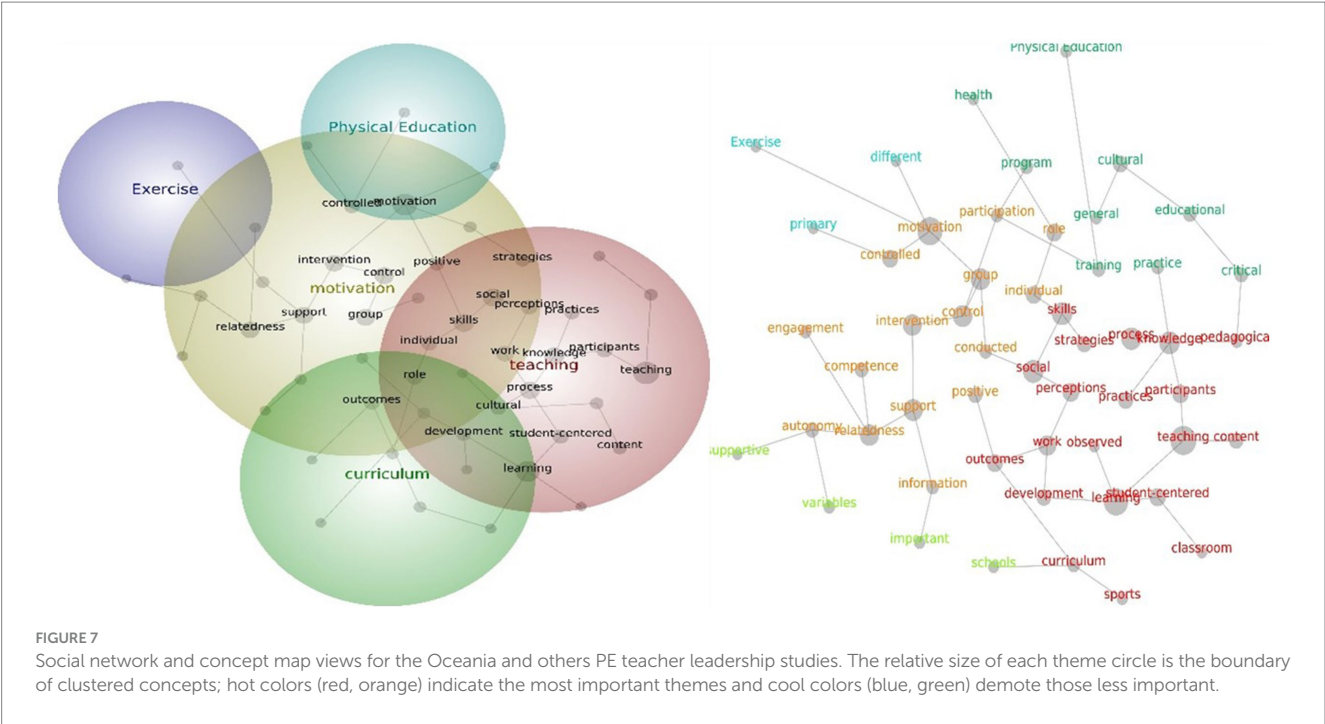


TABLE 2 Effects of autonomous support of PE teachers' behavior on student outcome variables.

Variables	Gender Segmentation	k	ES	−95%CI	+95%CI	Q	I ²	Tau
Satisfaction	Overall	59	0.518	0.461	0.572	4039.327	98.564	8.63E-02
	Female	31	0.456	0.345	0.555	3184.715	99.058	0.138782
	Male	28	0.582	0.538	0.622	643.107	95.801	2.78E-02
Amotivation	Overall	15	−0.138	−0.239	−0.034	567.562	97.533	4.14E-02
	Female	8	−0.254	−0.377	−0.123	172.094	95.932	3.66E-02
	Male	7	7.88E-03	−1.26E-02	2.83E-02	167.657	96.421	0.020951
Engagement	Overall	23	0.351	0.239	0.453	2257.753	99.025	8.79E-02
	Female	21	0.346	0.220	0.461	2204.881	99.092	0.101616
	Male	2	0.400	0.360	0.438	2.269	55.946	6.35E-04
Motivation	Overall	24	0.476	0.404	0.541	983.194	97.660	4.69E-02
	Female	11	0.522	0.428	0.606	297.234	96.635	4.07E-02
	Male	13	0.434	0.324	0.532	679.525	98.234	0.05441
Frustration	Overall	10	−9.77E-02	−0.201	8.54E-03	237.890	96.216	2.83E-02
	Female	8	−7.12E-02	−0.190	5.00E-02	200.468	96.508	0.029497
	Male	2	−0.205	−0.356	−4.53E-02	8.284	87.929	1.23E-02
Competence	Overall	14	0.323	0.171	0.459	998.725	98.698	9.28E-02
	Female	7	0.198	−4.17E-02	0.416	465.499	98.711	0.10464
	Male	7	0.440	0.322	0.544	174.342	96.558	3.29E-02

k, number of comparisons; CI, confidence interval; Q, Q-value; I², I-Squared; Tau, Tau-Squared.

and Ryan, 2012) which proposes how social factors can either enhance or undermine an individual's volitional form of motivation, well-being, and performance. Particularly, the level of intrinsic motivation that can be influenced by a person's perceived support or restraint of their psychological needs (i.e., competence and autonomy) in a social context (PE class). This theoretical approach is evident in most of the

articles included in this study (Cheon et al., 2022; Liu and Chung, 2017; Reeve et al., 2020) which resulted in a conceptual map with word concepts that are highly relevant and interlinked with this theoretical framework. The finding provides evidence that these theoretical approaches have concepts that can shed light in understanding human behaviors, especially how situational or

external variables such as a leader (i.e., teacher) can impact responses of followers (students).

The minor themes that were generated, which include engagement and values contained word concepts such as “structure,” “questionnaire,” “variables,” “reliability,” “validity,” and “children,” were found to be semantically connected, suggesting the type of research methodology conducted in this topic and the study participants from whom they collected the responses. This finding is not surprising, given the large number of articles that employed quantitative methods to examine PE teacher leadership, accounting for more than 70% of the included studies. However, it is interesting to point out that, through the use of the data mining tool, this quantitative information about the general profile of studies was also effectively identified via the connectivity of relevant themes and concepts generated from the automatic and systematic extraction, inspection, and analysis of each text contained in the entire set of articles. Moreover, with the available conceptual map visually displaying a network of interconnected concepts, detecting and classifying important themes and their relationships is much faster and more efficient, demonstrating that statistical records can also be reflected through textual outputs via data mining technology.

4.1 Concepts and themes based on regions (Asia, Europe, North America, Oceania and others)

Comparing the relevant concepts and themes based on the regional origins of published articles, the results showed that while the number of significant themes varied among regions (Asia: nine; Europe: five; North America: four; Oceania and others: four), each region's key concepts within the major themes were very similar, showing strong relationships with PE teacher leadership behaviors and student outcomes. For instance, high level concepts such as “student-centered,” “social process,” “caring,” “development,” “support,” “autonomy,” “learning,” and “teaching” reflect the PE teacher's teaching process and behaviors to carry out with students as well as the kind of classroom environment to cultivate during PE class. Other relevant concepts that are similar among regions include “motivation,” “performance,” “perceptions,” “positive,” “negative,” “knowledge,” and “engagement,” indicating the student outcomes commonly examined by researchers to be influenced by PE teacher leadership.

Interestingly, the word “health” was not generated as a relevant concept in Asia and Europe but was represented in North America, Oceania, and others. This discrepancy indicates that studies from the latter regions have managed to highlight the concept of health as an important aspect of PE and the significant role of PE teachers' leadership in facilitating the promotion of health. However, this emphasis on health is somewhat less pronounced in studies from Asia and Europe, which are estimated by the text-mining tool as an insignificant concept. Perhaps the literature included within these regions still places considerable emphasis on PE curriculum content, which is predominantly toward motor and sports skill development, performance-or competition-based programs, and physical activity participation (Katsarova, 2016; Hardman, 2008). In turn, PE teachers may feel obligated to prioritize these aspects in their teaching, which eventually led researchers to investigate the effectiveness of PE teachers' leadership and teaching behaviors in delivering PE lessons, using

traditional class-related outcome assessment tools to gauge students' perceptions and behaviors regarding their PE learning experiences.

Looking at the significant themes and highly relevant concepts generated in Asian and European studies, it is apparent that the connectivity of concepts mainly illustrates the direct effects of PE teachers' supportive and controlling teaching behaviors on certain behavioral (e.g., performance and engagement) and psychological (e.g., motivation) components of student learning in PE settings. Based on these findings, despite the fact that PE curricular reforms have been undertaken in recent years, incorporating the promotion of lifelong active and healthy living (D'Anna et al., 2019; Ha et al., 2008; Lee and Cho, 2014) among students, knowledge is still scarce when it comes to examining students' perceptions of their PE teachers' behaviors and instructions in cultivating the value and development of health and well-being as a learning aspect of PE. Therefore, more studies are needed to examine PE teachers' leadership in achieving the holistic goals of PE among students.

4.2 Relationship between PE teacher leadership and student outcomes

Overall, the results from Phase 2 of the HDST revealed small to large effects of PE teachers' transformational behaviors on students' learning outcomes. Particularly, PE teacher autonomy support had a strong relationship with student satisfaction and a moderate relationship with student motivation, engagement, and competence. By contrast, student amotivation and frustration had negative but very small associations with PE teacher autonomy support. This indicates that when students perceive that their PE teachers display leadership behaviors that support their autonomy, they are likely to experience greater levels of satisfaction and moderate levels of competence and engagement in PE. Moreover, students' feelings of amotivation and frustration tend to decrease with perceived autonomy support from their PE teachers. The present findings are consistent with previous meta-analyses that examined similar outcome variables related to PE teachers' behaviors (Lochbaum and Jean-Noel, 2016; Tao et al., 2022; Vasconcellos et al., 2020) which also showed comparable effect sizes. Additionally, the results align with the transformational teaching framework, wherein transformational teaching behaviors are assumed to affect students' intrapersonal psychological variables such as intrinsic motivation, self-efficacy, and attitudes, which then lead to behavior change. In this context, the transformational behaviors demonstrated by the PE teacher that nurture autonomy of students such as trusting them to make their own decisions, stimulating their critical thinking and other high-level cognitive skills, and empowering them to speak their minds, corresponds to idealized influence, intellectual stimulation, and inspirational motivation, respectively. When PE teachers utilize these behaviors, it can improve students' attitudes toward the teacher, increase their motivation in PE, enhance satisfaction and self-confidence, and reduce feelings of amotivation and frustration and eventually lead to greater student engagement in PE.

This result provides additional evidence about the importance of PE teachers' positive teaching and leadership, specifically behaviors that cultivate student autonomy, in developing various learning outcomes in students during PE classes. This finding also underscores that the influence of PE teachers' leadership may vary in degree depending on the type of learning domain being evaluated.

4.3 Relationship between PE teacher leadership and student outcomes based on gender

When examining gender as a moderating variable, the results showed that the effect of PE teacher leadership on student satisfaction, competence, and engagement was higher for males (satisfaction $ES=0.582$; competence $ES=0.44$; engagement $ES=0.400$) than for females (satisfaction $ES=0.456$; competence $ES=0.198$; engagement $ES=0.346$), while student motivation was greater for females ($ES=0.522$) than for males ($ES=0.434$). These findings suggest that perceptions of satisfaction, competence, and engagement tend to be higher in males than in females, and motivation tends to be higher in females than in males when PE teachers display high levels of positive and autonomy-enhancing leadership behaviors.

The differences in perceptions [i.e., satisfaction, competence, engagement, (a)motivation, and frustration] between male and female students are likely to be associated with the gender of the PE teacher, the degree and type of interactions the PE teacher shows the students, and the students' preferences for certain PE behaviors. Nicaise et al. (2007) examined PE teacher-student interactions during PE classes and reported that PE teachers gave more frequent praise, technical information, encouragement, criticism, organization, and misbehavioral feedback to male students, whereas they provided more positive reinforcements such as technical information and encouragement to girls. In another study, female PE teachers were observed to have fewer interactions with female students than male students, whereas male PE teachers had fewer interactions with male students than with female students (Davis and Nicaise, 2011). Finally, in a similar study on sports, the leadership preferences of young male and female athletes differed based on the gender of the coach. In particular, boys preferred that their male coaches display fewer occasions of democratic, autocratic, and social support than female coaches. Conversely, girls preferred that their male coaches show more frequent democratic, autocratic, and social support leadership behaviors than female coaches. Based on these previous findings, when male and female students perceive that their male and female PE teachers demonstrate positive leadership behaviors, such as supporting students to become independent learners and motivating them to explore innovative ways to play games and engage in physical activities during class, they are likely to feel greater satisfaction, motivation, engagement, and competence during PE class and experience slightly lower levels of frustration and amotivation.

In general, the present results highlight not only the importance of student gender as a moderating variable in the relationship between PE teacher leadership and student outcomes but also showcase the dynamics among the personal characteristics of both students and PE teachers. More importantly, this study adds new knowledge to the literature on PE leadership, addressing the call from previous researchers to examine this factor (Guo et al., 2023).

4.4 Divergence and convergence between qualitative and quantitative findings

Based on the overall summary from examining all textual documents using the automated text analysis, the words "motivation" and "satisfaction" are found to be relevant word concepts with high connectivity with PE teachers. Furthermore, these two concepts

acquired the highest ES values among the outcome variables examined in the meta-analysis. The correspondence in the results between the semantic and statistical information underscores the important function of the emergent themes and concepts from processing qualitative data in guiding researchers regarding which variables are worth exploring as potential outcome variables to undergo meta-analysis.

On the other hand, based on the overall result from the qualitative data, "health" was identified as a relevant concept with distinct connections with "student" and "goals" concepts contained in the teaching theme. This indicates that teaching PE is vital for students to achieve their health goals. Based on the text mining results, the teaching theme's connectivity score (129), compared with the main themes motivation (931), education (593), and support (511) was considerably low, suggesting very weak associations with these important themes and concepts. However, of all the included quantitative articles, no researchers directly examined whether students explicitly recognized the value of PE for health improvement through the teaching behaviors of their PE teachers, thereby reflecting a discrepancy between the qualitative and quantitative outcomes.

In many countries, the PE curricula have been revised to meet learners' current needs. From PE objectives mainly focused on developing students' motor and sport skills, current PE programs recently incorporate objectives that emphasize fostering the promotion of healthy lifestyle and the value of physical activity for fitness, and health (D'Anna et al., 2019; Kurokawa et al., 2020; SHAPE America, 2024). To determine whether the additional health-related objectives of PE education are truly effective, it is just appropriate the learning outcomes should be evaluated based on empirical evidence.

However, the present study's quantitative and qualitative findings reveal that a knowledge gap still exists regarding the influence of PE teachers' leadership on students' thoughts, attitudes, and behaviors toward PE and physical activities, above and beyond the frequently evaluated student-related outcomes (i.e., satisfaction, enjoyment, and motivation). Therefore, it is suggested that more comprehensive research be conducted on the role of PE teacher leadership. In particular, the scope of future studies should be expanded by examining outcome variables focused on students' experiences of their PE teachers' behaviors in communicating the value of PE and physical activity in developing and optimizing their overall health. Examining this topic not only sheds light on how PE teachers' leadership influences students' active participation in PE and subsequently resonates with students' lifelong involvement in physical activities but also contributes to the PE leadership literature.

The meta-analysis conducted as part of this review allowed us to investigate student gender as a moderating variable in the relationship between PE teacher leadership and student-related outcomes. From the results, we found that the magnitude of the PE teacher leadership-student outcome relationships differed between male and female students. While moderating variables are commonly examined in meta-analysis when there is substantial heterogeneity in the included studies, interestingly, the word "gender" or "sex" was not found as relevant concept in the results of the qualitative analysis. This corroborates the findings of a previous leadership review that employed the HDST mixed-method approach (Kim and Cruz, 2022). Therefore, the findings highlight that when examining textual documents using content analysis, the absence of relevant concepts pertaining to the personal characteristics of study participants can offer valuable information that may guide researchers in identifying potential variables that can be further explored quantitatively, which

in turn facilitates the understanding of a particular research topic through both macro-and micro-level approaches.

4.5 Implications

Following the findings of the present study, for researchers investigating the leadership phenomenon in PE settings, it is recommended that future studies focus more on evaluating students' cognition of the values they learn every time they attend PE classes, as well as how PE teachers overtly communicate these positive values to students. This involves using or creating evaluation tools in the form of questionnaires that measure students' appraisals toward the meaning of PE and physical activities for health attainment, enhancement, and maintenance. Putting additional emphasis on evaluating the cognitive aspects of students' perceptions of their (non) participation in PE through the behaviors of their PE teachers would provide important information for a better understanding of the complex dynamics of PE teachers' leadership and its impact on student outcomes.

For PE teachers, it is recommended that they should be aware of their students' responses when displaying certain behaviors during PE class. Given the findings that PE instructors' autonomy supportive behaviors have positive (satisfaction, motivation, competence, engagement) and negative (amotivation and frustration) relationships with student outcomes, PE teachers should strive to frequently demonstrate transformational leadership behaviors which also correspond with autonomy-supportive actions. One strategy is for PE teachers to display intellectual stimulation transformational behaviors focused on encouraging students' autonomy. This can be achieved by stimulating students' decision-making and problem-solving abilities. For instance, PE teachers could ask students to choose which physical activities would best suit their individual physical fitness level and motor skill capabilities. By giving students the opportunity to experience analyzing and evaluating options independently, rather than dictating them, they are likely to show positive emotions, attitudes, and behaviors toward the teacher and the class. In addition, considering the present findings that PE teacher leadership behaviors can affect male and female students' outcomes differently, developing new teaching strategies or adopting certain behaviors that would cater to the preferences of each group of students may eventually lead to a more motivational classroom climate and, in turn, better PE engagement. Previous studies have shown that male and female students have different preferences in PE classes, with female students favoring individual sports for fun, while male students enjoying team sports to exercise and build fitness (Cruz, 2021; Kuśnierz et al., 2020). In this case, to empower students and give them a voice in choosing activities during PE sessions, teachers can exhibit autonomy-supportive transformational behaviors such as inspirational motivation and individualized consideration. These behaviors include tailoring instructions and providing specific, constructive feedback (individualized consideration), as well as offering words of encouragement to promote greater effort and engagement in PE and communicating clear expectations about student behavior, health progress, and performance (inspirational motivation).

School administrators can invest in professional development programs that enhance PE teachers' transformational leadership behaviors and teaching skills. These programs should focus on

understanding the principles of transformational leadership and their application to both educational settings in general and physical education (PE) in particular (Beauchamp and Morton, 2011). Additionally, hands-on workshops can provide practical guidance on how, when, and where to demonstrate transformational behaviors in PE classes, as well as which students to focus on. By participating in such training, PE teachers will be better equipped to apply effective strategies based on transformational leadership principles, optimizing student experiences in the classroom while avoiding teaching behaviors that might elicit negative responses from students.

4.6 Limitations

The present study has limitations that need disclosure. First, only six student outcomes (satisfaction, motivation, engagement, competence, frustration and amotivation) were examined in the meta-analysis part of this study. However, these dependent variables were selected using automated processing, substantially mitigating researcher bias while increasing the identification of meaningful variables to evaluate, thereby facilitating researchers' decision-making in terms of the research variables worthy of exploration. Nonetheless, compared with previous reviews, the number of outcome variables examined related to student perceptions about their PE teachers' behaviors is similar to Lochbaum and Jean-Noel (2016), more than Guo et al., (2023) and Tao et al. (2022), but less than Vasconcellos et al. (2020), and therefore provides additional insights about the impact of PE teacher leadership on student outcomes.

Second, only gender was evaluated as a moderating variable in the relationship between PE teacher leadership and student outcomes. While we rigorously screened all quantitative studies to identify other potential moderators for this relationship (e.g., student age or academic level, PE teacher's gender), due to the lack of statistical data from the quantitative studies, we were unable to explore these variables. Hence, additional studies are suggested on this topic so that future researchers reviewing studies related to PE teacher leadership can precisely identify factors that may significantly affect students' positive and negative perceptions toward PE and physical activities.

Third, the analyses only included published articles with accessible full-texts, so some relevant studies on this topic may not have been included in the review. However, we made every effort to reach out to the authors for copies of their papers if the full texts were not available through our library repository. Likewise, another limitation of the study is that some articles were excluded due to a lack of agreement among authors. It is unknown how these articles might have contributed to our understanding of the topic.

Finally, the leadership behavior of PE teachers examined in the meta-analysis was limited to autonomy support, as this was explicitly highlighted in the overall results of the content analysis. This finding may be attributed to the fact that most of the included studies were grounded in Self-Determination Theory (SDT) when investigating the influence of PE teachers on student outcomes. Therefore, researchers are encouraged to further explore this topic through the lens of the transformational leadership framework, as transformational behaviors displayed by teachers and leaders have been shown to predict adaptive cognitive, emotional, and behavioral

responses in students and followers (Beauchamp and Morton, 2011). By using this paradigm, we can better understand the relationship between the transformational leadership behaviors of PE teachers in general, and their specific four dimensions in particular, on various student outcomes.

5 Conclusion

Overall, by reviewing both qualitative and quantitative studies on PE teacher leadership, we found that the autonomy-supportive and controlling leadership behaviors of PE teachers are important themes that are strongly connected with the classroom motivational climate and students' positive perceptions of PE, particularly motivation, satisfaction, competence, and engagement. Second, noticeable variances were found in the major themes and relevant word concepts generated among the included studies, based on the main author's regional affiliation. Third, the concept of health is not a prominent topic explicitly evaluated in relation to leadership in the PE domain. Fourth, PE teacher autonomy support had medium to large positive effects on student satisfaction, motivation, competence, and engagement. PE teachers' autonomy-supportive leadership had a marginally positive effect on students' feelings of amotivation and frustration in PE. Fifth, the effect of PE teachers' autonomy-supportive leadership on students' perceptions of satisfaction, motivation, engagement, competence, frustration, and amotivation differed between male and female students. Finally, the application of the HDST approach to summarize both qualitative and quantitative articles facilitated an understanding of the topic of leadership in the domain of PE in a more robust and comprehensive manner.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1442014/full#supplementary-material>

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Follow the eyes: gaze and grammaticality

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This paper studies the role of eye tracking in detecting grammatical violation in reading tasks. It tests the assumption that encountering syntactic violation has its correspondence in the behavioral patterns associated with gazing. Applying the *T-pattern analysis* offered by the research environment *Theme*, it is shown that the observation of grammaticality/agrammaticality in samples of experiments is reflected in the partial correlation of these categories across a number of structural patterns. It is however also shown that their expected difference in the total duration of focusing is not confirmed. It is suggested that associating eye tracking with an additional sound recording or with linguistic ERP studies could widen the categorical spectrum of identifying grammatical violations.

KEYWORDS

grammaticality, eye tracking, fixation, saccades, presentation order effects

1 Introduction

In our text based digital world one of the most widespread tools we use is the spell-checker. We rely on it in case we are unsure about the proper spelling of a given word, however, it also corrects us even in cases we do know the spelling, but the word is still, inadvertently, misspelled. In a way it is something similar to a slip of the tongue, when what we say is different from what is in our thought. It is a kind of difference captured in theoretical linguistics in terms of the distinction between competence and performance (*cf.*, among others, [Hauser et al., 2002](#)). Our commonly shared human linguistic competence is realized in our actual, concrete linguistic performance, the latter featuring non-arbitrary, but still individual characteristics. When we are reading, often we rush through some words without noticing a spelling error just because the abstract mechanism of our competence, that we might call predictive understanding, takes the lead over the analysis of some surface observation. We can say that seeing and noticing are two different actions which are not always in synchronicity or even equally manifested. Still, probably the most obvious way to reach closer to one's cognitive mechanism and learn about its certain functions is through performance, i.e., the observation of some relevant behavior.

This is what we see in a number of important neurophysiological studies aiming to identify certain linguistic processes in the brain such as syntactic or semantic processing (*cf.* [Angela, 2002, 2004](#); [Gunter and Friederici, 1999](#); [Jolsvai et al., 2011](#); [Kocsis et al., 2017](#)). As an electrophysiological response of the brain to the linguistic stimulus, especially the one representing a mismatch with respect to the grammar of a given language, the resulted event-related potential (ERP) is strongly associated with the timing of the presentation of the stimulus, and, as a result, the ERP signal can be considered as an indication of the type of the linguistic mismatch in question that, in turn, can lead to a better understanding of the neural basis of the given linguistic property (*cf.* [Angela, 2002](#)).

In order to ensure the exact onset time detection of the ERP signal with respect to the presentation of the given stimulus, such experiments rely on the presentation of the linguistic material (usually a sentence) as a sequence of individual words on the computer screen, with the caveat that this mode of presentation does not fully replicate the process of natural,

continuous reading. In a listening rather than reading experiment, this issue of properly detecting evoked potential as a response to grammatical mismatches can, however, be avoided. In Szalárdy et al. (2018), the subjects were presented with two continuous and concurrent speech streams, while the manipulation of the variables of attention and task affecting syntactic grammaticality was aimed at eliciting ERPs. As a result, the study argued that syntactic analysis is not automatic, syntactic violation only elicits an ERP response in the task condition.

As for reading tasks, an experimental setting conforming to natural, continuous reading can be supported by means of tracking eye movement while reading. Already in measuring reading comprehension, it was shown that registering eye movement and generating patterns of reading yields a more reliable insight into the formation of the process of linguistic and contextual comprehension than the established, widely used tests without relying on eye tracking (cf. Mézière et al., 2023). As for specific error detection tasks, there have been a number of psycholinguistic, communication and computational studies using the eye tracker, capturing data related to fixation and saccades and associating them with errors or other features of the text as stimulus, ultimately offering an insight into various aspects of language processing. A recent research topic *Eye-tracking while reading for psycholinguistic and computational models of language comprehension* in *Frontiers in Psychology* (cf. Palmović et al., 2023) represents a number of experimental approaches across a number of languages and different language types for the study of language processing by means of capturing how eye movement can reflect various linguistic errors. Even though capturing the same physical parameters (fixation and saccades), due to the often incompatible typological differences of the languages involved, no single model proved to be applicable to all of them (cf. Falcon et al., 2023).

There is an obvious similarity between studying the path the eyes take during reading or while observing a web page. Even though the path is essentially linear in reading a text whereas, at the same time, it is more determined by non-linearly organized, non-textual visual objects on a web page, the two different ways of forming a path of the gaze can appear in both modalities: while reading, the reader (especially the fast reader) can skip certain words or can return to an already passed detail and thus break linearity, whereas the observer of a web page can also turn to reading linearly a piece of text on the page. Techniques of scanpath analysis with eye tracking are compared and evaluated in Sukru et al. (2016), presenting a choice of approaches to capture the temporal and special progress of the eyes while reading/observing.

The aim of the present study is to examine the possible benefits of applying the approach of *T-pattern analysis* (TPA), (cf. Magnusson, 1996; Magnus et al., 2016) to error detection in reading tasks. TPA differs from previous models of behavioral studies by detecting temporal patterns with the following specific assumptions: (a) while the order of pattern components is important, these components (called events) need not necessarily be adjacent (i.e., there may occur other events in between without them belonging to the given pattern), (b) the time intervals between the events of the pattern should fall within a so-called critical interval (e.g., for events A and B), B following (either or not adjacently) A, they will form a single pattern AB if there is a (predefined) critical interval between A and B, (c) any pattern

candidate should occur in the observation period at least a certain (predefined) number of times. These key features of the TPA model may suggest that, for the analysis of reading tasks with focus on the path of the gaze, scanpath analysis can be a more suitable approach. However, if one is interested in capturing the overall characteristics of the process of reading, including the eventual discovery of further, short-timed patterns and larger patterns consisting of these patterns, or the kinds and distribution of them across the whole observation period as well as capture the pattern-wise difference within pairs of grammatical/agrammatical sentences, the holistic approach of TAP may reveal further important information about this kind of behavior. In what follows, we will apply the T-pattern analysis to test the extent to which the global, holistic difference between texts with and without grammatical errors can be identified by observing behavioral patterns associated with eye tracking.

2 Material and methods

The stimuli for the experiment consisted of 60 simple Hungarian sentences. They were based on the set of stimuli from a previous experiment on the processing of syntactic violations during listening to two concurrent speech streams (cf. Szalárdy et al., 2018). 30 contextually independent grammatical sentences were selected from newspaper news, covering a variety of everyday topics including internet use, sport, career guidance and recent history. Further 30 agrammatical sentences represented the agrammatical counterparts of the above grammatical ones with one of two types of errors each: 20 of them violating subject-object agreement and 10—violating verb-object agreement. In order to maintain the attention of the subjects during the experiment, each of the sentences contained a numeral phrase.

The subject selected for this study was a 26 year old healthy male university graduate.

Each of the sentences was visually presented only once at the center of a computer screen in a randomized order. The subject was asked to read the sentence aloud and judge its grammaticality by saying “correct” or “incorrect.” Reading time was not restricted, and the subject proceeded to the next sentence by pressing ENTER. The voice of the subject was also recorded with the purpose to identify further possible cues of agrammaticality. With Hungarian being an agglutinative language expressing agreement relations by word-final morphology, proper judgment required reading carefully up to the end of the respective words. Each word of each sentence was marked with a corresponding ROI to properly follow and identify the target of eye movement.

For data acquisition we used a ViewPoint 90 fps USB eye tracker from Arrington Research in binocular mode. Two computers were used, an Apple PowerMac for running the presentation software PsyScope v. B77 and a Windows computer for running the data acquisition software (ViewPoint v. 2.9.2), synchronized via the ethernet port. Eye data from the eye tracker hardware to the ViewPoint software traveled via the serial port. For stable viewing position and the restriction of head movement ViewPoint’s HeadLock™ Ultra Precision Head Positioner was used. Eye tracking was carried out with two desk mounted cameras and an illuminator for binocular eye tracking.

The overall settings of the experiment, including the positioning of the eyes (45 cm horizontal x 45 cm vertical from a 24 inch monitor) and the pupil based calibration followed the manufacturer's recommendations. The subject performed the task sitting alone in a sound proof room, with all other equipments being in, and the experiment leader observing from an adjacent room. The eye tracker recorded the resulting fixations and saccades of both eyes. The processing of the raw data was managed using ViewPoint's built-in Data Analyzer. Final data analysis was performed on data from a single eye.

3 Patterns of behavior as indication of variations in grammaticality

Reading takes place across time, accompanied by various markers of the cognitive processes enabling it. One of its noticeable markers is eye movement interpreted in terms of gaze direction, saccades and fixation. Gazing has its own patterns depending on the relative position and content of its object, spread across time. This temporality can be captured both by the simultaneity or consecutiveness of its components, their adjacency or non-adjacency. The patterns are not always obvious to the direct observer; they may often be captured only as a result of a longer observation period. A set of events becomes characteristic of a certain function only if they have multiple occurrences with the same interpretation, such as attention, control or correction. These events include, among others, the starting or stopping of an eye movement, the change in the speed of the movement, the change of the size of the pupil, even blinking. These patterns can be more generic, relating to some human- or culture-specific action, or on the contrary, more specific to an individual. These are all patterns of behavior, constituting the focus of *T-pattern analysis* as offered by the research environment *Theme* (cf. Magnus et al., 2016). In this section we are going to find out whether the judgement of grammaticality/agrammaticality can be supported by various patterns of eye movement.

In terms of *Theme* an instance of behavior is represented by an event occurring at a given point of time and specified by the behaviors (called items) taking place at that point of time. As such, an event can consist of a single item or multiple ones. As an example: if a saccade starts at a point of time and it is characterized by its direction (such as forward, backward or to a more remote target), then the two items (the start and the direction of the saccade) make a single event. There is a token-type relation between an event and an event type (ET): any event at a single time is the token, its multiple occurrences across the whole observation period constitute to the given event type.

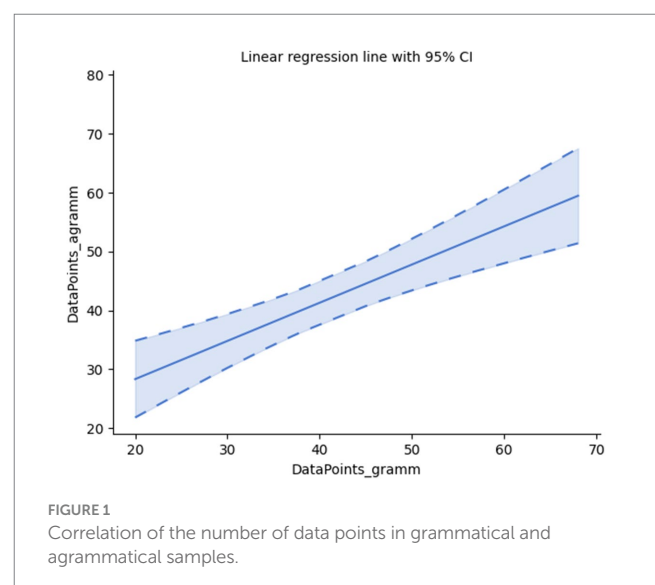
The fundamental criteria for any two events of the same or different type to form a pattern (called *T-pattern*) in *Theme* is that they should occur within a so-called *critical interval*, at multiple (usually at least 3) times, and at a certain significance level (usually $p = 0.005$ or better). In the case of eye tracking *saccades* and *fixations* serve as the primary event types, saccades associated with direction and fixations with duration. Since *Theme* considers the beginning and the end of an action as two separate events, the set of event types also includes the behaviors *begin* and *end*. In our study we identified the following ETs: *b* for *begin*, *e* for *end*, *f* for *fixation*, *s* for *saccade*, as well as the directions of the latter: *dwn* for *down*, *up* for *up*, and *bck* for *backwards*.

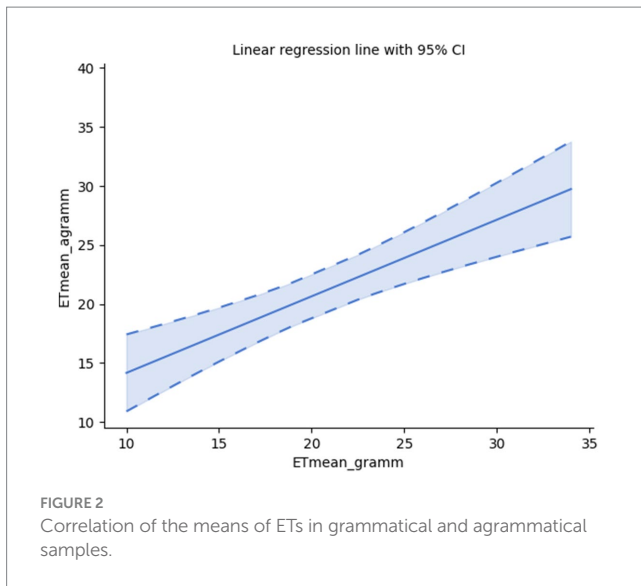
The most frequent patterns found in our data include those consisting of two ETs only, such as (e,s b,f) where the end of a saccade forms a pattern with the start of a fixation within the critical interval (each of the samples of the same pattern can have a variable interval within the predefined critical interval, in our case 1,500 ms). Other frequent patterns are (e,f e,s), where the end of the fixation forms a pattern with the end of the saccade, or (b,s,dwn e,s), where the beginning of a downwards saccade forms a pattern with the end of – obviously the same—saccade. The longest patterns found in our recordings include (b,s,up (e,s (b,f b,s,up)) (e,f (e,s b,s,up))) : an upwards moving saccade > (its) ending > the beginning of a fixation > the beginning of yet another upwards moving saccade > end of fixation > end of saccade > beginning of yet another upwards moving saccade, or the pattern ((b,s,dwn (e,f e,s)) (b,s,dwn (e,s b,f))) : a downwards moving saccade > end of fixation > end of a saccade > beginning of yet another downwards moving saccade > end of a saccade > beginning of a fixation.

Obviously, saccades and fixations are strongly related: considering our total data, out of 243 cases of the ET b,f (the beginning of a fixation) it is followed by b,s (the beginning of a saccade) 91 times, by the end of (the same) fixation 50 times, by the end of a saccade (e,s) 15 times, and there is a high number of occurrences (87) where b,f is the final element of the pattern. The end of a saccade (e,s), occurring altogether 312 times forms a pattern with the following b,f (beginning of fixation) most frequently, 143 times, by the end of a fixation (e,f) 53 times, by the beginning of yet another saccade (b,s) 42 times, and it is the final ET of any pattern in 72 times.

In what follows, instead of characterizing descriptively the gazing behavior of the reading of each of the grammatical/agrammatical pairs of sentences, we will consider parameters which are global to the set of all such pairs, assumed to be characteristic of the way one encounters grammatical issues with a text.

We might assume that noticing a grammatical violation will change the behavioral pattern associated with gazing as compared to the case when no grammatical violation is encountered. Let us examine this question based on a variety of parameters. First, find out if a difference in the number of registered datapoints within each of the samples can reflect such a distinction (see Figure 1).





It is found that, according to the number of data points (events), the gazing of grammatical and agrammatical samples are somewhat positively correlated but are still not identical: Pearson's correlation: $r(28) = 0.69$, $p < 0.001$, Spearman's rank-order correlation: $r_s(28) = 0.70$, $p < 0.001$. Their positive correlation can be attributed to the fact that in each pair of samples (grammatical vs. agrammatical; please note that the members of each pair were randomly, i.e., not adjacently presented among the samples) the gaze follows the same linguistic material, whereas the observation of the violation constitutes to their difference as well.

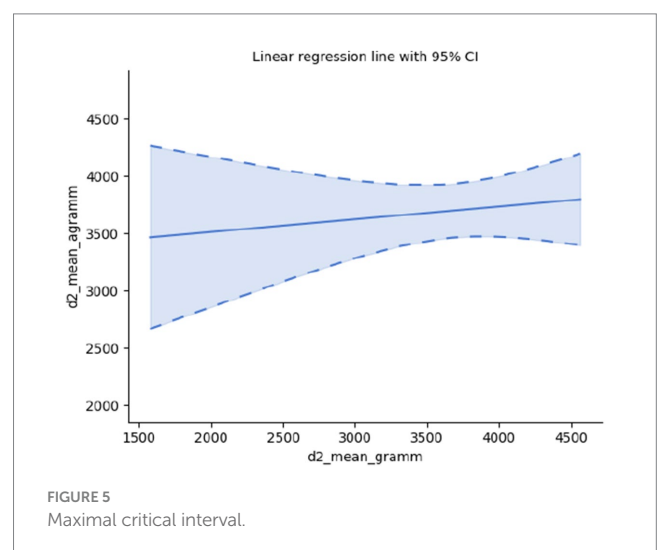
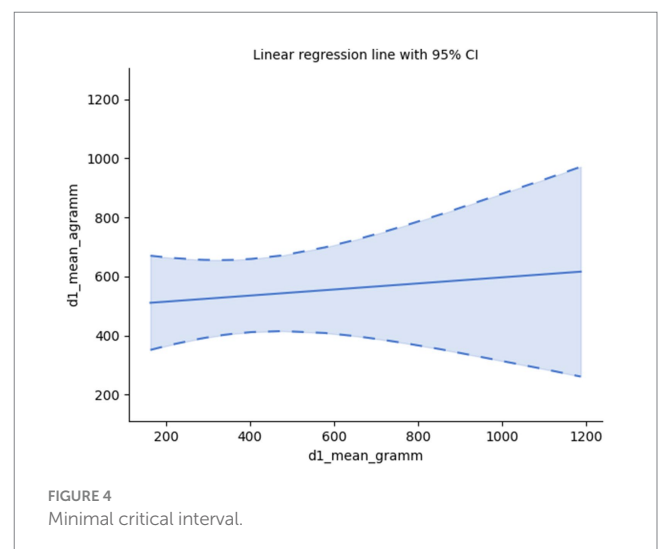
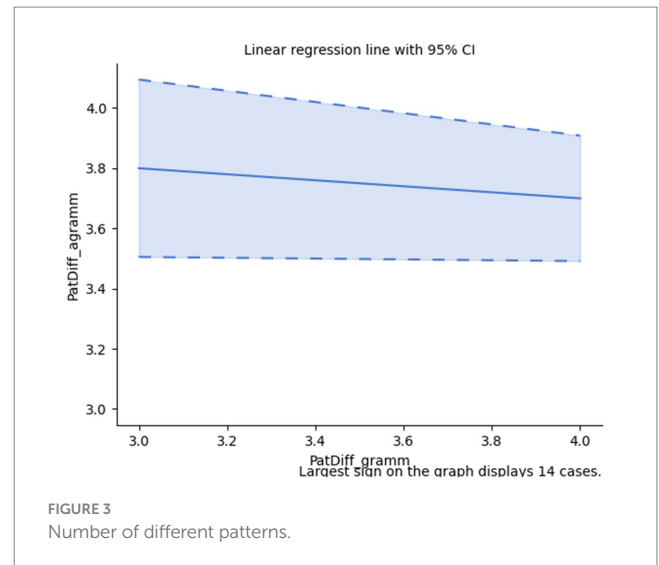
The two types of sentences have a similar relation regarding the mean value of the number of event types (ETs); cf. Figure 2.

As found, they are similarly correlated: Pearson's correlation: $r(28) = 0.69$, $p < 0.001$, Spearman's rank-order correlation: $r_s(28) = 0.70$, $p < 0.001$.

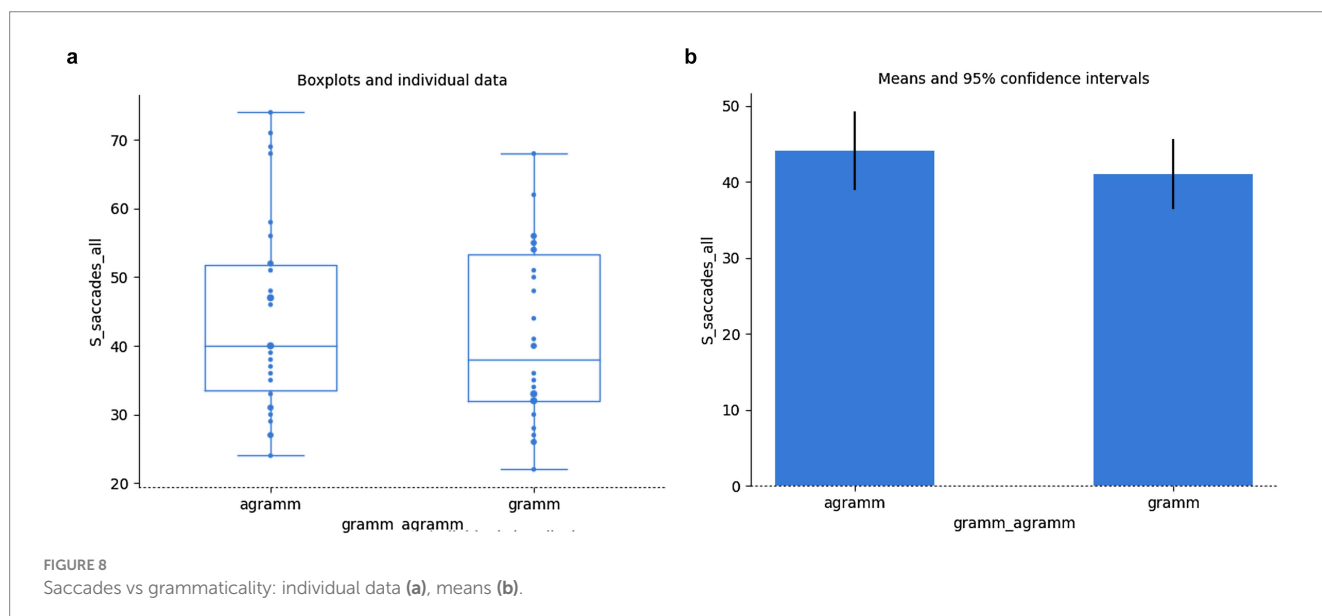
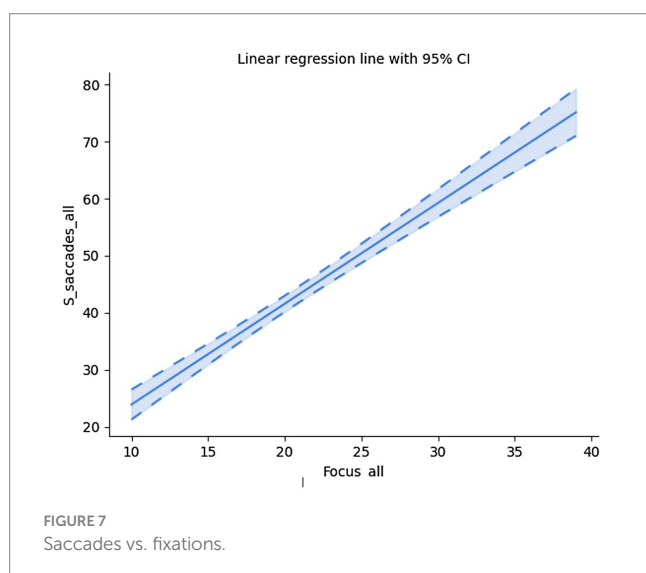
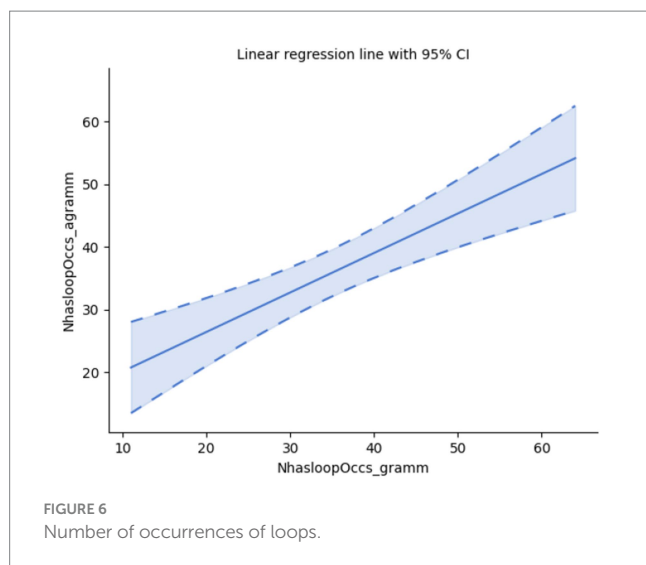
However, if we ask whether grammaticality/agrammaticality also determines significantly different numbers of patterns, Spearman's rank-order correlation ($r_s(28) = -0.11$, $p = 0.575$) shows a weak negative correlation, but, actually, this relation is not statistically significant. Accordingly, the actual difference between the number of patterns in grammatical and agrammatical sentences may not be due to their being grammatical or agrammatical, respectively; cf. Figure 3.

Further, considering the so-called critical interval, i.e., the minimal and maximal temporal distance within which events form a single pattern, these two parameters for pairs of grammatical and agrammatical samples appear to lack correlation, too: d1 mean: Spearman's rank-order correlation: $r_s(28) = -0.06$, $p = 0.752$, d2 mean: Spearman's rank-order correlation: $r_s(28) = 0.20$, $p = 0.278$; suggesting that the observed differences in the processing time of grammatical and agrammatical sentences may be due to other, non-grammatical factors; cf. Figures 4, 5.

Finally, pairs of samples do not significantly differ with respect to the number of loops within a sample (as such, if an event of focusing is followed by yet another event of focusing, as an expected pattern of repeated attention taking, it creates a loop within the pattern). Accordingly, this recursive formation of loops may be a property of gazing in general, regardless of the grammaticality status



of the reading stimulus; cf. Pearson's correlation: $r(28) = 0.69$, $p < 0.001$, Spearman's rank-order correlation: $r_s(28) = 0.66$, $p < 0.001$; cf. Figure 6.



4 Fixation as the reflection of grammaticality/agrammaticality

In addition to the global correlation between the eye tracking of grammatical/agrammatical pairs of samples, let us find out whether gaze movement, in particular saccades and fixation reflect this categorical difference in terms of direction and duration.

Since saccades and fixations are mutually dependent (the gaze moves to a position in order to fixate there), it is no surprise that the two are correlated (Spearman's rank-order correlation: $r_s(58)=0.89$, $p<0.001$); cf. Figure 7.

Even though there are more saccades in cases of agrammaticality, this fact does not amount to showing a significant difference (independent samples t -test: $t(58)=0.89$, $p=0.380$, Bayesian independent two-samples t -test: $BF_{10}=0.36$, $BF_{01}=2.74$); cf. Figures 8A,B.

As also expected, the target of saccades clearly correlates with the position of words in a sentence: Spearman's rank-order correlation: $r_s(58)=0.89$, $p<0.001$ (ari: region of interest, for eye A); cf. Figure 9.

The number of patterns may indicate the complexity of a given behavior. We may generally expect a simpler, more coherent set of behaviors to be reflected by a smaller number of different patterns. Accordingly, we might expect that encountering grammatical errors could result in a larger variety of patterns, too. Systematic, repetitive behavior involves stronger connection between components of a pattern resulting in one or another component becoming the *marker* of that pattern. Since samples with agrammaticality produce a larger number of patterns, we can expect there to be more patterns with markers, too. This is what we see in Figures 10A,B, even though the independent samples Mann-Whitney rank test does not indicate this difference as statistically significant ($U=499.50$, $p=0.467$):

As far as the role of fixation in tracking agrammaticality is concerned, according to popular opinion, encountering an error generates surprise, which is then reflected by a longer focus on the location of the error and/or an eventual returning/jumping to the source of the agrammaticality (cf. Bánréti et al., 2017). Let us now see, if the opinion holds, according to which a longer

focusing time should be expected in case agrammaticality is encountered.

Figures 11A, B show the boxplots and individual data regarding the total duration of fixations relevant to grammaticality (i.e., relevant to subject-verb agreement or subject-object differentiation):

Even though we observe higher means of data for the agrammatical samples, this difference is not significant. Result of independent samples Mann–Whitney rank test: $U = 496.50$, $p = 0.240$. In defense of the popular opinion let us then suggest that in each agrammatical sentence the incorrect agreement only concerned a single word, or at most, in case the construction itself was also double checked, two words, with this additional fixation time requiring little extra time from the total duration of the reading.

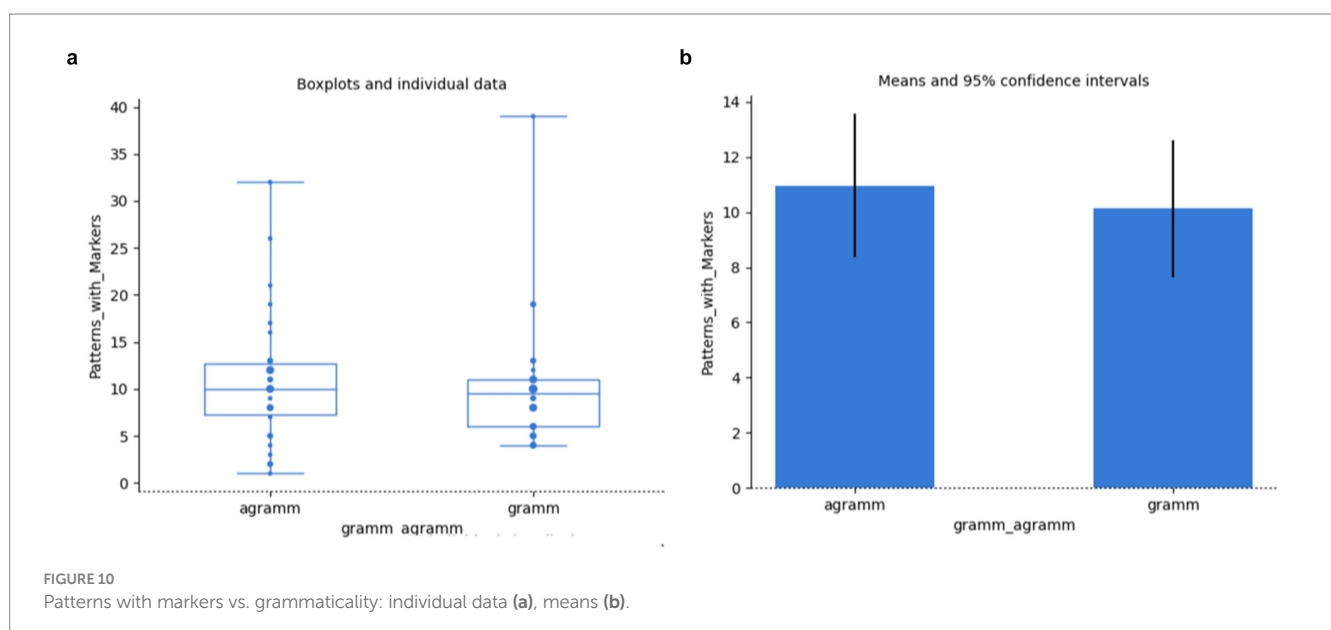
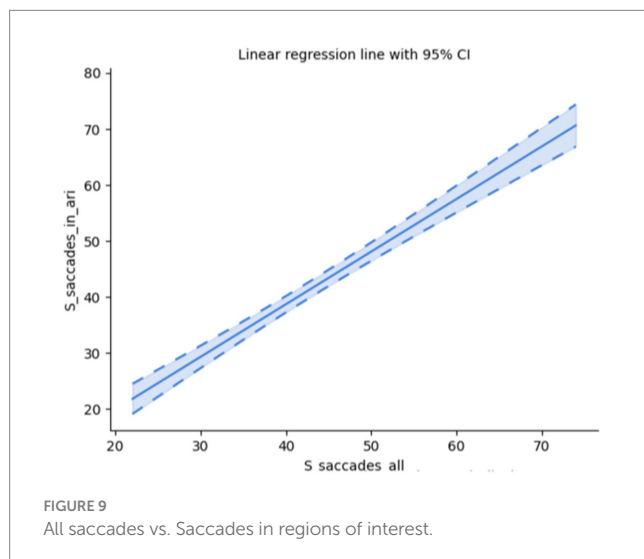
Again, we might assume that eventually the order of presentation (in view of a possible memory effect of whether the grammatical or the agrammatical sentence of the given pair was presented first) could influence the total duration of focusing at the relevant positions; – it

turned out it did not, either: Result of independent samples Mann–Whitney rank test: $U = 396.50$, $p = 0.714$; cf. Figures 12A,B.

The same is confirmed by selecting just the two regions of interest (ARI_first and ARI_second) involved in the grammaticality judgement of the given agreement relation within a given sentence. Contrary to the expectation that since the ungrammaticality is only encountered while gazing at the second word of the pair for agreement relation, the total duration of fixation on the first word of the agreement relation was not found to significantly correlate with the total duration of fixation on its second word across all the samples (Spearman's rank-order correlation: $r_s(58) = 0.20$, $p = 0.129$). Again, their variation with regard to grammaticality/agrammaticality was not found to be significant either (independent samples t -test: $t(58) = 1.03$, $p = 0.307$). The effect of the order of presentation of the grammatical/agrammatical pairs relative to each other, even though the means were not equal, did not prove to be statistically significant either: independent samples Mann–Whitney rank test: $U = 429.50$, $p = 0.759$ for the first word, and Welch's unequal variances t -test for the second word: $t(56.2) = -0.88$, $p = 0.383$; cf. Figures 13A,B and 14A,B, respectively:

5 Discussion

The results presented above confirmed that the eye tracking data showed only restricted cases of differences in gazing performance between grammatical and agrammatical samples. Such differences are formulated in terms of correlation relation: in most cases demonstrated above we found a certain degree of positive correlation between the pairs of grammatical/agrammatical samples attributed to their similar linguistic material. However, this correlation was only partial, which can be accounted for by the fact that – even though the task was to judge the samples by their grammaticality, syntactic analysis, as found in Szalárdy et al. (2018), is, in general, not automatic. Still, we can attribute the longer fixations observed in certain cases to the fact that grammatical (in our case: syntactic) violation generally require more extensive focusing.



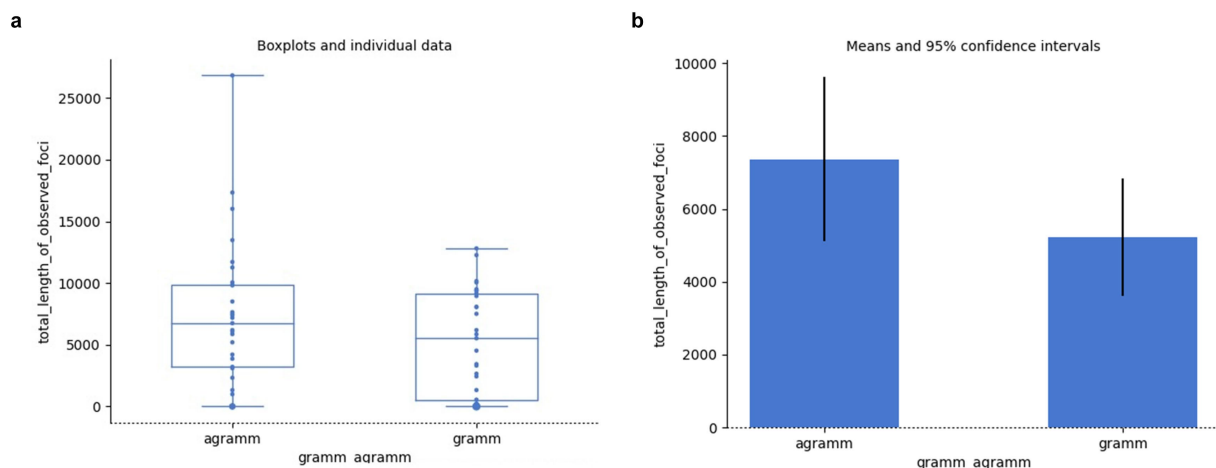


FIGURE 11
Total duration of fixations relevant to grammaticality: individual data (a), means (b).

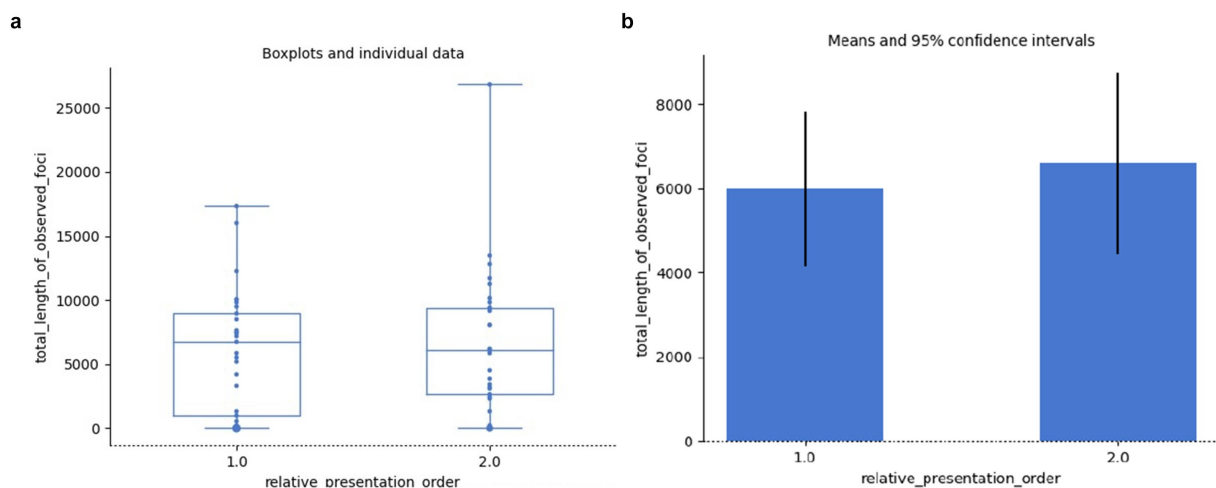


FIGURE 12
Total duration of fixations. Order of presentation of pairs of samples vs. grammaticality: individual data (a), means (b).

Another possibility for capturing some statistical difference regarding the duration of focusing between the grammatical and agrammatical samples could be attributed to their relative presentation order, due to a possible memory effect. The assumption could be that however random the presentation order of the corresponding grammatical/agrammatical samples of the pairs could be, memory would affect the performance of the observation of the second sample. The results, however, confirmed that relative order does not have a significant effect on error detection while reading, suggesting that presentation order may play a role in individual cases only.

All this leads us to suggest that in the present study it was the experimental task itself that conditioned the observed eye tracking behavior: since the task was to judge in each case the grammaticality of the sample, the subject took this task as given, paying equal attention to each of them, noticing and checking each case of grammatical agreement or the expected morphological case regardless of their presentation order or relying on previous familiarity of the sample. The increased duration

of fixation, however, even if proved not to be significant, showed that the agrammaticality of the corresponding samples was noticed and played its proper role in deciding the response as “correct” or “incorrect”.

6 Conclusion

The results of this pilot experiment argue for including eye tracking with restricted but certainly useful benefits in the exploration of the behavioral patterns associated with making grammatical judgements through reading. The observed restrictions, however, also point to the necessity of possible further improvements in the experimental paradigm. By considering eye tracking as a component of a more complex experiment, further development could take two additional directions: accompanied by reading aloud, the study of speech performance (including tempo change, restart, repair etc.) could offer additional dimensions for the discovery of behavioral patterns of reading. Furthermore, as a potential direction for future

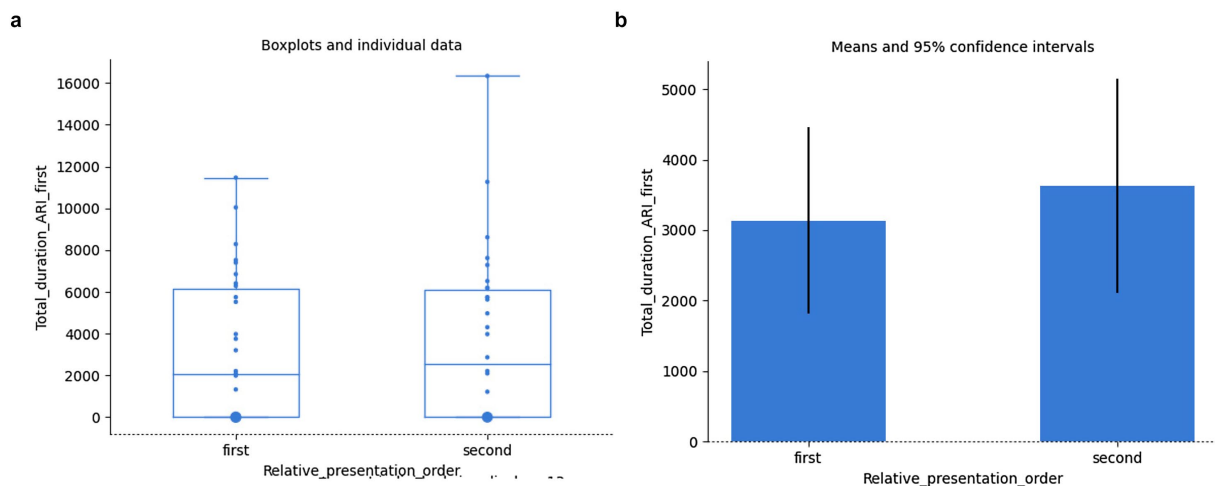


FIGURE 13

Total duration of fixations on the first words of agreement. Order of presentation vs. grammaticality: individual data (a), means (b).

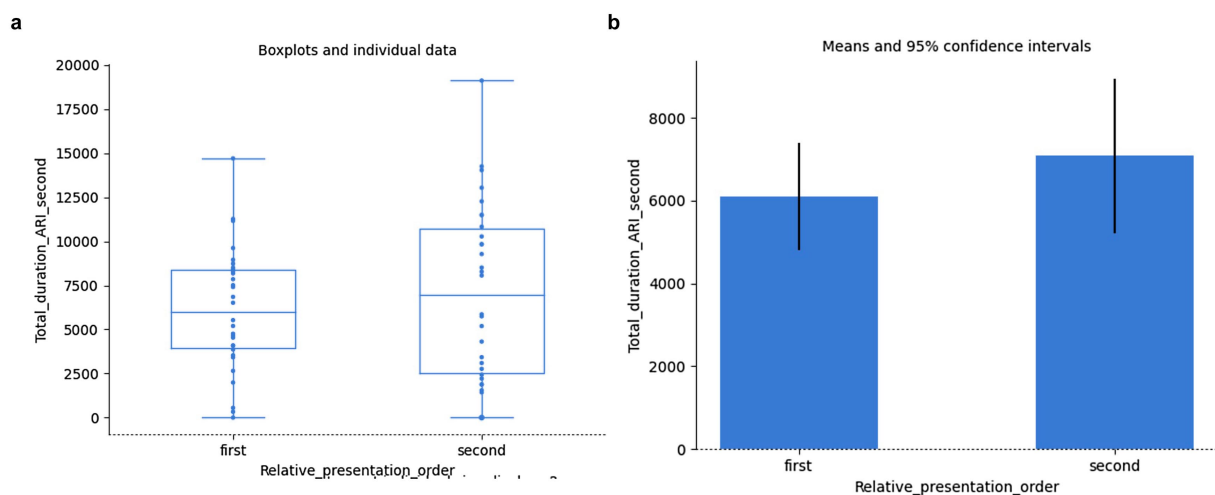


FIGURE 14

Total duration of fixations on all second words of agreement. Order of presentation vs. grammaticality: individual data (a), means (b).

research, synchronizing eye tracking with linguistic ERP studies in reading tasks could widen the categorical spectrum of identifying grammatical violations.

Finally, it has to be noted, that the wider scope of the present conclusions is limited by our study referring to only data from a single subject. The inclusion of the elaboration of the sound recording synchronized with the eye tracking data could also add a further aspect to the detection of behavioral patterns using eye tracking.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

LH: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization.

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In memoriam

This paper is dedicated to Aron, whose eyes will only be shining in our memories.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Being a Pakistani mother in Catalonia: a mixed methods study

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Introduction: In Pakistani migrant families, contextual transformation can affect adult caregivers' parental skills and their ability to exercise positive parenting. We focused on identifying and describing patterns, practices and beliefs about parenting, identifying differential characteristics between the context of origin and the host context, and exploring Pakistani immigrants' use of resources or assets in the area of parenting support.

Methods: Participants consisted of 20 women, established in Catalonia, Spain (<5 years of residence) who have children (at least one of preschool-age). We used a method of indirect observation based on verbal narrative data and textual material that allows integration between qualitative and quantitative elements. The analysis of polar coordinate (quantitative) was applied to obtain a map of interrelationships between codes/categories, based on code matrices. This method is innovative as this is the first study we know in which focus groups have been analyzed through polar coordinate.

Results: Our findings underscore the importance of examining in-depth the concept of family, parenting and upbringing from a cross-cultural perspective. Our results suggest that Pakistani migrant mothers dedicate resources and efforts to maintain the values and practices of origin, and to transmit them to the following generations.

Discussion: Constant communication among relatives using new technologies, the desire to return to Pakistan, and the absence of spaces for interaction between native and migrated families facilitate the maintenance of the upbringing model of origin and resistance to change. A nuclear family structure and access to educational and health services promote acculturation processes in favor of adaptation to the new reality.

KEYWORDS

parenting, Pakistani migrant families, acculturation, migrant motherhood, polar coordinate analysis, mixed methods

Introduction

The concept of parenting refers to the learning, facts, activities or responsibility of the people involved in the care of children. It also refers to their knowledge, attitudes and beliefs about health and nutrition, the importance they attribute to developmental environments, and the learning opportunities that they organize and make available to children within the home (Eraso et al., 2006). The family, as the main context of upbringing, has been one of the main focuses of empirical research in the fields of development and education (Carrión, 2015; Henriquez, 2014; Izzedin-Bouquet and Pachajoa-Londoño, 2009; Torío López et al., 2009). This has allowed us to advance in the knowledge available about the relationships established between fathers, mothers and children, and to determine which contextual and personal factors lead to better development of children (Carrión, 2015; Fuentes-Balderrama et al., 2022; Henriquez, 2014; Izzedin-Bouquet and Pachajoa-Londoño, 2009; Rivero et al., 2023; Vilaseca et al., 2022).

Parenting, upbringing, and migration

In migrated families there are several contextual transformations derived from the migratory process that can compromise the resources available to them in the exercise of parenting. Settling in a society other than one's own requires a considerable effort of psychological and cultural adjustment (Berry, 1997; Fuentes-Balderrama et al., 2022; Micolta, 2007), in which various factors are involved. Gallardo (2019) proposes an approach to the subject that considers points in the migration process. In the period before migration, the family's cultural values should be considered (DeHaan, 2011) and the reasons that led them to emigrate (Aruj, 2009; Buttler et al., 2023). At the time of migration, it should be observed how the country welcomes the family through its migration policies (Bornstein, 2017). Finally, after migration, the focus should be the loss of references and social support (Ali, 2008; Belsky, 1984; Bornstein and Bohr, 2011), the perception of belonging to a minority group (DeHaan, 2011) and aspects related to the support structure and opportunities provided to the family of migrant origin. Notably, one of the main reasons for migration in these families is the search for better conditions and opportunities for children (Levitt and Glick-Schiller, 2004; Mazzucato, 2008). That is, emphasis is placed on migration as a parental decision (Gallardo, 2019; Perreira et al., 2006).

Within post-migration factors, the concept of parental acculturation has begun to be introduced (Berry et al., 1986; Bornstein and Bohr, 2011; Eltanamly et al., 2022; Gallardo, 2019) related to the dilemmas that parents face when they abandon or retain the typical parenting forms from their culture of origin and adopt or reject the parenting methods of the receiving culture (Gallardo, 2019). This is a particularly sensitive issue, since all cultures have specific parenting patterns that are transmitted across generations, which validate what it means to carry out "successful parenting" (Baker, 2016; Bornstein and Bohr, 2011; Keller et al., 2006; Roer-Stier, 2001). In this way, raising children in a culture different from the initial one creates tension between the expectations of being parents that are validated by the culture of origin and the expectations and demands associated with parental roles in the receiving culture (Roer-Stier, 2001).

In studies of the behavior of parents with their children, it is essential to consider two basic aspects: the cultural principles of the group of which they form a part, which affects how they interpret the needs of their children, and the characteristics of the environment(s) in which they have to raise and educate their children, which modulate their responses to these needs (D'Andrade, 2001; Le Vine, 1980, 2003). The way that parents face difficulties that arise on the path to achieving the goals that have been set will be modulated by the group they belong to and culturally determined mechanisms, in close connection with the context that each society establishes as adaptive. A family that decides to migrate loses the opportunity to act according to its values and traditions. Parents find themselves in the position of choosing between modifying and adapting their practices to the new environment, or maintaining the original practices, even if they are not fully adaptive in the host society (Berry et al., 1986; Deng and Marlowe, 2013; Eltanamly et al., 2022).

Parenting and upbringing in Pakistan

Recent research conducted in Pakistan has centered on the issue of parenting (Jeong et al., 2019; Obradovic et al., 2016; Rasheed and

Yousafzai, 2015; Shamama-Tus-Sabah et al., 2011; Sikander et al., 2018; Yousafzai et al., 2015) and offers us specific knowledge about the defining characteristics of the parenting model at source. In Pakistan, Islam is the official religion and creates a cultural foundation that structures the self and its relationship with immediate family and relatives, and non-family members (Selin, 2014). Therefore, Muslim values provide the core of parenting norms that cut across social and economic classes even though the emphasis and role of religion varies in the lives of families (Zaman, 2014).

Family structure directly affects parenting in Pakistan (Selin, 2014). Families attach enormous importance to duty and obligation, rather than to the individual rights of family members. The most common structure of a family living under the same roof is that of the extended family, vertically and horizontally. This can include three generations: grandparents, sons, their wives, and unmarried sons or daughters and siblings. Usually, the oldest father is the head of the family and its main breadwinner until the adult children can contribute to the family economy. The mother's responsibility is to manage the household and children, and when they live in a joint family, to care for their in-laws and maintain family harmony.

The upbringing, training and teaching (*tarbiyat*) and education (*taleem*) of children (Erdal et al., 2016) is the responsibility of the parents and members of the extended family, including grandparents, aunts and uncles. Grandmothers are often the key decision-makers on issues related to pregnant mothers and young children in low-resource settings (Chung et al., 2019) and active participants in feeding, bathing and playing with children (Lingam et al., 2014; Sharma and Kanani, 2006). In many contexts, they are perceived as wise and experienced, serving as teachers to young mothers and passing on fundamental traditions and knowledge (Aubel, 2012; Mumtaz and Salway, 2007). According to Moazam (Selin, 2014), the first lesson of childhood is focused on respecting the elders.

Parenting and upbringing in migrant families of Pakistani origin in Catalonia

Pakistan is among the countries with the most emigrants in the world ranking, with 8.8 million Pakistanis residing abroad. In Europe, Spain is in fourth place among the main receiving countries, just behind the United Kingdom, Italy and Germany.

In Spain, the group from Pakistan has grown continuously in the last decade from 79,984 people in 2002 to 100,496 people in 2022, with a slight population decrease between 2013 and 2016 that coincided with the forecast closure of borders in the United Kingdom, the main European destination, because of the withdrawal of this country from the European Union. More than half of the Pakistani population in Spain, 55,771 people, are in Catalonia (National Institute of Statistics, 2022). However, despite Pakistani being one of the most numerous non-EU populations, little is known about this population in many areas. This is a challenge for professionals responsible for their care and support. The Pakistani population is a very heterogeneous group, in terms of their experiences before the migratory process, and how each one of them has reconstructed their cultural parameters in the host society. The available knowledge about parenting in Pakistani families is still insufficient and not easily transferable to a migration context.

In the present study, carried out using a mixed methods framework (Johnson and Onwuegbuzie, 2004; Karasz and Singelis, 2009), we used a method of indirect observation based on verbal narrative data and textual material (Anguera, 2021; Anguera et al., 2018). This approach is ideally suited for the integration of potentially highly complex qualitative and quantitative elements, especially in situations in which the starting point is the conversations carried out in a focus group. Until recently, the qualitative nature of the material would have disqualified it for use in a mixed methods framework, but recent methodological advances in the diachronic analysis of qualitative data have made its application possible (Anguera, 2020; Anguera et al., 2021; Onwuegbuzie and Johnson, 2021).

We want to highlight its innovative character in the methodological field as it is the second study that we are aware of in which focus groups are treated with indirect observational methods and analyzed through polar coordinate analysis (Bonilla et al., 2024). Indirect observation is an appropriate method to capture behaviors displayed or reported by participants themselves (in the case of this study, ideas, experiences, expectations and values). Polar coordinate analysis was chosen as it permits analysis of the interrelations between coded behaviors.

As we have seen, migrant families may face various challenges that require psychological and cultural adjustments and can jeopardize successful parenting. These challenges include those related to migration itself, the birth of children, and the parental acculturation process (Berry, 1997; Fuentes-Balderrama et al., 2022; Micolita, 2007). The interaction between the family model and cultural values of the country of origin and the new references of the host society can lead to tensions, opportunities, and challenges that need to be addressed (Baker, 2016; Bornstein and Bohr, 2011; Keller et al., 2006; Roer-Stier, 2001). Moreover, we are aware that the family structure has an impact on parenting in Pakistan (Selin, 2014), with the prevalent extended family arrangement where multiple generations reside under the same roof. After migration, these families may lose their direct support in parenting, daily organization, and the values associated with communal care. Thus, after a review of the literature, we identify several critical topics related to parenting and childrearing among migrant mothers in general and Pakistani mothers in particular that will be addressed in the focus groups. They can be summarized as tensions between parental aims, values and practices in the culture of origin and those of the host culture, and knowledge and use of resources offered by the community.

This study aims to add to the body of knowledge regarding parenting in families of Pakistani origin in the context of migration through its three objectives, which stem from the theoretical and conceptual framework relating to the main topics identified in the scientific literature (1) to offer an approximation to guidelines, practices and beliefs on the upbringing of families of Pakistani origin who migrated to Catalonia; (2) to establish and describe the differential characteristics between the context of origin and the host context that are associated with opportunities and barriers in parenting practices; and (3) to explore the use that these families make of resources or assets in the area related to support in upbringing. The first two objectives highlight the tensions between parental aims, values and practices in the culture of origin and the host culture. The third objective relates to the knowledge and use of the resources offered by the community.

Method

Design

Within the mixed methods framework, as we already stated in the introduction section, we used a method of indirect observation based on verbal narrative data and textual material. In this methodological context, our approach to quantification is not based on transforming qualitative data into quantitative ones, as explained in Chang et al. (2009). Instead, we use a more innovative method of quantizing, QUAL-QUAN-QUAL (Anguera et al., 2020), according to which we organize the qualitative data collected, which we code using the indirect observation instrument. We then apply quality control and data analysis techniques to the code matrices obtained in the registry. This methodology, based on observational procedures, has unique characteristics that make it a mixed method, as discussed in Sánchez-Algarra and Anguera (2013), Anguera et al. (2017), and Anguera and Hernández-Mendo (2016).

The observational design used is nomothetic/punctual/multidimensional (N/P/M) (Anguera et al., 2001). It is nomothetic because the members of each of the three focus groups participate; punctual (although with intra-session follow-up) because each of the focus groups met for one session, which was recorded from start to finish; and multidimensional because, depending on the theoretical framework, various dimensions were proposed as part of the instrument.

Participants

Participants were 20 mothers between 29 and 49 years old ($M_{age} = 35.47$, $SD_{age} = 4.376$) who had between one and five children ($M_{n_children} = 2.37$, $SD_{n_children} = 1.165$) and had been living in Catalonia for a period of between 1 month and 5 years ($M_{years_cat} = 3.21$, $SD_{years_cat} = 1.512$). Each focus group had homogeneous inclusion criteria, but members were heterogeneous in terms of age, schooling, profession, and area of origin (rural or urban).

We selected the participants according to the following inclusion criteria: (1) woman, (2) established in Catalonia, Spain, for no more than 5 years and (3) with at least one child of preschool age, to guarantee that all participants were involved in parenting experiences at the time. The condition of representativeness was not necessary. Data on sociodemographic variables were also collected (Supplementary Table S1).

A maximum of 5 years of residence was established as an inclusion criterion to observe conflicts related to the acculturation process. Five years is the time required to exercise the right to apply for legal permanent residence.

This study was approved by the Bioethics Committee of the University of Barcelona (IRB00003099). Before the meeting, all participants received verbal information in their native language, Urdu, about the objectives of the study, and consent to participate was requested through a document translated into this language. Likewise, we anonymized the transcripts to ensure the confidentiality and privacy of the participants.

Instruments

We distinguish between observational instruments and recording and analysis instruments.

Observation instrument

The indirect observation instrument, which we developed *ad hoc*, combines field format and category systems, based on the theoretical framework and, to a large degree, the responses obtained in the three focus groups (Anguera et al., 2007).

We used a nomothetic approach (Gibbs, 2007) based on grounded theory (Strauss and Corbin, 1990, 1998) in three stages. In the first stage, we fragmented the information that was recorded and transcribed into 500 units of meaning, using complete sentences as a criterion, to which we assigned a descriptor or code. In the second stage, we grouped the codes into categories (axial coding). Finally, in the third stage, we developed themes that expressed the content of each group (selective coding). Once this indirect observation tool had been created, we coded the narratives through the dimensions and category systems. The category systems that were part of the observation instrument were exhaustive and mutually exclusive.

The instrument (Supplementary Table S2) was built by organizing the emerging codes into sub-dimensions and then into six dimensions, aligning with the study's objectives: Objective1. *Changes after maternity* (CA), *Significance and meaning of maternity* (SE), *Parenting model* (MO), *Basic individual needs of family members* (NE); Objective2. *Acculturation* (AC); and Objective 3. *Support network* (RE). These dimensions emerged from the participants' responses to the questions that were discussed in the focus groups, following the objectives of the study and supported by the theoretical framework. Each of these dimensions allowed the construction of respective category systems, which met the essential conditions of exhaustivity and mutual exclusivity. Each category was defined, a code was assigned to it, and an example was presented to illustrate that it was extracted from the responses obtained in the focus groups. This observation tool fully meets the requirements outlined in sections 9 and 10 of the MQCOM (Chacón-Moscoso et al., 2019).

We recorded the interviews using a mobile application and an audio recorder (two simultaneous recordings). After each session, we translated and manually transcribed the entire content of the interviews, including the interpreter's translations during the development of the focus groups.

Recording and analysis instruments

We used the Excel program for recording data. Data quality control was performed using the free GSEQ program (Bakeman and Quera, 2011).¹ Data analysis was conducted using the free program HOISAN (Hernández-Mendo et al., 2012) accessible at www.menpas.com, and the figures were optimized using the free program R (Rodríguez-Medina et al., 2022).²

Procedure

In the planning of the focus groups (Doody et al., 2013; Gozávez Pérez et al., 2012; Krueger and Casey, 2000), we considered the indications offered by Hamui-Sutton and Varela-Ruiz (2013) concerning the preparation of the focus group, the

number of participants, duration, the space, and the role of the moderator.

During October and November 2021, we held meetings with three women of Pakistani origin who are considered community leaders and who participate in the social transformation and inclusion of women from various associations. At these meetings, the women's collaboration was requested in order to identify and organize three focus groups. From this first contact, the "snowball" technique was used to select the participants (Heckathorn, 2011; Navarrete et al., 2022). This method allows a sample to be defined through references made by people who share the information or know others and who are interested in the research. Participants were contacted through telephone calls and the collaborating institutions were contacted face-to-face.

During November and December 2021, we conducted three focus groups lasting between 73 and 78 min, a duration considered adequate for this purpose (Gerger Swartling, 2006; Krueger and Casey, 2000).

We conducted three focus groups. Each group have been organized independently, both in terms of location and timing, and it had either six or seven participants, following the recommended size of six to twelve participants for focus groups (Gerger Swartling, 2006). The goal was to ensure that everyone had the chance to express themselves, ask questions, and influence the collective results (Webler, 1995). Each group was moderated by a facilitator who asked predetermined questions and guided the discussion to address the research objectives and a professional interpreter of Pakistani origin (both cultural background and gender were considered to facilitate communication and establish a safe space for women). The vehicular language used was Urdu.

The moderator introduced the topics according to a previous script divided into four thematic sections: a common one (A) addressed in the three focus groups, with introductory questions about parenting, and three sections based on the study objectives: questions about guidelines, practices and beliefs regarding upbringing (B); questions aimed at establishing and describing the differential characteristics between the context of origin and the host context that are associated with opportunities and barriers in parenting practices (C); and questions about the use that these families make of resources or assets in the area related to support in upbringing (D). Sections B, C, and D are divided among different focus groups to reduce the number of questions, in line with the recommendations made in previous work on focus groups (Gerger Swartling, 2006; Krueger and Casey, 2000). We assigned sections to each focus group based on the order of the sections and the timing of the group, ensuring that each section was covered in two groups (with the exception of section A, which was introductory and was included in all groups).

We distributed the questions among the groups according to the following organization:

- Focus group 1: sections A, B and C.
- Focus group 2: sections A, C and D.
- Focus group 3: sections A, B and D.

The interviews were audio-recorded, translated and transcribed in full, including the interpreter's translations during the development of the focus groups.

To code the answers obtained in the focus groups, we segmented the code using syntactic criteria (Anguera, 2020; Anguera, 2021;

¹ <https://www.mangold-international.com/en/products/software/gseq.html>

² https://jairoedmed.shinyapps.io/HOISAN_to_R_2022/

Bonilla et al., 2024) to provide the textual units. Once all textual units were available, the recording was completed using the Excel program, which involved creating a matrix code with six columns corresponding to the dimensions of the indirect observation instrument and as many rows as textual units obtained. Finally, the corresponding code was placed in each box. This was the last action that corresponded to the first stage “WHAT” in the *mixed methods approach*.

Based on the code matrix obtained, data quality control was conducted, followed by data analysis as specified in the subsequent sections.

Data quality control

The analysis of concordance of the coded record between two independent observers (coding 33% of the total textual units), with which the QUAN stage of the QUAL-QUAN-QUAL mixed methods approach begins, obtained a Kappa coefficient (Cohen, 1960) of 0.7999. We rated this as satisfactory (Landis and Koch, 1997).

Data analysis strategy

On the quantitative side, the analysis of polar coordinate was used (Sackett, 1980) to obtain a map of interrelationships between the codes/categories based on the code matrices to which we have referred (Anguera et al., 2021). The polar coordinate analysis is extremely strong and is based on the quantitative study of the sequentiality of the qualitative records that are obtained (successive interventions by the participants in the focus groups).

This requires initial designation of the focal behavior (the category that, according to the goals of the study, is proposed as the center to analyze its interrelationships with the other categories), the conditioned behaviors (all behaviors about which we want to know their interrelationship with the focal behavior), and the number of lags (in a sequential recording, the lag is the distance, measured in number of codes, between the criterion behavior and the conditioned behavior), both prospective (positive) and retrospective (negative), that will be considered (in our case, the number ranged from +1 to +5, and from −1 to −5 respectively).

The polar coordinate analysis is considered a second stage of the lag sequential analysis (Bakeman, 1978). In the polar coordinate analysis, the prospective perspective (from the moment a focal behavior occurs) and the retrospective perspective (textual units that happened before the occurrence of the focal behavior) are integrated. However, we are not referring to the classic retrospective approach (Sackett, 1980), but to genuine retrospectively as proposed by Anguera (1997), since it is consolidated and incorporated into the HOISAN program (Hernández-Mendo et al., 2012) to which we will refer.

The large volume of calculations that would be required to develop prospective and retrospective approaches is greatly simplified by the parameters $Z_{\text{sum prospective}}$ and $Z_{\text{sum retrospective}}$. Sackett (1980) proposed these parameters from a proposal made by Cochran (1954) to reduce data, as long as they are independent. Here they are independent because they are the successive results obtained in lag sequential analyses that have the focal behavior of the polar coordinate analysis as the criterion behavior, the same conditioned behaviors and successive lags (whether prospective or retrospective).

Based on prospective Z_{sum} and retrospective Z_{sum} values, Sackett (1980) proposed the vectorization of the relationships between focal behavior and conditioned behaviors. There will be as many vectors as conditioned behaviors. Each vector has a length or radius

$\text{Length} = \sqrt{(Z_{\text{sum prospective}})^2 + (Z_{\text{sum retrospective}})^2}$, and the angle φ of the vector is found from its trigonometric function Arc sin,

which is expressed as follows: $\text{Arc sin } \varphi = \frac{(Z_{\text{sum retrospective}})}{\text{Length}}$.

This angle φ will be subject to adjustments depending on the quadrant it is in, as indicated in Table 1 (Anguera et al., 2021). In addition, this table provides the indications for the interpretation of the vector. It shows the relationship between the focal behavior and the respective conditioned behavior (each conditioned behavior generates a vector), and it is reciprocal.

The polar coordinate analysis was carried out using the free program HOISAN (Hernández-Mendo et al., 2012), which provides, for each conditioned behavior, the quadrant in which the vector is located, $Z_{\text{sum prospective}}$, $Z_{\text{sum retrospective}}$, the vector length or radius, the significance level, and the angle. The graphic representation has been optimized using R (Rodríguez-Medina et al., 2022).

The great power and applicability of polar coordinate analysis have become evident in recent years in different areas of behavior, such as Developmental Psychology (Belza et al., 2020; Sagastui et al., 2021; Sagastui et al., 2023), Educational Psychology (Alarcón-Espinoza et al., 2023; García-Fariña et al., 2021; Terroba et al., 2022), Clinical Psychology (Arias-Pujol et al., 2022; Rodríguez-Medina et al., 2022), Health Psychology (Muñoz-Violant et al., 2021; Portell et al., 2019), Sports Psychology (Aragon et al., 2017; Iván-Baragaño et al., 2023; Izquierdo and Anguera, 2021; Maneiro et al., 2019) and Environmental Psychology (Pérez-Tejera et al., 2022), among others (Chacón-Moscoso et al., 2023; Del Giacco et al., 2020). It has been found to be a strong technique that greatly reduces data while it provides reliable information on the interrelationships between the categories of the observation instrument and specifically between the proposals, such as the focal behavior and conditioned behaviors.

TABLE 1 Profile of the vectors according to the quadrant in which they are found.

Quadrant	Angle	Relationships between focal behavior and conditioned behaviors
I	$(0 < \varphi < 90) = \varphi$	Focal behavior and conditioned behavior activate each other.
II	$(90 < \varphi < 180) = 180 - \varphi$	Focal behavior inhibits conditioned behavior, which activates focal behavior.
III	$(180 < \varphi < 270) = 180 + \varphi$	Focal behavior and conditioned behavior mutually inhibit each other.
IV	$(270 < \varphi < 360) = 360 - \varphi$	Focal behavior activates conditioned behavior, which inhibits focal behavior.

Results

Our interest is focused on identifying and describing patterns, practices and beliefs about parenting in families of Pakistani origin and identifying differential characteristics between the context of origin and the host context that are associated with opportunities and barriers in parenting practices. Our aim was also to determine the use that Pakistani families make of the resources or assets in the area of parenting support.

In this section, we describe the results of detecting regularities between emergent codes and their grouping into higher-order categories or central categories. The following are the results of the polar coordinate analysis of the significant relationship of focal and conditioned behaviors that activate each other (quadrant I) in the selected units. The tables have been divided into three groups that correspond to the objectives of the study.

To thoroughly study the relationship between focal behaviors and all other conditioned behaviors, we performed 81 polar coordinate analyses considering each category as a focal behavior and all other behaviors shown sequentially as conditioned ones (included in the [Supplementary material](#)). We selected six focal behaviors, one for each coded dimension, based on the study objectives, their connection with the theoretical framework, and

considering that the interrelationships found with each conditioned behavior are highly significant.

Polar coordinate analysis

For all tables ([Tables 2–7](#)), the prospective and retrospective Zsum values are presented in the second and third columns, and the values of vector length and its angle are shown in the fourth and fifth columns.

Vector maps ([Figures 1–6](#)) are presented through polar coordinate analysis, to provide a map of interrelationships between the designated focal and conditioned behaviors.

Guidelines, practices, and beliefs about parenting in families of Pakistani origin

[Table 2](#) highly significant and mutually activating interactions (quadrant I) were obtained between the focal behavior *CA1 Organization* and the conditioned behaviors *CA21 Changes in the focus of conversation* with a radius of length 5.22 and an angle of 67.7°; *CA3 Tension in the distribution of time between husband and child* with a radius of length 5.2 and an angle of 21.26°; *CA42 Loss*

TABLE 2 Significant and highly significant vectors corresponding to quadrant I focal behavior: CA1 organization.

Category	Quadrant	Prospective Zsum	Zsum Retrospective	Ratio	Length	Significance	Angle
CA_CA21	I	2.03	4.81	0.92	5.22	**	67.13
CA_CA3	I	4.85	1.89	0.36	5.2	**	21.26
CA_CA42	I	4.82	7.6	0.84	9	**	57.63
MO_MO11	I	5.59	4.44	0.62	7.14	**	38.47
MO_MO12	I	6.21	6.21	0.71	8.78	**	45.02
MO_MO22	I	7.32	3.87	0.47	8.27	**	27.85
AC_AC222	I	3.21	0.56	0.17	3.26	**	9.86
AC_AC232	I	2.68	0.8	0.29	2.8	**	16.56
AC_AC233	I	7.04	1.34	0.19	7.17	**	10.81
AC_AC241	I	3.42	2.03	0.51	3.98	**	30.68
RE_RE112	I	0.06	5.31	1	5.31	**	89.32

Focal behaviors and conditioned behaviors activate each other.

TABLE 3 Significant and highly significant vectors corresponding to quadrant I focal behavior: SE21 responsibility.

Category	Quadrant	Prospective Zsum	Zsum Retrospective	Ratio	Length	Significance	Angle
MO_MO411	I	0.06	3.77	1	3.78	**	89.09
MO_MO414	I	18.01	21.83	0.77	28.3	**	50.48
MO_MO425	I	6.53	1.88	0.28	6.79	**	16.06
NE_NE11	I	1.02	4.31	0.97	4.43	**	76.73
NE_NE13	I	0.57	5.96	1	5.98	**	84.51
RE_RE321	I	0.73	3.45	0.98	3.53	**	78.04
RE_RE322	I	1.29	3.11	0.92	3.37	**	67.5

Focal behaviors and conditioned behaviors activate each other.

TABLE 4 Significant and highly significant vectors corresponding to quadrant I focal behavior: MO2111 present family values.

Category	Quadrant	Prospective Zsum	Zsum Retrospective	Ratio	Length	Significance	Angle
MO_MO32	I	0.58	5.98	1	6	**	84.44
MO_MO5	I	4.63	5.98	0.79	7.56	**	52.26
NE_NE23	I	2.28	2.28	0.71	3.22	**	44.97
AC_AC211	I	2.98	2.98	0.71	4.21	**	44.99
AC_AC213	I	5.73	10.5	0.88	11.96	**	61.39
AC_AC223	I	2.98	1.71	0.5	3.43	**	29.87
AC_AC245	I	13.87	9.77	0.58	16.96	**	35.16
AC_AC4	I	3.26	6.71	0.9	7.46	**	64.06

Focal behaviors and conditioned behaviors activate each other.

TABLE 5 Significant and highly significant vectors corresponding to quadrant I focal behavior: NE21 link.

Category	Quadrant	Prospective Zsum	Zsum Retrospective	Ratio	Length	Significance	Angle
MO_MO11	I	2.51	1.83	0.59	3.1	**	36.1
MO_MO31	I	9.61	4.94	0.46	10.81	**	27.2
MO_MO32	I	0.58	10.31	1	10.33	**	86.78
MO_MO415	I	4.9	4.91	0.71	6.93	**	45.03
NE_NE11	I	2.67	1.01	0.35	2.85	**	20.76
NE_NE21	I	11.07	11.07	0.71	15.66	**	4.5
NE_NE23	I	1.34	2.75	0.9	3.06	**	64.09
AC_AC211	I	4.93	0.27	0.06	4.94	**	3.16
AC_AC231	I	7.6	1.02	0.13	7.67	**	7.61
AC_AC234	I	3.26	4.6	0.82	5.64	**	54.73
AC_AC241	I	5.96	1.01	0.17	6.04	**	9.66

Focal behaviors and conditioned behaviors activate each other.

TABLE 6 Significant and highly significant vectors corresponding to quadrant I focal behavior: AC4.

Category	Quadrant	Prospective Zsum	Zsum Retrospective	Ratio	Length	Significance	Angle
MO_MO2112	I	8.76	7.45	0.65	11.5	**	40.4
MO_MO32	I	2.96	0.01	0	2.96	**	0.27
MO_MO411	I	4.43	1.95	0.4	4.84	**	23.8
MO_MO413	I	6.66	4.73	0.58	8.17	**	35.35
MO_MO5	I	3.69	1.48	0.37	3.98	**	21.89
AC_AC211	I	2.78	5.7	0.9	6.34	**	63.95
AC_AC213	I	6.58	3.11	0.43	7.28	**	25.32
AC_AC223	I	2.57	3.95	0.84	4.72	**	56.95
AC_AC236	I	1.39	5.26	0.97	5.44	**	75.21
AC_AC245	I	1.29	3.52	0.94	3.75	**	69.92
AC_AC4	I	14.71	14.71	0.71	20.8	**	4.5

Concern for the loss of cultural/religious values and/or acquisition of practices of the host society. Focal behaviors and conditioned behaviors activate each other.

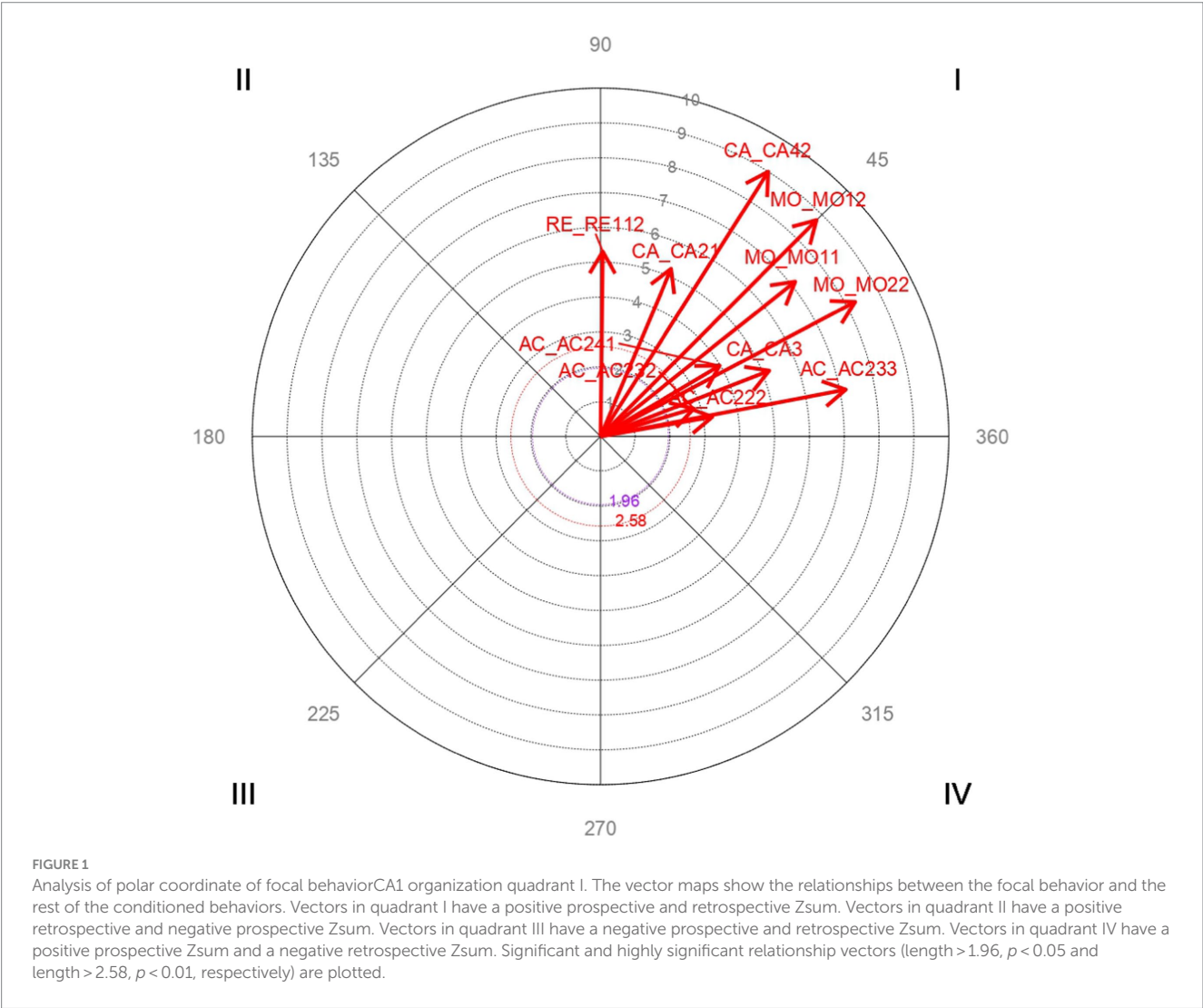
of freedom with a radius of length 9 and an angle of 57.63°; *MO11 Support of the family-in-law in bringing up their children* with a radius of length 7.14 and an angle of 38.47°; *MO12 Responsibilities*

with the extended family make parenting difficult with a radius of length 8.78 and an angle of 45.02°; *MO22 Difficulties due to the loss of extended family in support for bringing up the children* with a

TABLE 7 Significant and highly significant vectors corresponding to quadrant I focal behavior: RE3311 barriers to participation.

Category	Quadrant	Prospective Zsum	Zsum Retrospective	Ratio	Length	Significance	Angle
MO_MO416	I	5.49	1.48	0.26	5.69	*	15.04
NE_NE12	I	6.1	2.81	0.42	6.72	**	24.76
RE_RE111	I	0.25	3.72	1	3.73	**	86.21
RE_RE311	I	2.12	0.55	0.25	2.19	**	14.5
RE_RE3311	I	17.83	17.83	0.71	25.21	*	4.5
RE_RE3312	I	11	11.01	0.71	15.56	**	45.01
RE_RE332	I	4.94	2.1	0.39	5.36	**	23

Focal behaviors and conditioned behaviors activate each other.



radius of length 8.27 and an angle of 27.85°; AC222 Greater difficulty in work-life balance with a radius of length 3.26 and an angle of 9.86°; AC232 Cultural and linguistic differences hinder social inclusion with a radius of length 2.8 and an angle of 16.56°; AC233 Ease of work-life balance with a radius of length 7.17 and an angle of 10.81°; AC241 Other responsibilities make it difficult to dedicate time to parenting with a radius of length 3.98 and an angle of 30.98°;

RE112 Information between equals with a radius of length 5.31 and an angle of 89.32°.

Figure 1 shows the highly significant vectors for the focal behavior CA1 Organization and the 11 conditioned behaviors.

Table 3 highly significant and mutually activating interactions (quadrant I) were found between the focal behavior SE21 Responsibility and the conditioned behaviors MO411 Transmission of cultural values,

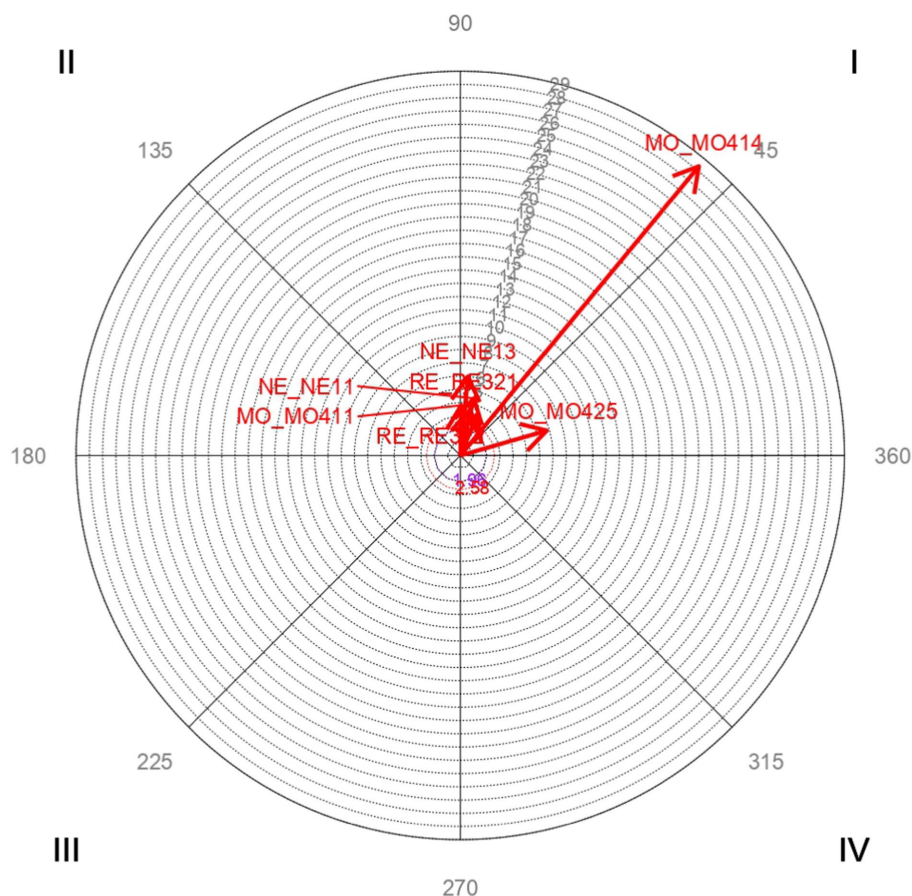


FIGURE 2

Analysis of polar coordinate of focal behavior SE21 responsibility quadrant I. The vector maps show the relationships between the focal behavior and the rest of the conditioned behavior. Vectors in quadrant I have a positive prospective and retrospective Zsum. Vectors in quadrant II have a positive retrospective and negative prospective Zsum. Vectors in quadrant III have a negative prospective and retrospective Zsum. Vectors in quadrant IV have a positive prospective Zsum and a negative retrospective Zsum. Significant and highly significant relationship vectors (length > 1.96, $p < 0.05$ and length > 2.58, $p < 0.01$, respectively) are plotted.

practices and attitudes with a radius of length 3.78 and an angle of 89.091°; MO414 Support in studies with a radius of length 28.3 and an angle of 50.48°; MO425 Tasks that require linguistic competence with a radius of length 6.79 and an angle of 16.06°; NE11 Emotional well-being of the mother with a longitude radius of 4.43 and an angle of 76.73°; NE13 Physical well-being of the mother with a radius of length 5.98 and an angle of 84.51°; RE321 Opportunities of the educational system with a radius of length 3.53 and an angle of 78.04°; and RE322 Limitations of the educational system with a radius of length 3.37 and an angle of 67.5°.

Figure 2 shows the highly significant vectors for the focal behavior SE21 responsibility and the 7 conditioned behaviors.

Table 4 highly significant and mutually activating interactions (quadrant I) were obtained between the focal behavior MO2111 Present family values and the conditioned behaviors MO32 Religion with a radius of length 6 and an angle of 84.44°; MO5 Culturally determined practices with a radius of length 7.56 and an angle of 52.26°; NE23 Home environment with a radius of length 3.22 and an angle of 44.97°; AC211 More dedication of time and/or a better link with a radius of length 4.21 and an angle of 44.99°; AC213 It improves the transmission of cultural values and practices with a radius of length 11.96 and an angle of 61.39°; AC223 Cultural and

linguistic differences hinder social inclusion with a radius of length 3.43 and an angle of 29.87°; AC245 Difficulty controlling habits and behaviors of children with a radius of length 16.96 and an angle of 35.16°; AC4 Concern for the loss of cultural/religious values and/or acquisition of practices of the host society with a radius of length 7.46 and an angle of 64.06°.

Figure 3 shows the highly significant vectors for the focal behavior MO2111 Present Family Values and the 8 conditioned behaviors.

Table 5 highly significant and mutually activating interactions (quadrant I) were obtained between the focal behavior NE21 Link and the conditioned behaviors MO11 Support of the family in-law in parenting with a radius of length 3.1 and an angle of 36.1°; MO31 Personal autonomy with a radius of length 10.81 and an angle of 27.2°; MO32 Religion with a radius of length 10.33 and an angle of 86.78°; MO415 Emotional support and link with a radius of length 6.93 and an angle of 45.03°; NE11 Emotional well-being with a length radius of 2.85 and an angle of 20.76°; NE23 Home environment with a radius of length 3.06 and an angle of 64.09°; AC211 More dedication of time and/or a better link with a radius of length 4.94 and an angle of 3.16°; AC231 Family-in-law link with a radius of length 7.67 and an angle of 7.61°; AC234 More options to occupy your free time with a

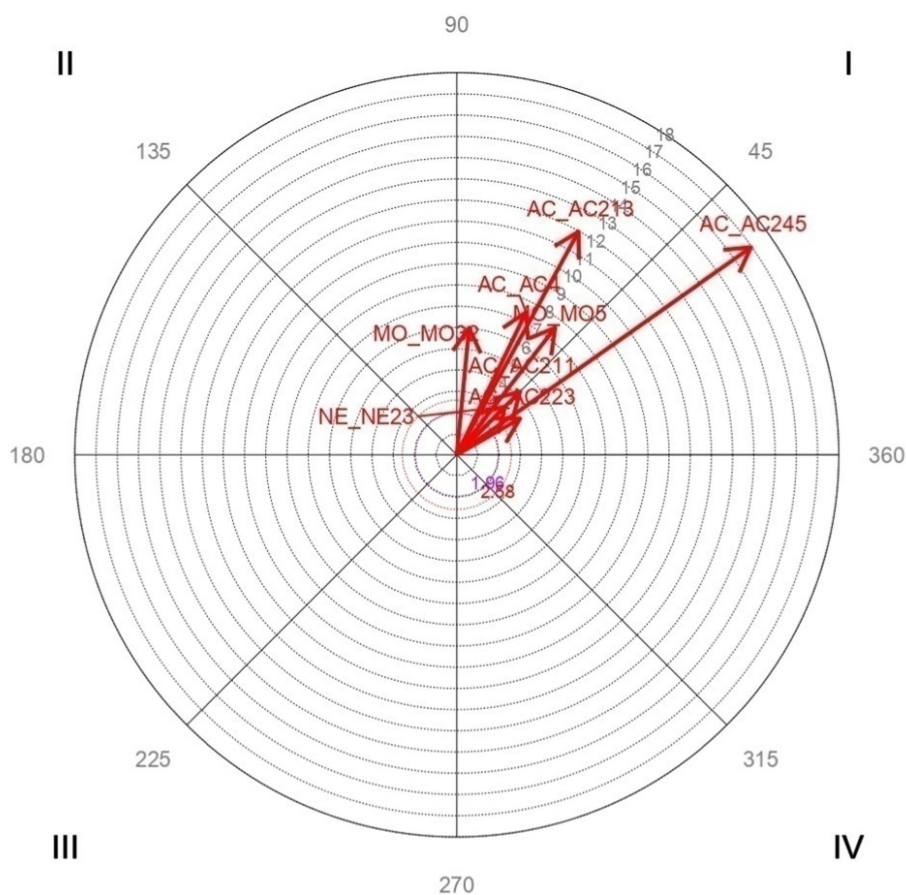


FIGURE 3

Analysis of polar coordinate of focal behavior MO2111 present family values quadrant I. The vector maps show the relationships between the focal behavior and the rest of the conditioned behaviors. Vectors in quadrant I have a positive prospective and retrospective Zsum. Vectors in quadrant II have a positive retrospective and negative prospective Zsum. Vectors in quadrant III have a negative prospective and retrospective Zsum. Vectors in quadrant IV have a positive prospective Zsum and a negative retrospective Zsum. Significant and highly significant relationship vectors (length > 1.96, $p < 0.05$ and length > 2.58, $p < 0.01$, respectively) are plotted.

radius of length 5.64 and an angle of 54.73° ; AC241 *Other responsibilities make it difficult to dedicate time to parenting with a radius of length 6.04 and an angle of 9.66° .*

Figure 4 shows the highly significant vectors for the focal behavior NE21 *Link* and the 11 conditioned behaviors.

Differential characteristics between the context of origin and the host context that is associated with opportunities and barriers in parenting practices

Table 6 highly significant and mutually activating interactions (quadrant I) were obtained between the focal behavior AC4 *Concern for the loss of cultural/religious values and/or acquisition of practices of the host society* and the conditioned behaviors MO2112 *Loss of values after migration* with a radius of length 11.5 and an angle of 40.4° ; MO32 *Religion* with a radius of length 2.96 and an angle of 0.27° ; MO411 *Transmission of cultural values, practices and attitudes* with a radius of length 4.84 and an angle of 23.8° ; MO413 *Surveillance* with a radius of length 8.17 and an angle of 35.35° ; MO5 *Culturally determined practices* with a radius of length 3.98 and an angle of 21.89° ; AC211 *Longer dedication time and better bond* with a radius of

length 6.34 and an angle of 63.95° ; AC213 *It improves the transmission of cultural values and practices* with a length radius of 7.28 and an angle of 25.32° ; AC223 *Cultural and linguistic differences hinder social inclusion* with a radius of longitude 4.72 and an angle of 56.95° ; AC236 *To share cultural values and practices* with a radius of length 5.44 and an angle of 75.21° ; AC245 *Difficulty controlling habits and behaviors of children* with a radius of length 3.75 and an angle of 69.92° .

Figure 5 shows the highly significant vectors for the focal behavior AC4 *Concern for the loss of cultural/religious values and/or acquisition of practices of the host society* and the 11 conditioned behaviors.

Determine the use they make of resources or assets in the area of parenting support

Table 7 highly significant and mutually activating interactions (quadrant I) were obtained between the focal behavior RE3311 *Barriers to participation* and the conditioned behaviors MO416 *Husband care* with a radius of length 5.69 and an angle of 15.04° ; NE12 *Family support* with a radius of length 6.72 and an angle of 24.76° ; RE111 *Information between equals* with a radius of length 3.73 and an angle of 86.21° ; RE311 *Opportunities offered by the health system* with

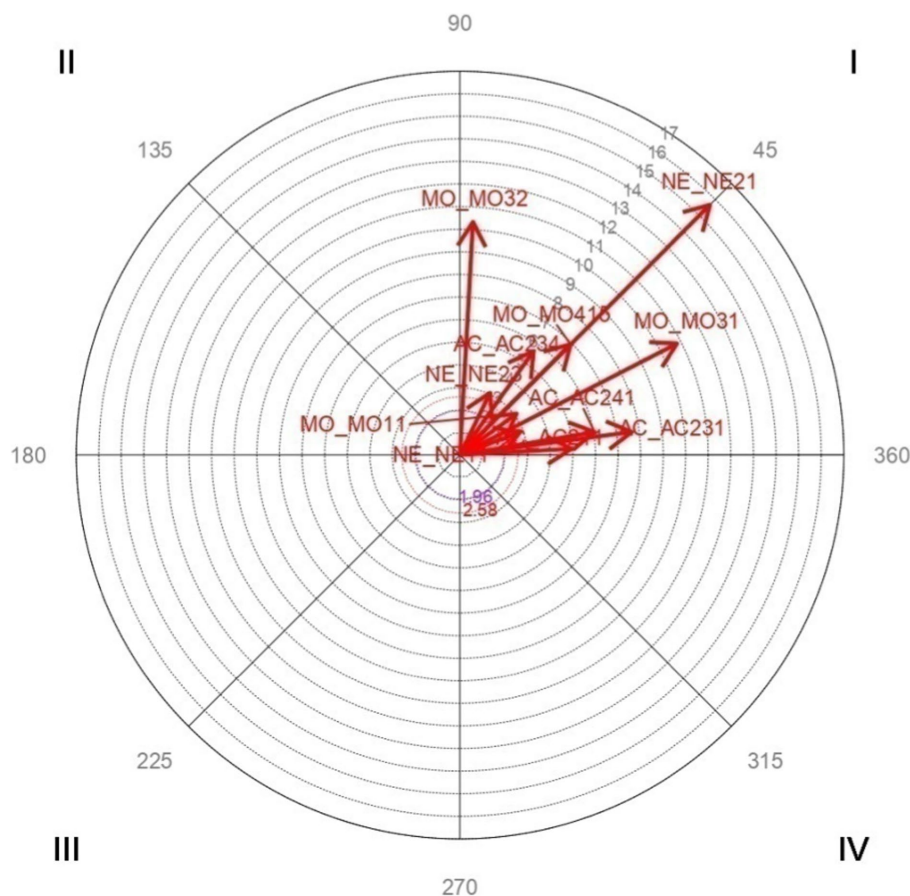


FIGURE 4

Analysis of polar coordinate of focal behavior NE21 link quadrant I. The vector maps show the relationships between the focal behavior and the rest of the conditioned behaviors. Vectors in quadrant I have a positive prospective and retrospective Zsum. Vectors in quadrant II have a positive retrospective and negative prospective Zsum. Vectors in quadrant III have a negative prospective and retrospective Zsum. Vectors in quadrant IV have a positive prospective Zsum and a negative retrospective Zsum. Significant and highly significant relationship vectors (length > 1.96, $p < 0.05$ and length > 2.58, $p < 0.01$, respectively) are plotted.

a radius of length 2.19 and an angle of 14.5° ; RE3312 *Opportunities to participate* with a radius of length 15.56 and an angle of 45.01° ; RE332 *No need or interest in participating* with a radius of length 5.36 and an angle of 23° .

Figure 6 shows the significant and highly significant vectors for the focal behavior RE3311 *Barriers to participation* and the 7 conditioned behaviors.

Discussion

We interpret and describe the significance of our findings in three sections according to the study objectives.

Patterns, practices, and beliefs about parenting in families originally from Pakistan

A first point to highlight refers to the *organization* (CA21) dimension, defined in terms of the changes that occur after

maternity in the timing of activities, priorities and new tasks that are added to the usual responsibilities of caring for the family and the home (Table 2). This reveals changes in routines and schedules to adapt to the new needs and rhythms of the children in the family and the incorporation of new tasks related to upbringing. This new organization causes interpersonal conflicts in the couple (husbands feel displaced and receive little attention to their needs) (CA3), and intrapersonal conflicts (mothers see their freedom and personal time reduced) (CA42). The focus of the family's conversation is changed (CA21), with greater attention to aspects related to caring for the baby.

According to the concept of parenting defined by Eraso et al. (2006), within the family, Pakistani mothers assume responsibility for care (SE21) (Table 3) (Goodnow, 1985; Henriquez, 2014; Torío López et al., 2009). This care includes management of the home (cleanliness and order, food and clothing); education and transmission of values, cultural and religious practices (MO411) (Goodnow, 1985); the care of mother-child, family and community ties; monitoring formal education and stimulating the intellect and competencies of children, especially regarding their autonomy (MO414) (Deci and Ryan, 1987; Frodi et al., 1985; Landry et al., 1997).

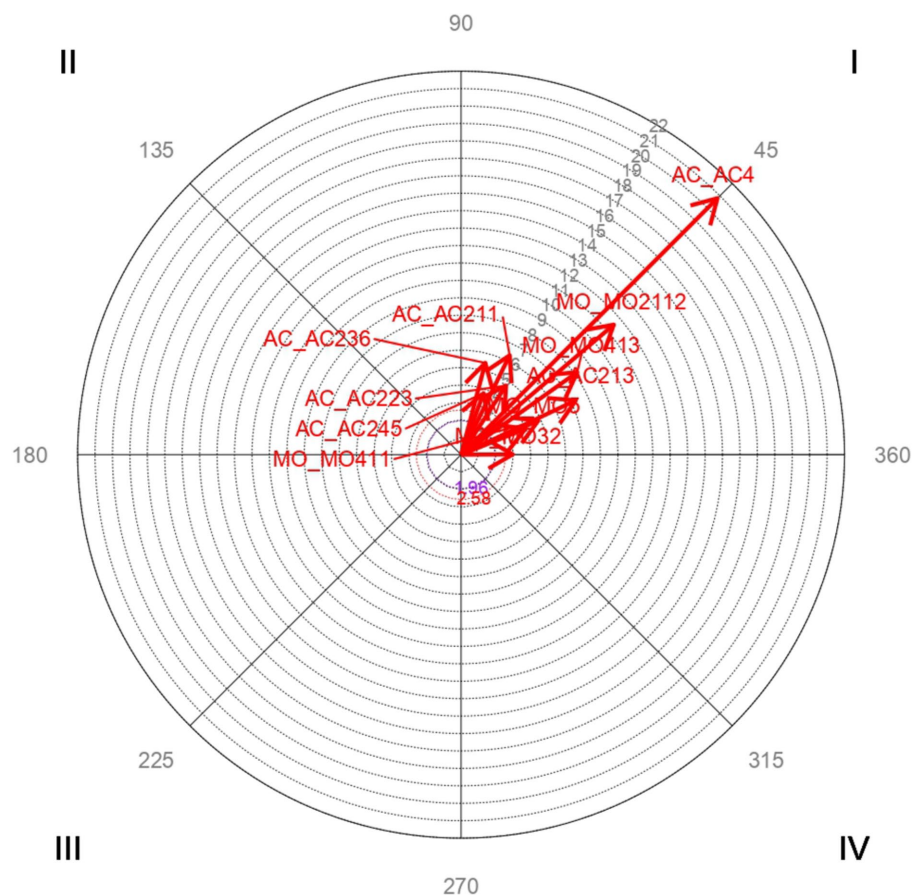


FIGURE 5

Analysis of polar coordinate of focal behavior AC4 concern for the loss. Concern for the loss of cultural/religious values and/or acquisition of practices of the host society quadrant I. The vector maps show the relationships between the focal behavior and the rest of the conditioned behaviors. Vectors in quadrant I have a positive prospective and retrospective Zsum. Vectors in quadrant II have a positive retrospective and negative prospective Zsum. Vectors in quadrant III have a negative prospective and retrospective Zsum. Vectors in quadrant IV have a positive prospective Zsum and a negative retrospective Zsum. Significant and highly significant relationship vectors (length > 1.96, $p < 0.05$ and length > 2.58, $p < 0.01$, respectively) are plotted.

Cultural (MO2111) and religious (MO32) values are fundamental in the maternal role and the assumption of related responsibilities (Table 4). Motherhood is conceived as a divine mandate and a life goal, so society and the family prepare women for it. In contrast, the paternal role is mainly focused on economic support (MO421). Fathers are responsible for procedures that require linguistic competence outside the home (medical visits, family-school relationships, etc.) (MO425). They play a secondary role in upbringing and participate mainly in moments of leisure and mediated monitoring of the education of their children (MO428).

Mothers assume the responsibility for transmitting cultural guidelines and practices (AC213), monitoring, reviewing and redirecting behaviors that are contrary to their own and facilitating the children's participation in community and religious spaces (MO32). In general, a desire to maintain the values and cultural practices of origin in the children of the family is present. The mothers expressed fear of the new generation's assimilation into the receiving society and the incorporation of associated behaviors that are contrary to the values in the country of origin, especially during adolescence (D'Andrade, 2001; Le Vine, 1980, 2003) (AC4). Likewise, they had some difficulties in correctly supporting their children's learning and

schooling due to linguistic, cultural, knowledge and value differences between educational systems (AC223). These factors generated a desire to return to their country of origin (AC3) (Erdal et al., 2016).

As notable aspects in the assessment of parenting in Pakistan and Catalonia, mothers expressed a longing for living with family-in-law in Pakistan, the ties that are associated with this, and the facilities offered in terms of organizational support and distribution of tasks (Ali, 2008; Belsky, 1984; Bornstein and Bohr, 2011) (MO11). However, they positively valued the possibility of spending time raising and caring for their children in the new context, free from taking on other family responsibilities focused on caring for the group (MO12).

One point to consider is the basic needs that mothers identified as variables that determine the context of the development of their children and the possibility of carrying out successful parenting (Table 5). The emotional (NE11) and physical (NE13) well-being of the mother was mentioned as a personal variable that generates better development. In addition, a conflict-free environment (NE23) in the context of the home and the need to allocate time and space to meet the emotional and material needs of the children (AC211) were mentioned as aspects that relate to a better mother-child relationship (Ainsworth, 1973; Bowlby, 1958; Rodrigo and Palacios, 1998).

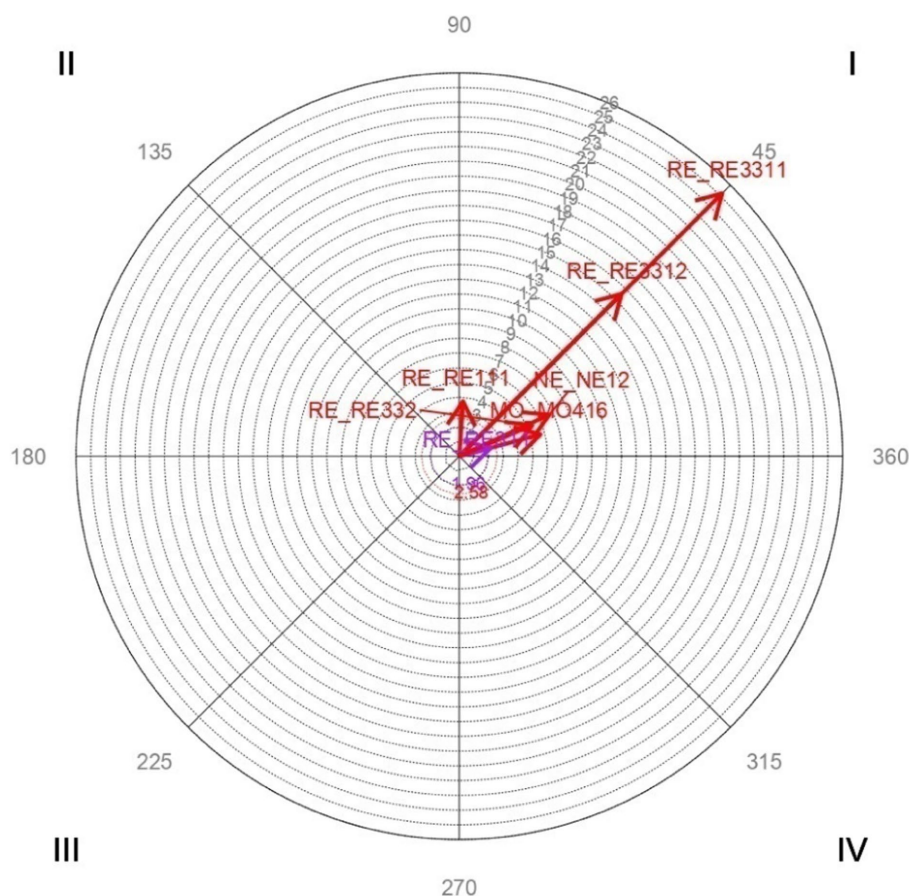


FIGURE 6

Analysis of polar coordinate of focal behavior RE3311 barriers to participation quadrant I. The vector maps show the relationships between the focal behavior and the rest of the conditioned behaviors. Vectors in quadrant I have a positive prospective and retrospective Zsum. Vectors in quadrant II have a positive retrospective and negative prospective Zsum. Vectors in quadrant III have a negative prospective and retrospective Zsum. Vectors in quadrant IV have a positive prospective Zsum and a negative retrospective Zsum. Significant and highly significant relationship vectors (length > 1.96, $p < 0.05$ and length > 2.58, $p < 0.01$, respectively) are plotted.

Differential characteristics between the context of origin and the host context that is associated with opportunities and barriers in parenting practices

The loss of family, culture (Delgado-Gaitan and Trueba, 1991), religious and identity values of origin and the incorporation of host practices and the values of the host society into the new generations was a source of family concern (AC4) (Table 6) (Bolognani, 2014; Bornstein and Bohr, 2011; Eltanamly et al., 2022; Foner and Dreby, 2011; Gallardo, 2019; Giguère et al., 2010). That is why families devote time to monitoring habits, behaviors and practices (MO413) (Musitu et al., 1988; Shaw, 2000) and the informal teaching (MO411) of religion from an early age at home and in places of worship (MO32). Attending a community mosque offers mothers a place for learning and socializing among equals (AC213). The family-in-law of origin continues to maintain a certain control over the migrated family and expects adequate continuity of family values from the latter. Interestingly, no longer living with family-in-law, a situation that is inherent to the migration process, is the reason for the loss of one of the most precious values: the collectivist conception of the individual,

associated with dedication to the group and the community (MO2112), in favor of individuality and personal freedom (Eltanamly et al., 2022; Selin, 2014).

Regarding the acculturation process itself, which is understood as the modification of cognition and behaviors as a result of contact with different cultural groups (Berry, 1997; Berry et al., 1986; Szapocznik et al., 1978), the study participants stated that they had little interaction with native families and few common spaces for participation. They perceived that Catalan mothers had little willingness to share knowledge. The language barrier and cultural differences were perceived as a barrier to their social inclusion and participation (AC223). Despite this, there was widespread appreciation among participants for good parenting practices in native Catalan families (AC122). The ability to set limits and the time spent interacting with children stood out as strengths. The Pakistani mothers perceived that these aspects need to be improved by women in their community raising their children (AC124). In contrast, they observed that Catalan women dedicate less time to family care (AC123). They associated this time particularly with cooking. For Pakistani migrant mothers, spending time cooking is a sign of affection and care for the family.

Determining the use they make of the resources or assets in the area of parenting support

Some barriers reduce mothers' participation in local parenting spaces and in family activities offered in their area, in which they do not feel addressed (Table 7). They usually do not access information about these spaces and if they do, they do not consider that the spaces meet their needs (RE3311). Usually, mothers convey a feeling of loneliness in raising children, (AC231) a lack of space in which they can share and learn from each other and from professionals with a cross-cultural perspective who can accompany them according to their idiosyncrasies. Participation in organizations is concentrated mainly in religious spaces (RE111).

The relatives, from a distance, are presented as a source of information and constant validation (RE211). The use of information and communication technologies (ICT) has facilitated fluid communication between the relatives in Pakistan and the nuclear family in Catalonia and the possibility of carrying out, to a certain extent, shared upbringing between the contexts (Bornstein and Bohr, 2011; Keller et al., 2006; Roer-Stier, 2001). The support network in Catalonia is based on the relationship with other migrant mothers in the community who offer, sporadically, emotional and logistic support (RE112) and the possibility of sharing experiences and information about parenting (RE111).

Regarding public resources in Catalonia, social equity in access to quality services and good treatment was valued positively (RE311), in contrast to the country of origin. The health system stood out as a benchmark in monitoring and follow-up during pregnancy and childbirth and for facilitating access to information and care in situations of difficulty or complication. Regarding parenting indications and guidelines that are offered, those that do not clash with culturally determined values and practices are accepted and incorporated (AC112). As an example, the difficulties in following instructions received about the cultural practice of positioning the baby that gives rise to *flat head syndrome* or *positional plagiocephaly* are highlighted. The participants express discrepancies with the professionals when they positively assess their practice, or they avoid a possible conflict within the framework of the family-in-law in the country of origin.

The educational system was highly valued for offering global, holistic attention to children, better emotional education and for having a greater capacity to detect and attend to difficulties and barriers in learning (RE321). However, a perceived low educational level in each primary school stage was considered a barrier to a possible return to the country of origin (RE322); particularly mothers expressed concerns about the low English level and the excess of playing time during the early years (RE323).

Conclusion

Our findings underscore the importance of examining the concepts of family, parenting, and upbringing from a cross-cultural perspective, to obtain knowledge that helps the design of interventions that are adapted to the real needs of migrant families. To the best of our knowledge, this is the first study to explore concurrent patterns and inter-relational code maps between focal behaviors related to the

parenting model, acculturation traits, characteristics of the support network and the use of local resources for support in maternity and parenting. It is also the first study to analyze focus groups through polar coordinates. The observations made suggest that migrant families of Pakistani origin, especially mothers, dedicate resources and effort to the maintenance of values and practices from their country of origin, and their transmission to the following generations. New technologies, which allow constant communication with the relatives in the country of origin, the desire to return and the absence of spaces for interaction between native and migrated families, facilitate the maintenance of the upbringing model of the homeland and resistance to change. Even so, certain contextual conditions deriving from migration, such as a structure of coexistence limited to the nuclear family and access to the educational system and the health system promote acculturation processes and favor adaptation to the new context. Although our study was carried out in a specific geographical context, Catalonia, we believe that our conclusions can be extended to Pakistani mothers who have migrated to other highly industrialized and economically developed regions in Europe. The data provided by this study can constitute a basis for future research on migrant motherhood and are likely to be relevant for professionals working with migrant mothers of Pakistani origin. The activation and deactivation relationships established through polar coordinate analysis can help identify the most suitable questions for obtaining a certain type of information from participants in focus groups or discussion groups, or through interviews or questionnaires in both research and professional contexts.

Limitations and future lines of research

Certain limitations must be considered. The main limitation refers to the representativeness of the sample participants (Denton, 2007). Recruitment through female leaders from the community and social organizations may include a bias in the participants' profile. Those most predisposed to participating in gathering and mutual learning spaces with other women are likely to have been chosen. These women may be more predisposed to share experiences of maternity.

Second, the observers who coded the data were not blind to the objectives of the study. Future research may consider blinding observers to avoid bias.

Given the qualitative nature of the data, other quantitative analysis techniques could also be used. For instance, the detection of T-Patterns has proved to be highly applicable in recent years, both in direct observation (Pic et al., 2018, 2020) and in indirect observation (Arias-Pujol and Anguera, 2020; Blanchet et al., 2005). Since this technique aims to detect regularities over time, and since in indirect observation counting the duration of each uttered phrase would not be feasible, conventional units should be used instead of temporal ones.

Finally, we must note the language barrier. Even though the researcher acted as a moderator, guided the dialogue between the participants, gave the floor and encouraged equitable participation, the intervention was limited by the need to have the mediation of a Spanish-Urdu interpreter, with the aim of facilitating communication between the parties. In this sense, we prioritized communication in Urdu, the vehicular language of women, to offer a space for natural and fluid conversation between them.

New investigations will be able to examine more exhaustively some aspects derived from data, such as interactions between other focal and conditioned behaviors, or from other issues such as the influence of new technologies on the perception of loneliness in maternity in migrant mothers, the characteristics that define a culturally sensitive parenting space, or the communication channels mothers use to find out about the resources that the area offers. Likewise, it will be necessary to include the voice and experience of fathers as figures involved in bonding with and raising the children.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Bioethics Committee of the University of Barcelona (IRB00003099). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

ME: Writing – original draft, Writing – review & editing. MR: Writing – original draft, Writing – review & editing. MTA: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer EH declared a past co-authorship with the author MA to the handling editor.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1386029/full#supplementary-material>

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Effects of multilevel metacognition on group performance and regulation in collaborative learning

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Group metacognition is essential for effective collaboration. However, existing research mainly focuses on individual metacognition in collaborative learning, and some studies focused on interpersonal metacognition. The understanding of group metacognition is limited. Less attention has been paid to how multilevel metacognition, including individual metacognition, interpersonal metacognition, and group metacognition, functions. There is also less research on whether group metacognition influences collaborative learning through other levels of metacognition. To investigate the emergence of multilevel metacognition among learners with varying achievement and its effects on group performance and regulation patterns, this study employed both traditional and process analyses to examine how the distribution and interactions of multilevel metacognition influence group performance and group regulation. The study revealed that in collaborative learning, group metacognition exerts the most significant influence on group performance compared to other metacognitive levels, such as individual metacognition and interpersonal metacognition. Specifically, the study identified three collaborative achievement categories by judging the degree of collaborative benefit based on individual preparation and group performance: H_T category, EF category and L_T category. The H_T and EF categories performed better and developed more group metacognition, while the L_T category exhibited poorer performance and less group metacognition. The study highlights the role of other levels of metacognition in forming group metacognition, with multilevel metacognitive interactions elucidating the mechanisms of group metacognition. These insights provide practical insights for multilevel metacognition and offers guidance for collaborative learning interventions, particularly those targeting group metacognition.

KEYWORDS

multilevel metacognition, group metacognition, individual metacognition, interpersonal metacognition, collaborative learning

1 Introduction

Collaborative learning promotes active learner engagement through social interactions and fosters high-level awareness, better control of the learning process, and positive interdependence and responsibility connections among learners (Tang et al., 2022). However, achieving efficient collaboration requires high-quality participatory interactions among group members to manage the dynamic nature of groups and foster effective collaboration (Badhe et al., 2023). Metacognitive interactions during group processes play a pivotal role in effective collaboration

(Bakhtiar and Hadwin, 2020). Metacognitive interaction is the process by which groups in collaborative learning monitor and regulate their learning processes, including setting goals, planning, monitoring, and evaluating (Molenaar et al., 2011). Metacognitive interaction involves multiple levels of metacognition: individual, interpersonal, and group. Individual Metacognition (IM) refers to the process by which individuals monitor and regulate their cognitive activities to improve their collaborative participation. Interpersonal metacognition (IPM) encompasses the sharing of metacognitive strategies among members, along with providing mutual support to facilitate group learning. Group metacognition (GM) entails the collective monitoring and regulation of cognitive processes within the group. Influenced by the social environment, metacognition during group interactions gradually evolves from the individual level to the interpersonal level and, ultimately, to the group level (Iiskala et al., 2021; Waller et al., 2021). There is a pressing need to explore metacognitive interaction from a multilevel perspective to understand how groups collaborate for learning success. However, existing studies have primarily explored metacognitive interactions by focusing on level-specific metacognition, such as IM development, the effectiveness of collaborative learning through IPM (Briñol and DeMarree, 2012) or the level and impact of GM (Biasutti and Frate, 2018). Research on level-specific metacognition has concentrated on IM, with little attention given to GM. However, research on metacognition in collaborative learning has shifted focus from the individual to the group, recognizing GM as a key component of successful collaboration (Rapchak, 2018). More researchers are advocating for increased exploration of GM (Biasutti and Frate, 2018; Liu et al., 2023). Moreover, studies have demonstrated positive effects of metacognition across different levels (Kim and Moore, 2019; Socratous and Ioannou, 2022). However, the interaction between different levels has not been comprehensively explored. Research on how to develop GM is still in the early stages. Researchers need to explore the role of individuals in groups by identifying different levels of metacognition and revealing how GM influences the process and performance of collaborative learning. Furthermore, metacognitive interaction in collaborative learning unfolds sequentially as a temporal process. Sequentiality refers to when behaviors occur and how they interact with each other over time. Sequential methods and stochastic views of sequences are well suited for conversational analysis, enabling the exploration of temporality and enhancing the understanding of group processes (Sagr and López-Pernas, 2023). Sequential analyses of metacognitive interaction processes, particularly how multilevel metacognition interacts, contribute to a deeper understanding of group regulation (Iiskala et al., 2021). However, only a few studies have focused on the temporal and sequential aspects of metacognitive interaction (Su et al., 2018; Zheng et al., 2023). There is a need for comprehensive exploration of how multilevel metacognition, IM, IPM, and GM, change over time during collaborative interactions, influencing group regulation and group performance. Group regulation refers to the patterns formed through the interactions of various levels of metacognition within the group, while group performance represents the collective learning outcomes resulting from these interactions.

Therefore, based on statistical analysis, this study proposes a fusion sequence analysis approach (sequence analysis fused with sequence mining) to investigate the multilevel characteristics of metacognitive interactions. The objective is to determine how group learners form GM through IM and IPM to explain effective collaboration.

1.1 Cooccurrence of multilevel metacognition in the collaborative learning group

1.1.1 Multilevel metacognition in group process collaborative learning

The level of participation and impact of metacognitive activities within a group depend on members' subsequent metacognitive contributions after the initial trigger and their influence on the group in collaboration. This illustrates how members within a group, among themselves, and as a whole regulate their metacognition to achieve common goals, forming the basic process of metacognitive interaction. This highlights the multilevel nature of metacognitive interaction, blending individual tendencies and group influence (Kelly, 2018; Waller et al., 2021), involving individuals in the group and the group as social entities. Metacognition in collaborative learning can be divided into three levels based on the participants and actors involved in metacognitive interaction: IM, IPM, and GM (Thompson and Cohen, 2012; Iiskala et al., 2021).

IM focuses on how individuals monitor and control their cognitive processes, such as task understanding, planning, monitoring, evaluation, and reflection (Meijer et al., 2006). In metacognitive interactions, learners externalize IM by sharing their thoughts and selection strategies for collaborative tasks. The participants and influencers in this process were all individual learners. Research has shown that more successful individuals exhibit more metacognitive processes in collaborative learning, and learners with higher levels of metacognition may guide metacognitive interaction (Smith and Mancy, 2018). While the role and developmental changes in IM are the main focus of relevant research, it is also important to explore how individuals impact groups and promote collaboration.

IPM, dominated by individuals, focuses on how individuals monitor and control the cognition of group members (Molenaar et al., 2014) without being constrained by group goals (Tang et al., 2022). The participants were individuals within the group, while the influencers were group members. This concept emphasizes the awareness and regulation of others' thinking for learning purposes (Stanton et al., 2021), which can help individuals better understand and adapt to social interaction environments. By stimulating each other's metacognitive processes (Halmo et al., 2022), effective collaboration among learners can be promoted. Studies have demonstrated the interconnectedness of the IM and IPM (Haataja et al., 2022a,b; Kelly, 2018; Smith and Mancy, 2018). However, effective collaboration within a group is contingent upon these interpersonal influences being aligned with common goals. Without such alignment, the impact on group-level collaboration might be minimal (Hurme et al., 2015).

GM views a group as a whole, focusing on how the group monitors and regulates collective cognition to ensure its accuracy and enhance group decision-making ability. Both the participants and influencers are the group. GM can be seen as an extension of

Abbreviations: IM, individual metacognition; IPM, interpersonal metacognition; GM, group metacognition; H_T, category high-transactivity achievement category; EF, category effective achievement category; L_T, category low-transactivity achievement category.

learner metacognition in interpersonal interactions (Socratous and Ioannou, 2019). The early concept of GM was similar to social metacognition, emphasizing group members' cognition and regulation. Currently, GM stresses its cognitive and regulatory role in group cognition following metacognitive interactions focused on individuals (Siegel, 2012). When interpersonal shared cognitions are considered group primary thoughts, learners can recognize and regulate these shared thoughts at the group level (Briñol and DeMarree, 2012). GM ensures the achievement of collaborative goals and improves the quality of group decision-making and the efficiency of group tasks.

1.1.2 Cooccurrence of multilevel metacognition

IM, IPM, and GM coexist in interactions (Hurme et al., 2015; Molenaar et al., 2014). Studies increasingly emphasize the importance of the GM. For instance, Haataja et al. reported a positive correlation between metacognitive interaction and group performance, highlighting the significance of metacognitive interaction and individual monitoring in relation to achievement (Haataja et al., 2022a). Additionally, Huang et al. found that IM has a limited impact on group performance in online collaborative learning, emphasizing the need for more attention to GM (Huang et al., 2021). Iiskala et al. (2011) revealed the interconnection between the IM and the GM, a relationship that deserves further investigation. Molenaar et al. explored the relationship between different types of social metacognitive interactions and learners' metacognitive knowledge, emphasizing the importance of distinguishing levels of metacognitive interaction in groups (Molenaar et al., 2014). Furthermore, exploring how the IM can be extended to the GM is necessary (Huang et al., 2021; Iiskala et al., 2011; Socratous and Ioannou, 2022). A comprehensive examination of how different levels of metacognition interact to support the development of the GM is necessary (Halmo et al., 2022). Moreover, understanding the metacognitive interaction of complex groups through technology deserves attention (Järvelä et al., 2021). Empirical research on the relationship between GM and learners' performance is still limited (Haataja et al., 2022a) but may offer insights into how metacognitive interaction affects group performance.

1.2 The role of group metacognition in collaborative learning

Emphasizing GM in collaborative learning allows researchers to focus on interactions between members and purposeful group coordination (Kwon et al., 2013). Specifically, a group member's metacognition contributes to discussing how to handle group tasks, activating the group metacognitive process. When other members recognize the similarities of their metacognition and further develop this information, GM begins to develop. Subsequently, when this information impacts a group's direction or outcome, the GM plays a pivotal role (Hurme et al., 2009). In collaboration, the GM promotes the continuation of proper cognitive processes or prevents collective cognition from developing in the opposite direction (Iiskala et al., 2011). Through GM, group members can adjust their collective cognition based on their common goals, addressing lower levels of perceptual difficulties (Hurme et al., 2009).

The role of GM in collaborative learning is evident in various ways. First, its critical importance has been demonstrated, and there

is a focus on measuring its impact on learning and behavior. Chalmers define GM as including group planning, monitoring, and evaluation (Chalmers, 2009). Biasutti et al. proposed that GM can be assessed through four dimensions: group cognitive knowledge, planning, monitoring, and evaluation (Biasutti and Frate, 2018). Siegel et al. suggested that GM comprises meta-social awareness, monitoring understanding, and monitoring processes, which develop through acceptance, rejection, and recombination (Siegel, 2012). Zheng et al. described group metacognitive behavior as orientation, planning, executing strategies, monitoring and control, evaluation and reflection, and adaptive metacognition (Zheng et al., 2019). Considering the impact of goals on metacognitive interaction and the need to distinguish among different levels of metacognition, this study conceptualizes GM across four dimensions: group orientation, group planning, group monitoring, and group evaluation. Second, the focus has shifted to enhancing GM to promote collaboration. For instance, Liu et al. reported that social sharing regulation supports the improvement of learners' GM (Liu et al., 2023). Li et al. discovered that collaboration based on metacognitive regulation is beneficial for enhancing learners' GM (Li et al., 2023). Socratous and Ioannou (2022) observed that learners in structured courses exhibit higher levels of GM and collaborative learning performance than those in unstructured courses. Structured course group provided direct instruction, significantly increasing GM and improving collaboration quality. In contrast, unstructured course group, although offering more autonomy, did not effectively support learners in developing GM through productive failure. Finally, some studies have investigated how GM improve collaborative learning (Teng, 2020; Uslu and Durak, 2022; Zheng et al., 2019). For example, Teng (2020) explored the effects of GM support on metacognitive awareness and learning performance. Zheng et al. (2019) investigated the impact of group metacognitive scaffolding on group metacognitive behavior and performance. Other studies have examined the influence of GM on learners (Uslu and Durak, 2022).

Existing studies have highlighted the significant role of GM in collaborative learning, primarily focusing on its impact on collaborative learning performance. However, there is limited research on how successful groups engage in GM from a process perspective, particularly in understanding group patterns. Longitudinal research on how the GM changes over time deserves attention (Zheng et al., 2019) to provide targeted support for the GM. Additionally, while some studies examine the group's metacognitive process from a regulatory perspective, there is a lack of analysis distinguishing levels of metacognitive interactions based on the participants and influencers. For instance, the GM has been explored as a complex shared learning dynamic or coregulation (Olesova et al., 2023). Further research is necessary to comprehend how learners progress toward GM in collaboration (Olesova et al., 2023). Moreover, existing studies have focused predominantly on how traditional statistical methods measure the GM, with some researchers using the chronologically ordered representation diagram for tool-related activity (CORDTRA) to offer initial evidence on how the GM in collaboration changes over time (Socratous and Ioannou, 2019). Therefore, reliable methods capable of analyzing GM in large-scale collaboration datasets are essential for bridging this gap (Liu et al., 2023; Tang et al., 2022).

The purpose of this study is to investigate how multilevel metacognition affects collaborative learning. The study focuses on the

effects of different levels of metacognition on group performance, as well as the effects of sequential interactions of other levels of metacognition on group regulation.

Specifically, the study identifies three achievement group categories, revealing the specific effects of each category on group performance. By analyzing the distribution and differences of multilevel metacognition across these categories, the study aims to elucidate how multilevel metacognition influences group regulation. The following questions will be addressed.

This study aimed to investigate how multilevel metacognition influence collaborative learning focusing on the effects of multilevel metacognition on group performance, as well as the effects of sequential interactions of multilevel metacognition on group regulation. Specifically, the study identifies three achievement group categories, revealing the specific effects of each category on group performance. By analyzing the distribution and differences of multilevel metacognition across these categories, the study aims to elucidate how multilevel metacognition influences group regulation. The following questions will be addressed:

RQ1: What is the distribution of multilevel metacognition (IM, IPM and GM), across group categories with varying achievements in collaborative learning, and how it affect group performance?

RQ2: What are the sequential characteristics and patterns of multilevel metacognition across learner groups with different achievements, and how do interactions of multilevel metacognition influence group regulation?

2 Materials and methods

2.1 Participants and setting

This study examines online collaborative learning in higher education in China, specifically within the undergraduate course titled “Teaching Media and Technology,” which was offered during the spring semester of 2022. Collaborative learning tasks are the main learning activities and are designed to facilitate group-based design and practical problem solving related to teaching media and technology. Research consent forms were distributed through social media (WeChat) to invite students to participate, resulting in 66 participants. Drawing on prior knowledge, researchers formed 14 heterogeneous groups, each consisting of at least four participants. However, one group withdrew midway due to members’ inability to engage in real-time collaborative tasks. Therefore, 13 groups with a total of 61 participants were included in the analysis.

2.2 Collaborative learning environment and tasks

The online collaborative learning environment is facilitated by Tencent Meeting, which provides features such as text chat, audio and video communication, screen sharing, notes and comments, resource sharing, and collaborative editing. During collaboration, group members initially review task requirements through an online video conference, share their understanding and opinions, confirm goals

and tasks, and then allocate tasks. Subsequently, the group gathers collectively shared resources and finalize the group plan. Members then communicate offline to support individual task completion through voice and text chat and upload completed personal tasks. Finally, during the second video conference, members share the status of completion, evaluate and provide suggestions, monitor task progress, negotiate modifications, and ultimately complete the group task. Learners’ collaborative task performance was assessed based on two main components: (1) individual preparation performance (40%), evaluating the completion of the individual task; and (2) group task performance (60%), assessing the completion and quality of the group’s collaborative task. This collaborative task contributes to 20% of the overall course performance.

2.3 Data collection

In this study, computer screen videos were collected to capture data during collaborative learning, with each group producing two video conference records for every task. Groups are more likely to employ GM in more complex learning tasks. Therefore, the fourth collaborative learning task, which involved designing a teaching model using teaching media and technology, was selected for exploring GM. All the groups had no prior experience with the task and possessed similar levels of prior knowledge. Furthermore, following the completion of three collaborative learning tasks, group members became more familiar with each other, improved their utilization of online collaboration platforms, and developed a deeper understanding of effective collaboration. Ultimately, 26 segments, totaling about 20 h video data, were collected (avg: 1.5 h; min: 0.8 h; max: 2.38 h).

2.3.1 Data coding

Based on the literature, we encoded the group metacognitive process (Table 1). It is crucial for researchers to examine the influence of cognition and social experience on learners’ engagement in metacognitive interactions (De Backer et al., 2022) and to characterize the entire collaborative process. We encoded cognition and social behavior to gain a more precise understanding of the group’s metacognitive interaction. The research divides metacognitive interaction into independent segments based on the end of the discussion or interrupted discourse and then encodes the events within each segment. In this study, GM events were defined as the stage at which participants completed collaborative learning tasks, during which participants collectively regulated group cognition based on the group goal. To identify GM, the study conducted the following three preparatory procedures in advance.

First, it is essential to distinguish between cognitive codes and metacognitive codes. This study follows Nelsons (1999) ‘relative difference’ criterion, defining ‘metacognitive activities as activities that use information from cognitive activities or control cognitive activities through modification’. For example, “sharing task completion” is encoded as cognitive behavior, while “evaluating task completion” is classified as metacognitive behavior. Social behaviors are coded as other behaviors.

Second, episodes are identified by recognizing the interactive turns in the video. In interactive situations, a turn is typically defined as a continuous unit of communication that starts and ends with one

TABLE 1 Metacognitive interaction coding framework.

Levels	Events	Description	Example
IM	Orientation (IM_O)	Discuss personal goals and task understanding, activate individual prior knowledge	"My goal is to improve my instructional design skills and actively participate in group discussions."
	Plan (IM_P)	Develop a plan for personal task scheduling, time management, and strategy selection	"I plan to complete the portion of the assignment I'm responsible for by next Wednesday."
	Monitoring (IM_M)	Monitor individual task understanding, task completion, and progress	"I have realized that the second part of my assignment appears to lack a clear connection to the task assigned to B."
	Evaluation (IM_E)	Evaluate individual learning content, process, plan, and achievements	"While I achieved my goals, I realized that my intense focus on expressing my views occasionally caused me to lose sight of the group's overall process."
IPM	Orientation (IPM_O)	Discuss understanding of group members' learning goals and tasks, acquire knowledge and beliefs of group members, and activate their prior knowledge	"You need to strengthen your focus on collaborative learning skills."
	Plan (IPM_P)	Assist group members in developing a plan for task scheduling, time management, and strategy selection	"You could complete the case study before beginning the individual task."
	Monitoring (IPM_M)	Monitor the task understanding, completion status, and progress of group members	"Is your second part of the assignment in line with the requirements of the task?"
	Evaluation (IPM_E)	Evaluate the learning content, process, plan, and achievements of group members	"You completed the task very well!"
GM	Orientation (GM_O)	Discuss group goals and task understanding, acquire knowledge and beliefs of group members, and activate group prior knowledge	"Our group should learn how to be more efficient while acquiring knowledge"
	Plan (GM_P)	Develop a plan for group task scheduling, time management, and strategy selection	"We plan to hold the second phase of discussions next Friday to confirm the progress of the modifications and enhance the group's tasks."
	Monitoring (GM_M)	Monitor group direction, task understanding, task completion, progress, and collaboration	"We have basically completed the first stage of discussion and identified the existing problems."
	Evaluation (GM_E)	Evaluate group learning content, process, plan, achievements, and collaboration.	"The group goals have been achieved, and our division of labor is well-organized, but there is a phenomenon of procrastination."
Cognition (C)		Share task information, personal task content, repeat task-related content, describe task processing, explain task content and extrapolate or summarize task content	"The ASSURE model comprises six segments."
Others (Ot)		Perform social coordination, off-task statements and other unclassifiable behaviors	"Do not worry, we can talk about it together."

person and transitions with a response from another. For instance, if Person A begins to explain, Person A's turn starts. If Person B interrupts, this signifies the end of Person A's turn and the beginning of Person B's turn. Subsequently, if Person C responds to Person B, it indicates that Person B's turn has ended and Person C's turn has started. In the video interaction, a turn occurs when a member's discourse or actions are interrupted by peers' discourse or actions (Iiskala et al., 2011). When coding the utterance in a turn, attention was paid to whether the meaning of the utterance was divisible. If it was divisible, it was coded according to its meanings. If it was not divisible, it was coded according to the predominant purpose of its meaning. Typically, a group metacognitive segment comprises three levels of metacognition, two key discourses, and one group consensus. The three levels include the IM, IPM, and GM, which are formed by the support of the first two levels. The two discourses refer to the initiation and suspension or termination of collaborative dialog (Iiskala et al., 2011). A group consensus refers to the participation of more than half of the members in the discussion,

leading to a consistent group understanding after the collaborative dialog.

Finally, we focused on the three levels and four events in metacognitive interaction. The three levels refer to individual, interpersonal, and group metacognition (see Table 1). This study primarily discerns the levels of metacognition through participants and influencers in metacognitive interaction. IM involves metacognitive dialog directed toward self-questioning or self-explanation, influencing only the individual learner. 'I' is usually used to indicate the subject's intention. IPM refers to interactions guided by mutual assistance in completing individual tasks involving a guiding or reciprocal relationship between members. Usually, 'you,' or member names, are used to identify the affected individuals. GM refers to interactions guided by shared goals to form GM and accomplish group tasks. The use of 'we' emphasizes group decision-making. The four events include goal setting, planning, monitoring, and evaluation (see Table 1). Two researchers coded the video data (200 turns) based on metacognitive interaction coding framework. Cohen's kappa value

was 0.91 (95%CI: 0.85–0.97, $p < 0.001$), indicating good agreement (Fleiss, 1981).

2.3.2 Analytical methods

To effectively differentiate learner differences, clusters were delineated using latent profile analysis (LPA). The LPA explains the correlation between explicit indicators by determining potential categories. The optimal number of profiles was determined by the Akaike information criterion (AIC) and Bayesian information criterion (BIC), with smaller values indicating better model selection results. This study used the R package mclust to conduct LPA and determine group categories.

For the distribution of different levels of metacognition within a group of learners and to what extent GM is established (RQ1), this study used descriptive statistics to understand the distribution of different levels of metacognition within a category. One-way analysis of variance (ANCOVA) was also used to assess the impact of GM on students' collaborative learning performance.

To characterize and identify the sequential features and patterns of metacognitive interaction among learners with different achievements (RQ2), stochastic process analysis was used. Considering the impact of single-method flatness on result accuracy, this study integrates sequence analysis using Lag Sequential Analysis (LSA) via the lagseq package in R (version 4.3.1) to identify key sequence features and sequence mining implementing cSPADE via the arulesSequences package in R (version 4.3.1) to investigate sequence rules and patterns among different categories, complementing the LSA results. LSA is used to analyze the lag effect in behaviors or time series, focusing on the temporal correlation between pairs of events and identifying behavioral characteristics. In contrast, sequence mining reveals relationships between consecutive events, focusing on discovering meaningful patterns to identify frequent rules and patterns in ordered events. Direct and indirect sequential meanings complement each other to support a deeper understanding of sequential dynamics. Specifically, LSA calculates transfer probabilities or frequencies between events by constructing

transfer matrices between target events and further tests whether the transitions are significant using z -scores, which indicate significant transitions when $z > 1.96$. Sequence mining uses algorithms to discover frequent rules or patterns based on support and confidence. Support measures how often a sequence in a frequent rule occurs in the entire set of sequences, while confidence indicates the probability of occurrence of a sub-sequence given that the frequent rule contains a preceding sequence.

3 Results

This study used LPA to categorize the initial groups based on individual preparations and group task performance, resulting in distinct achievement levels. Figure 1 indicates that when the number of categories is 3, the values for AIC (262), BIC (276), and entropy (0.989) are minimized, suggesting a reasonable division. The collaborative learning performance of the different categories is shown in Table 2. Category 1, comprising 20 learners, included four groups. This achievement category exhibited a low score for individual preparation, but the most significant improvement in the group task was achieved through collaboration. Thus, this group was called the high-transactivity collaborative achievement category (H_T category). In Category 2, the scores for both individual preparation and group tasks are higher, signifying effective collaboration among learners in these groups; hence, this group is referred to as the effective collaborative achievement category (EF category) and contains five groups, with 23 learners. Category 3, named the low-transactivity collaborative achievement category (L_T category), had four groups with 19 participants and demonstrated lower scores for individual preparation and group tasks, suggesting ineffective collaboration compared to other learner categories. The Kruskal–Wallis test revealed a significant difference in individual preparation performance between the categories ($p = 0.016 < 0.05$). However, there was no significant difference in group task performance between the categories ($p = 0.131 > 0.05$). Post-hoc test

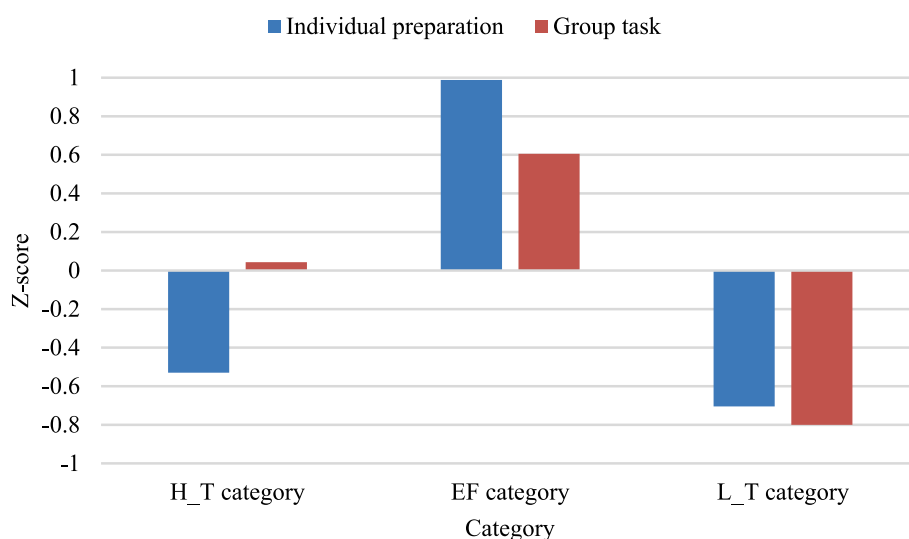


FIGURE 1
Category recognition based on group performance.

using Dunn's test indicated a significant difference between the EF category and L_T category regarding group task performance. These results suggest that different categories performed differently in the individual preparation, and some of these differences were partially mitigated through group work. This reflects the fact that different categories benefited differently from collaboration. Although overall differences in group task performance were not significant, significant differences existed between particular categories, revealing intra-category heterogeneity. It is essential to understand the dynamics of collaboration within different categories to explain the extent of benefits and the reasons for these differences.

3.1 The impact of multilevel metacognition on group performance across different group categories

The significance of fostering group metacognition via multilevel interactions has been highlighted. This study investigates how multilevel metacognition influence group performance by examining its distribution and the differences observed across categories with differing achievement. Specifically, we analyzed the frequency and percentage of each encoding to identify metacognitive distribution characteristics and differences at the individual, interpersonal, and group levels of the different categories, as shown in Table 3. The distribution characteristics revealed that all three categories were characterized primarily by IPM. However, the H_T category exhibited the highest frequency of GM (Freq. = 116, Perc = 6.69%), the EF category had the most frequent IPM (Freq. = 1,108, Perc = 60.12%), and the L_T category displayed the highest frequency of IM (Freq. = 343, Perc = 22.11%). Specifically, H_T category showed the most frequent evaluations of individuals and interpersonal levels (IM_E: Freq. = 96, Perc = 26.45%; IPM_E: Freq. = 341, Perc = 32.95%), while EF category exhibited the most frequent monitoring of

individuals and interpersonal levels (IM_M: Freq. = 195, Perc = 31.45%; IPM_M: Freq. = 576, Perc = 51.99%). From the perspective of GM development, certain categories show a higher tendency toward GM, which plays a more significant role in their performance, as demonstrated by their higher GM frequencies. The H_T category demonstrated the highest formation of GM, including group orientation, planning, monitoring, and evaluation. The EF category ranked second, especially in terms of group orientation. In contrast, the L_T category exhibited the lowest level of GM, especially in terms of group orientation and planning.

Second, a one-way ANOVA was conducted to examine the effects and variations in metacognitive levels on the performance of various categories. The differences in IM and IPM among the three categories did not significantly differ (IM: $F = 0.038$, $p = 0.963$; IPM: $F = 0.637$, $p = 0.549$), while the differences in GM were statistically significant ($F = 5.6$, $p = 0.023 < 0.05$). Additionally, the effect quantity (η^2) was 0.542, indicating a moderate effect, as shown in Table 4. These findings suggest significant disparities in GM across collaborative achievement categories. The results confirm that while IM and IPM are present across categories, they do not significantly account for the variance in group performance. Instead, GM stands out as the key to differentiating high-performing categories (such as H_T category) from lower-performing one. The GM emerges as a crucial determinant of group performance, surpassing the influence of individuals and the IPM. Furthermore, fostering the development of GM has proven beneficial for enhancing group performance within small groups.

3.2 Sequential characteristics and patterns of multilevel metacognitive interactions in categories with different achievements

This study used LSA to analyze the sequential characteristics of multilevel metacognitive interactions. To ensure result reliability, transitions with $Fre \geq 12$ and $z > 1.96$ were selected, as shown in Figure 2. Among them, the H_T category exhibited 12 direct transformations, 7 occurring between different levels and 5 occurring within a single level (see Figure 2a). EF category also demonstrated 12 direct transformations, with 9 occurring between different levels and 3 occurring within a single level (see Figure 2b). However, the L_T category generated 10 significant transitions, with 6 occurring between different levels and 4 occurring within a single level (see Figure 2c). All categories showed the highest conversion toward IPM, with GM

TABLE 2 Group performance of different categories.

Category	N	Individual preparation performance	Group task performance
H_T category	20	23.9	33.6
EF category	23	26.1	34.8
L_T category	19	24.2	31.8

N means the number of students included in each category.

TABLE 3 Distribution of multilevel metacognition (total frequency of means within each category).

Category		Individual level	Interpersonal level	Group level	C	Ot
		IM (O, P, M, E)	IPM (O, P, M, E)	GM (O, P, M, E)		
H_T category (N = 20)	Freq.	363 (22, 106, 139, 96)	1,035 (36, 194, 464, 341)	116 (3, 14, 54, 45)	191	30
	Perc	20.92% (6.06, 29.20, 38.29, 26.45%)	59.65% (3.48, 18.74, 44.83, 32.95%)	6.69% (2.59, 12.07, 46.55, 38.79%)	11.01%	1.73%
EF category (N = 23)	Freq.	407 (15, 128, 195, 69)	1,108 (27, 217, 576, 288)	70 (0, 6, 32, 32)	148	110
	Perc	22.08% (3.69, 31.45, 47.91, 16.95%)	60.12% (2.44, 19.58, 51.99, 25.99%)	3.80% (0.00, 8.57, 45.71, 45.71%)	8.03%	5.97%
L_T category (N = 19)	Freq.	343 (11, 95, 153, 84)	731 (3, 150, 340, 238)	32 (0, 2, 17, 13)	216	229
	Perc	22.11% (3.21, 27.70, 44.61, 24.49%)	47.13% (0.41, 20.52, 46.51, 32.56%)	2.06% (0.00, 6.25, 53.13, 40.63%)	13.93%	14.76%

N means the number of students included in each category.

mainly formed through the IPM. The H_T category displayed greater conversion toward IPM, while the L_T category exhibited a poor correlation between behaviors. Additionally, cognitive sharing primarily facilitates individual monitoring (C→IM_M), while other behavior is typically characterized by its ongoing nature (Ot→Ot).

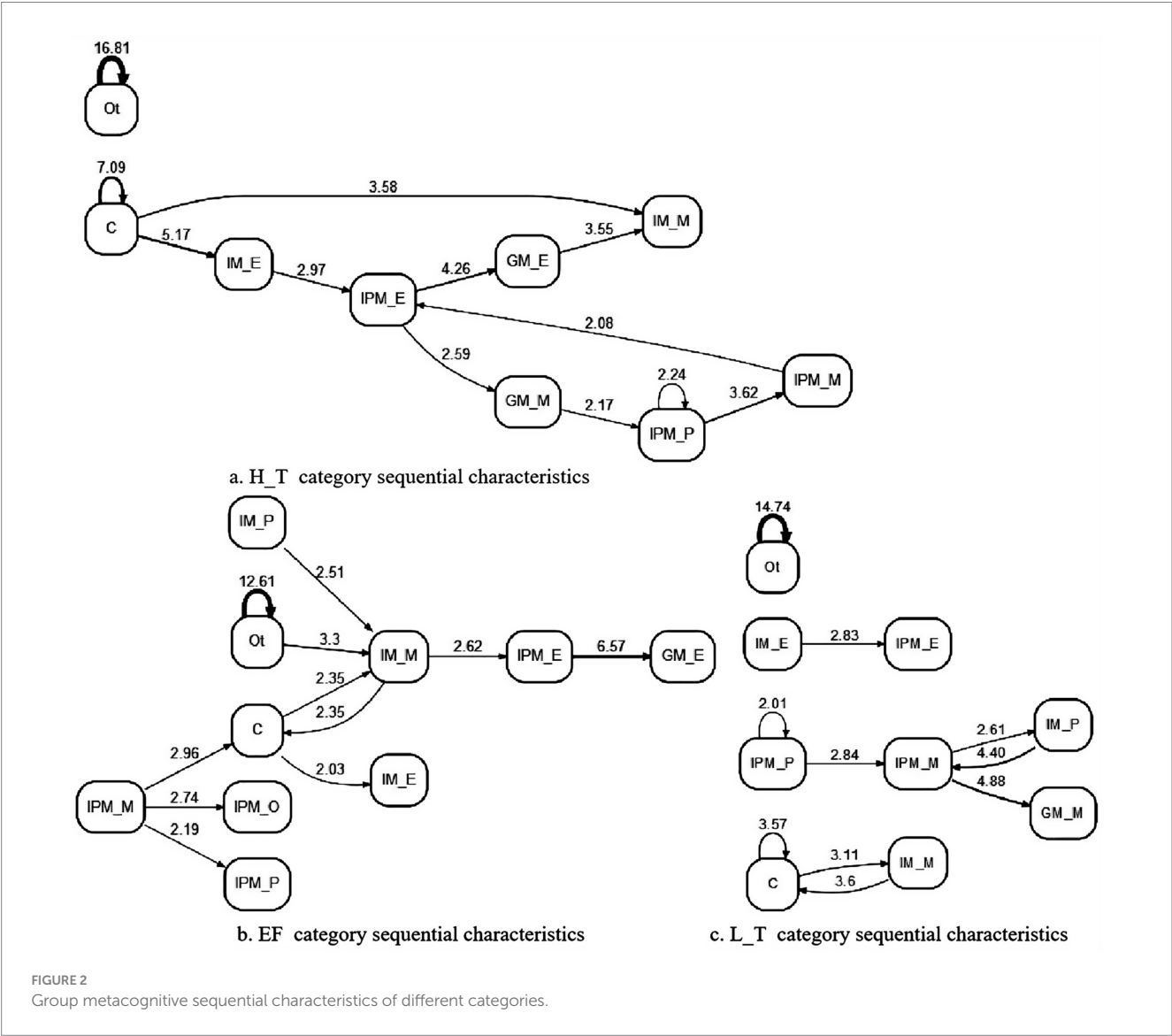
At the individual level, the H_T category exhibited the transition from individual evaluation to interpersonal evaluation (IM_E→IPM_E), whereas the EF category exhibited the transitions from individual planning to individual monitoring or cognitive sharing, and from individual monitoring to interpersonal evaluation (IM_P→IM_M, IM_M→C and IM_M→IPM_E). In addition, the L_T category

exhibited the transitions from individual planning to interpersonal evaluation (IM_E→IPM_E) and from individual evaluation to interpersonal monitoring (IM_P→IPM_M). At the interpersonal level, the H_T category exhibited the following transitions from interpersonal evaluation to group monitoring and evaluation (IPM_E→GM_M, IPM_E→GM_E) while forming the transition from internal planning, monitoring, and evaluation sequences at the interpersonal level (IPM_P→IPM_M, IPM_M→IPM_E). The EF category supports interpersonal planning and goal setting through interpersonal monitoring (IPM_M→C, IPM_M→IPM_P, IPM_M→IPM_O), while reaching agreement through interpersonal evaluation and group evaluation (IPM_E→GM_E). The L_T category exhibited the following transitions from interpersonal planning to interpersonal monitoring and further to group monitoring (IPM_P→IPM_M, IPM_M→GM_M), while interpersonal monitoring also supports individual planning (IPM_M→IM_P). At the group level, the H_T category demonstrated the transition from group evaluation to individual monitoring (GM_E→IM_M) and the transition from group evaluation to interpersonal planning (GM_E→IPM_P), whereas the other categories lacked transitions from GM to other levels. Sequence analysis revealed

TABLE 4 One-way ANOVA results for GM in different categories.

Category	N	Mean	SD	SE	F	p	η^2
H_T category	4	24.00	9.31	4.65	5.90*	0.02	0.54
EF category	5	14.00	4.18	1.87			
L_T category	4	8.50	5.45	2.72			

N means the number of groups included in each category.



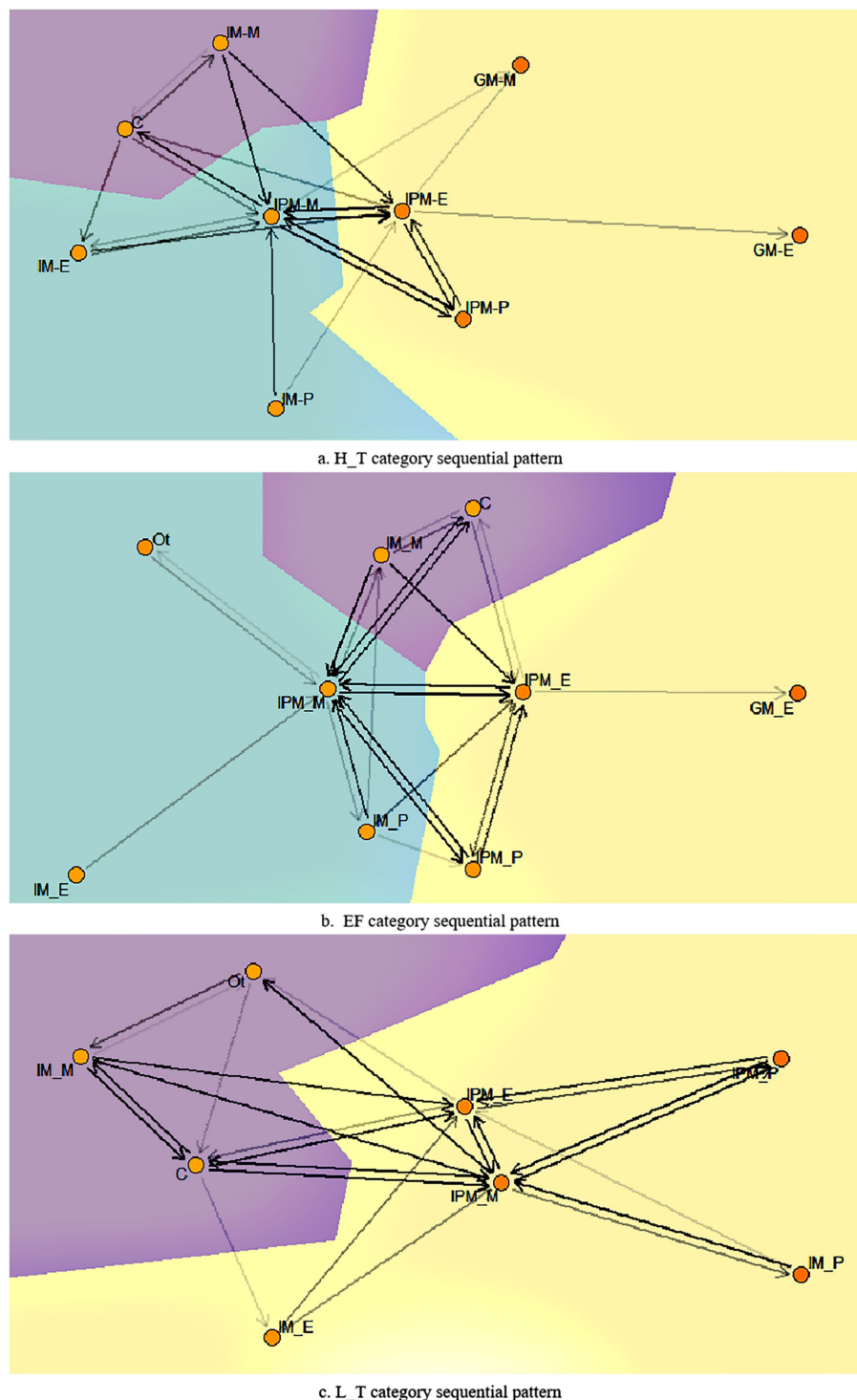


FIGURE 3
Group metacognitive patterns of different categories.

that transformations occurred mainly between different levels of metacognition, focusing on initiating or directing toward IPM. IM plays a pivotal role in enhancing metacognitive interaction effectiveness. Additionally, transformations originating from GM represent a significant process influencing group transactivity.

This study used cSPADE to mine group metacognitive patterns, as shown in Figure 3, to analyze how learners form GM and explain

differences across categories. Each category comprises four or five groups, enabling the identification of commonalities and the establishment of a coherent pattern. The circles in the pattern represent specific events involving learners in the collaborative process. Edge weights within the pattern were determined by transition frequency, and symmetry and local aggregation were calculated based on edge weights to illustrate the optimal cluster structure of micro processes. The background color is

used to distinguish between different trends, and the background area reflects the proportion of the trend in the overall pattern. In [Figure 3](#), all three categories develop a group metacognitive pattern centered on interpersonal monitoring and evaluation, including three important behavioral trends: bidirectional transformation between cognitive sharing and individual monitoring, extension of IM to IPM, and a trend toward GM influenced by IPM. H_T category exhibited prominent transitions between IM and IPM, purposefully extending to GM. Individuals in this category actively took responsibility for their own metacognitive processes but also extended this responsibility to the group level. This sustained effort resulted in the emergence of group monitoring and group evaluation (see [Figure 3a](#)). EF category spends effort coordinating group activities through interpersonal monitoring. Group members focus on adjusting and achieving each other's goals, and IM plays a prominent role, particularly in monitoring and planning. This focus on IM leads to strong interactions within and between IM and IPM, ultimately resulting in GM, such as group evaluation (see [Figure 3b](#)). Conversely, L_T category dedicates more effort to coordination, with relatively limited efforts in IM, resulting in a low interaction mode guided by IM and IPM without extending to group-level dynamics (see [Figure 3c](#)). This finding is consistent with research findings on metacognitive similarity as a marker for identifying group metacognition ([Robinson and Gonnerman, 2020](#)). And in contrast to inter-level correlations ([Zheng et al., 2023](#)), our findings add new understanding of how metacognitive processes at each level transition and interact across levels in collaborative learning.

To identify key transformations in group patterns and understand the rules contributing to metacognitive processes, the study analyzed the frequent sequence rules of different categories, as shown in [Table 5](#). The support level in the table represents the frequency of rules, while the confidence level represents the probability of rules being true. We set the minimum support for frequent rule occurrences to 0.25 and the minimum confidence level to 0.6. All three categories have established rules ranging from individual monitoring to interpersonal monitoring, indicating that individual monitoring triggers interpersonal monitoring. Additionally, interpersonal monitoring is central to group metacognitive patterns, and supporting individual monitoring is vital for activating group metacognitive process. Moreover, all rules are guided by interpersonal monitoring, which plays a crucial role in forming GM. The H_T category formed the most rules, followed by the EF category, while the L_T category had the fewest rules. The interpersonal monitoring rules of the H_T category and EF category are triggered by continuous interpersonal monitoring and planning, suggesting that interpersonal planning may play an important role in forming GM.

4 Discussion and implications

4.1 Interpersonal metacognition is the main theme, but group metacognition is key to influencing collaborative learning

The descriptive analysis supported the findings from previous research. The overall impact of varying levels of metacognition on group regulation and performance across all categories was examined. IPM, particularly interpersonal monitoring, prevails in metacognitive interaction, validating the idea that sharing metacognitive thinking enhances opportunities for group members to engage in metacognitive interactions ([Haataja et al., 2022a,b](#); [Iiskala et al., 2021](#)). Furthermore,

TABLE 5 Group metacognitive frequent sequence rules for collaborative categories.

Category	Rules	Support	Confidence
H_T category	{IPM-M}>	0.43	0.62
	{IPM-M}>	0.30	0.72
	{IPM-M}>	0.30	0.68
	{IPM-E}>	0.26	0.63
EF category	{IPM_M}>	0.51	0.64
	{IPM_M}>	0.39	0.77
	{IPM_M}>	0.32	0.66
L_T category	{IPM_M}>	0.32	0.75
	{IPM_M}>	0.30	0.66

the greater frequency of interpersonal evaluations aligns with the need for ongoing coordination and calibration among members through evaluations to maintain consistent group understanding during metacognitive interactions ([Kwon et al., 2014](#)). Moreover, consistent with the findings of other studies ([Järvelä et al., 2021](#); [Stehle, 2022](#)), individual monitoring emerged as the most common individual metacognitive process, indicating that learners activate other levels of metacognition through autonomous monitoring. Additionally, group members are more likely to establish group consensuses through continuous monitoring and evaluation. The emergence of metacognitive similarity as a hallmark of GM ([Robinson and Gonnerman, 2020](#)) underscores the potential significance of monitoring and evaluation. While group goals and plans were less frequent, significant disparities were observed between group categories that did and did not engage in these aspects ([Hogenkamp et al., 2021](#)). This underscores the potential importance of group goals and plans in shaping the GM, warranting further exploration.

Specifically, significant differences in GM were observed among group categories with varying achievements, indicating GM is crucial to differences in collaborative learning performance. Unlike previous studies that directly examined the correlation between GM and collaborative learning achievement ([Liu et al., 2023](#)), this study identified group categories based on differences in individual preparation and group performance. It then analyzed variations in GM under different achievement changes to assess the impact of GM on collaborative learning. Consistent with Liu et al.'s research ([Liu et al., 2023](#)), this study also confirmed that GM facilitates learners' gains from collaborative learning. However, the extent to which learners benefit from collaborative learning is linked to the degree of GM development. Specifically, a higher level of GM corresponds to learners receiving benefits from collaborative learning more easily, as observed in the H_T category in this study. This combined assessment of individual preparation and group task performances focuses on the influence of individuals on the group. GM supports explaining how individual preparation performance relates to changes in group task performance. Additionally, this study aligns with Smith's research ([Smith and Mancy, 2018](#)), further validating that more successful individuals exhibit more metacognitive processes, such as the EF category. Individual preparation performance helps explain the role and actual effects of IM within groups, contributing to our understanding of the in-depth effects of multilevel metacognition on group performance. Multilevel process analysis is necessary to correspond with the hierarchical composition and changes in group performance.

4.2 Differences in individual and interpersonal metacognition support group metacognition in different categories

Based on the sequential interaction of the GM with different levels of metacognition, it has been confirmed that the IM is the foundation of other levels of metacognition (Socratous and Ioannou, 2022). Metacognitive sharing promotes common understanding (Gandolfi et al., 2023), and whether IM promotes metacognitive co-construction is crucial for influencing GM. For instance, at the individual level, H_T category and L_T category interact through metacognitive sharing from individual evaluation to interpersonal evaluation and individual planning to interpersonal monitoring. In contrast, EF category focuses on metacognitive co-construction triggered by self-directed monitoring of individual plans and the co-construction of individual monitoring to control cognitive activities and interpersonal evaluation. The IPM plays a crucial role in shaping the IM and forming the GM. Variations in the process of IPM are a significant factor contributing to different group patterns. For instance, at the interpersonal level, H_T category experiences a transition from planning to monitoring, then to evaluation, and finally to group monitoring or evaluation, thereby establishing a path for GM formation driven by IPM. In contrast, L_T category engages in sharing plans and co-constructing monitoring to group monitoring and individual plans, suggesting that high-performance categories are more inclined to extend interpersonal metacognition to the group level, while low-performance category need to exert effort to adjust IM. Whether GM contributes to differences in collaborative learning performance is a crucial consideration. Only the H_T category experienced a significant shift in GM, impacting IM and IPM, suggesting that GM further promotes metacognition engagement. However, achieving this influence may require external support.

Research indicates that all three group categories develop a metacognitive interaction pattern centered on IPM_M and IPM_E. However, only H_T category and EF category exhibited GM in this pattern. The lack of frequent rules related to the GM may contribute to a lower GM. Specifically, the sequential pattern yields additional insights into how IM and IPM contribute to GM. First, cognitive sharing and IM lay the groundwork for subsequent shifts in trends. While cognitive sharing and individual monitoring create opportunities for metacognitive interactions (Haataja et al., 2022a,b), they come with the caveat of reducing the effort required for social coordination. For instance, within the H_T category and EF category, cognitive sharing and self-monitoring promote participation in metacognitive interactions. In contrast, despite a similar trend in the L_T category, social coordination is needed, and social conflict may exist. Moreover, IM makes additional contributions by helping learners benefit from interpersonal interactions, thus reducing the effort required for GM (Gandolfi et al., 2023). For instance, compared with other categories, EF category generates more IPM through individual planning and evaluation. Second, interpersonal monitoring is the center of the second trend of all categories and is the key to shifting behavioral trends, signifying that group members have the opportunity to develop partial shared understanding through metacognitive co-construction. Finally, high-performing categories support more interpersonal metacognitive co-construction and are more likely to extend IPM to GM. In H_T category, interpersonal monitoring and evaluation consistently lead to group monitoring or evaluation, suggesting more negotiation processes within such groups (Gandolfi

et al., 2023). This underscores the positive interdependence, increased metacognitive interactions, and greater team productivity of active metacognitive categories compared with the passive one. However, the pattern lacks representation of the sequence characterization of GM on individuals and IPM, requiring further validation.

4.3 Comprehensive understanding of the development of group metacognition

The statistical analysis, sequential characteristics, and patterns of metacognitive interaction suggest that each collaborative group member's participation depends on coordinated metacognitive knowledge, monitoring, and control. Learners' potential metacognitive abilities are realized through group collaboration (Badhe et al., 2023), and their learning outcomes are influenced by GM. Failure to calibrate metacognitive monitoring or control may endanger collaboration and its outcomes (Winne et al., 2013). This can also further explain why interpersonal metacognition among H_T category can activate IM. H_T category learners benefit from IPM by calibrating each other's metacognition and promoting their metacognitive contributions (Kolić-Vehovec et al., 2022), leading to the construction of GM (Molenaar et al., 2014). In EF category, accurate IM enables effective IPM, promoting the sharing and co-construction of metacognition at the interpersonal level by identifying consistency between metacognitions (Gandolfi et al., 2023) and forming GM. Conversely, in the L_T category, less individual metacognitive participation and increased interpersonal metacognition and coordination did not positively impact the group level metacognition. This may result in poor individual metacognitive accuracy (Haataja et al., 2022a), with the IPM failing to calibrate or activate IM. Additionally, interpersonal metacognitive support may be ignored, resulting in less GM and hindering effective collaboration (Järvelä et al., 2021). This finding underscores the important role of individual metacognitive effort and interpersonal metacognitive alignment in forming GM. Individual metacognitive effort helps establish effective metacognitive interaction, serving as the foundation of GM. Interpersonal metacognitive alignment combines IM and group cognition (Gandolfi et al., 2023), promotes the contribution of IM by group members, and effectively links IM and GM, forming a virtuous cycle. The contribution of IM or IPM to the collaborative group, as well as the impact of GM, may influence what learners gain from collaborative learning (Paans et al., 2019). H_T category benefits individuals and group through metacognitive interactions, while EF category maximizes the impact of metacognitive efforts on individuals through such interactions. In contrast, L_T category either ignore or fail to support sustained metacognitive interactions, leading to improved performance after completing collaborative tasks. This further confirms that GM affects collaborative learning performance.

4.4 Limitations and future research

This research has several limitations. First, the small sample size limits the generalizability and statistical power of the results for detecting group metacognitive pattern effects. Additionally, the data were collected from a large, selective public university and may not represent all college students. Future research should employ a larger

sample size and conduct more detailed investigations into how different collaborative learning groups form and develop GM. Second, while the study grouped learners based on their metacognitive levels, it did not analyze their prior knowledge or learning motivation. Due to the mid-academic year of data collection, future research should explore how learners' individual characteristics affect GM. Third, this study focuses on how different levels of metacognition within a group interact to facilitate GM development. Although the impacts of individual and IPM on GM density were identified, future research could further explore the significance and predictive power of the impact of IM and IPM on GM. This could enable the development of personalized interventions and support. Concurrently, a deeper analysis of individual learner characteristics within the overall group and different group categories is warranted. Additionally, further exploration of how GM translates to IM or IPM is needed. Finally, this study was conducted in a natural collaborative learning environment, and the impact of support tools on GM was not considered. Hence, further exploration is needed to determine whether different support tools affect the GM.

5 Conclusion

The multilevel feature of metacognition significantly influences GM. However, traditional analysis methods often fail to connect multiple levels, limiting insights into how complex collaborative metacognitive interaction processes shape GM. From a methodological perspective, a combined approach using sequence analysis and process mining was used to examine the multilevel features of collaborative metacognitive interactions. The research results preliminarily validate the effectiveness of the coding framework in conceptualizing multilevel metacognition, as well as the significant impact of GM on collaborative learning performance. They emphasize the importance of IPM for GM and the critical role of monitoring and evaluating transitions across the individual, interpersonal, and group levels. IPM plays an important mediating role in promoting students' metacognitive interaction while using GM. Moreover, it is essential to explore how to support IM more effectively and to understand how individual characteristics may impact on low IM interactions. The positive impact of GM on metacognitive interactions necessitates specific support to optimize these interactions. Additionally, the role of social behavior on group metacognition also deserves further exploration. The group metacognitive pattern can guide educational practice and provide guidance for researchers in the transition of L_T category to H_T and EF categories, as well as provide a basis for supporting researchers in creating H_T category or EF category metacognitive patterns. Moreover, the fusion analysis method proposed in this study mitigates the impact of ontology flatness and method assumptions, enabling researchers to conduct more comprehensive temporal analysis.

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Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving human participants were reviewed and approved by the Local Ethics Committee of Northeast Normal University in China. The participants provided their written informed consent to participate in this study.

Author contributions

LQ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Visualization, Writing – original draft, Writing – review & editing. WZ: Conceptualization, Resources, Writing – review & editing, Funding acquisition. FL: Writing – review & editing, Funding acquisition. XX: Writing – review & editing, Conceptualization. JT: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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On quantitizing revisited

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This article builds on the highly cited 2009 article authored by Professor Emerita Margarete Sandelowski and her colleagues by critically reevaluating the process of quantitizing—transforming qualitative data into quantitative forms—a technique that has surprisingly not proliferated in academic research, presumably due to a shortage of methodological exploration in this area. This article responds to this shortfall by proposing a comprehensive meta-framework using the 5W1H approach, which outlines why, when, what, where, how, and who should engage in quantitizing, thereby integrating several frameworks and models across both mixed and multiple methods research. Central to this framework is the *DIME-Driven Model of Quantitizing*, which categorizes quantitizing into **D**escriptive, **I**nferential, **M**easurement, and **E**xploratory types, each enhancing the utility and precision of quantitizing. This innovative model supports the article's broader advocacy for quantitizing as a crucial methodological tool across diverse research traditions. This article explores the application and value of quantitizing across qualitative, quantitative, and mixed methods research traditions, demonstrating its broad relevance and transformative potential. It discusses the variable adoption of quantitizing based on differing philosophical perspectives related to ontology, epistemology, axiology, and methodology. Despite these differences, only a few research philosophies completely reject quantitizing. The article advocates for a balanced use of quantitizing to complement qualitative analyses and to enhance research clarity and applicability without compromising the richness of qualitative data. It serves as a comprehensive resource for understanding the complexities and utility of quantitizing, aiming to inspire researchers to consider this approach to enrich their analytical tools and to enhance the depth and applicability of their research findings.

KEYWORDS

quantitizing, DIME-Driven Model of Quantitizing, mixed methods research, 1 + 1 = 1 integration approach, qualitative data, data transformation, inter-respondent matrix, quantitative analysis

On quantitizing revisited

A landmark publication on quantitizing

A decade and a half ago, the landmark mixed methodological article entitled, “On Quantitizing,” co-authored by [Sandelowski et al. \(2009\)](#), was published in the *Journal of Mixed Methods Research (JMMR)*. Since its publication, it has received more than 1,000 citations. Their article, which is extremely thought-provoking, provides a comprehensive examination of quantitizing, covering philosophical and theoretical aspects. [Sandelowski et al. \(2009\)](#) define quantitizing as “the numerical translation, transformation, or conversion of qualitative data” (p. 208). More specifically, these authors describe quantitizing as representing

the process of assigning numerical (nominal or ordinal) values to data conceived as not numerical (or, following the previous discussion, to experience formed into words, visual displays, or something else conceived as qualitative). The not-numerical data typically referred to are segments of text in the form of written transcripts or field notes produced from interviews or participant observations that were themselves formed to accommodate the analyses planned (Emerson et al., 1995; Poland, 2002). The method used to accomplish this process is usually a variation of content, constant comparison, or domain analyses (e.g., Charmaz, 2006; Hsieh and Shannon, 2005; Spradley, 1979), whereby a priori and/or data-derived codes are attached to segments of text and numerical values are then assigned to those codes. (p. 2019–210)

Sandelowski et al. (2009) challenge readers to think critically about the practice of quantizing in the field of mixed methods research. In particular, they critique the conventional practices and assumptions underlying quantizing, providing a fresh perspective on how qualitative data are transformed into quantitative measures. Their discussion is relevant across various disciplines that utilize mixed methods research, making it a valuable resource for a broad audience of researchers.

Sandelowski et al. (2009) delve into the inherent challenges and subjective decisions involved in translating qualitative data into a numerical format that can be integrated with quantitative data. Further, they elaborate on the complexity involved in counting and making judgments about data. They emphasize that counting is not a straightforward, objective activity but is influenced by subjective judgments about what constitutes a countable object. That is, they illustrate how these activities are both inherently subjective and intersubjective. The subjectivity extends to the interpretation of qualitative data in research, wherein different analytical approaches can lead to different outcomes. Sandelowski et al. (2009) emphasize that the distinction between qualitative and quantitative data is not as rigid as traditionally thought, with each influencing and constituting the other. They discuss how the methodological choices, particularly in the design of data collection tools like questionnaires, inherently shape the data collected, affecting its interpretation and the validity of research conclusions. The theme of subjectivity is central, highlighting how qualitative data's transformation into numerical values is heavily dependent on human judgment and interpretation. The challenges of integrating qualitative and quantitative data are highlighted, particularly how qualitative data are forced to fit into pre-defined quantitative frameworks, which can distort the original data's meaning.

More specifically, Sandelowski et al. (2009) addressed the “foundational assumptions” (p. 208; e.g., qualitative and quantitative data are two types of data; quantizing represents a unidirectional process that is generally different from qualifying; counting is an unequivocal process), *judgments* (e.g., deciding on what and how to count), and *compromises* [e.g., “balancing numerical precision with narrative complexity” (p. 208)] involved in quantizing. Further, they (p. 219–220) outlined the following three standpoints that illuminate the benefits of quantizing: “conditional complementarity,” “critical remediation,” and “analytic alternation.” According to the authors, from the

perspective of conditional complementarity, quantizing is considered to enhance the value of qualitative data only if transforming it into quantitative form facilitates deeper insight and allows researchers to address significant questions or to test hypotheses in ways that would not be possible via other methods. Conversely, from the perspective of critical remediation, qualitative research enhances quantitative research by compensating for its deficiencies, namely, its failure to consider complexity, context, voice, and discourse. Here, qualitative research is viewed as crucial for ensuring the validity of quantitative methods. Consequently, the authors recognize the usefulness of redefining the concept of critical remediation to appreciate the value of quantizing. In this context, refining the numerical precision of qualitative data and ensuring that their compatibility with quantitative data are seen as ways to augment the value of qualitative data.

Overall, Sandelowski et al. (2009) provide a detailed critique of the process of quantizing, shedding light on its complexity and the nuanced decision-making involved. Further, they provide a deep and critical examination of the assumptions underlying the process of quantizing in research. Their use of practical examples, such as different interpretations of questionnaire scales, is laudable, effectively illustrating the theoretical points and making complex concepts more accessible.

A brief history of the word “quantizing”

The term *quantizing* dates back to at least 1894, as identified via an extensive search of the Google Scholar database. F. D. Allen first used the term in his discussion on ancient Roman poetry in an article wherein he critiqued the Word-accent Theory advocated by scholars like Keller, Thurneysen, and Westphal. Allen favored Alexander Reichardt's approach, which emphasized the quantitative analysis (i.e., quantizing) of Saturnian meter, focusing on syllable length over stress patterns. He expressed this preference by noting, “Reichardt arrays himself with decision on the side of a *quantizing* Saturnian, and dismisses the word-accent theory of Keller, Thurneysen and Westphal with brief comments that will seem wholly inadequate to the adherents of that doctrine” [emphasis added] (Allen, 1894, p. 207). This quotation highlights Allen's endorsement of Reichardt's methodology, which centers on the quantity of syllables as the primary structural element in verse, a common practice in classical metrics, particularly in Latin and Greek poetry. This traditional approach, known as quantitative meter, contrasts with the accentual meter, which bases the rhythmic structure on natural word stress. The debate over these approaches significantly has influenced the interpretation of ancient texts and the understanding of poetic forms in classical studies.

In terms of the Scopus database, the earliest documented use of the term *quantizing* was that by Escudie et al. (1965). These authors described quantizing as a method for converting a continuous range of values into a finite range of discrete values, a process essential in digital signal processing. This technique allows for the transformation of analog signals—continuous in nature—into digital signals, which are discrete and thus compatible with digital systems such as computers and digital circuits. In their discussion, the authors emphasized the increasing reliance on these

methods, noting that signal processing “more and more often uses sampling and *quantitizing* methods” [emphasis added] (p. 161), underscoring the critical role these techniques play in the functionality of the circuits under study.

The next earliest article in the Scopus database is that by Schippers et al. (1967). These authors stated that “A device was designed which used gypsum and electrical conductivity means of detecting and *quantitizing* the amount of water emanating underground plant parts under natural conditions” [emphasis added] (p. 90). Here, the term “*quantitizing*” refers to the process of quantifying or measuring the amount of water emanating from underground plant parts in a precise, numerical form. More specifically, *quantitizing* involves turning a qualitative observation—water emanation—into quantifiable data that can be measured and analyzed statistically or numerically. The authors describe a device they designed that utilizes gypsum blocks and electrical conductivity as a means to detect and to measure (or to *quantitize*) the amount of water. Gypsum blocks are used in soil moisture measurement; they absorb water from the soil, which changes their electrical conductivity. This change in conductivity then can be measured and converted into an estimate of the soil moisture level. In this instance, the term “*quantitizing*” is used to describe the transformation of the qualitative aspect of moisture presence into quantitative, measurable units, thereby allowing for more precise scientific analysis and conclusions regarding the behavior and characteristics of water movement around underground plant parts. This quantification is essential for systematically studying environmental and biological processes, enabling the researchers to derive more detailed and accurate insights from their observations.

A systematic review of the Scopus database from 1960 to April 16, 2024, focused on the occurrences of the word “*quantitizing*” or one of its variants (i.e., *quantitize*, *quantitized*, *quantitizes*, *quantitising*, *quantitise*, *quantitised*, and *quantitises*) in titles or abstracts, reveals its application across at least 23 different fields and disciplines. Figure 1 illustrates the frequency of Scopus-indexed publications that mention “*quantitizing*” or its variants. From this figure, it is evident that the field of social sciences leads in the number of publications ($n = 34$), followed by medicine ($n = 15$), engineering ($n = 14$), and psychology ($n = 13$). This spread underscores the broad relevance and utility of the concept across a diverse range of scholarly areas.

In the social sciences, Caracelli and Greene (1993) are credited with initially discussing the concept of data transformation, specifically the conversion of one data type into another to facilitate combined analysis. However, it was Tashakkori and Teddlie (1998) who appear to have first used the term “*quantitizing*” or its variants within this discipline. In their seminal textbook on mixed methods research, they credited Miles and Huberman (1994) for inspiring their application of the technique. They specifically noted: “In this application, the qualitative data would be converted to numbers using the ‘*quantitizing*’ technique described by Miles and Huberman (1994)” [emphasis in original] (p. 19).

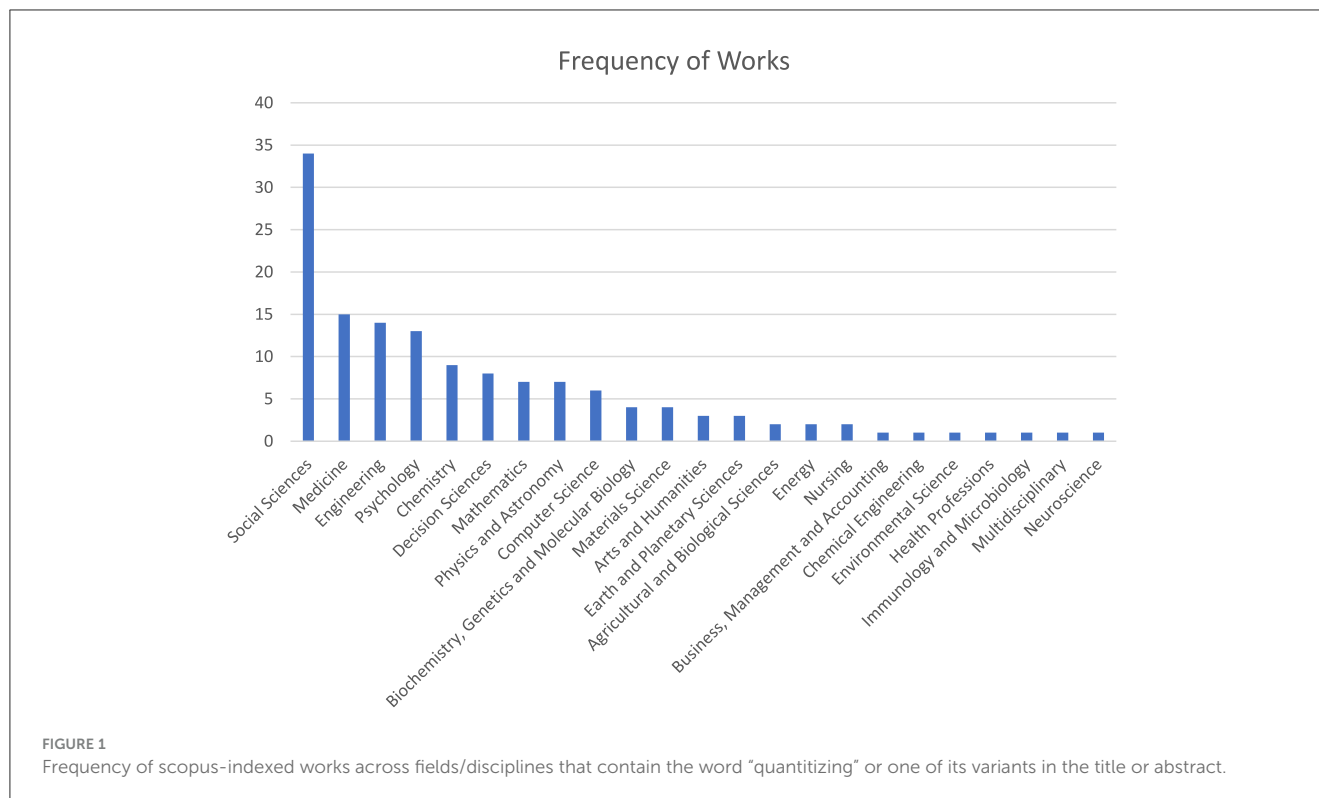
Following the publication of Tashakkori and Teddlie’s (1998) book, Sandelowski (2001) journal article appears to be the first to use the word “*quantitizing*”—doing so on one occasion when citing Tashakkori and Teddlie (1998). The term was first used in a Scopus-indexed article by Onwuegbuzie (2003). Intriguingly,

Sandelowski et al. (2009) did not reference Tashakkori and Teddlie’s (1998) work, but, instead, cited Sandelowski (2001) and Onwuegbuzie and Teddlie (2003) as the earliest sources employing the term *quantitizing*.

Developments in *quantitizing* since 2009

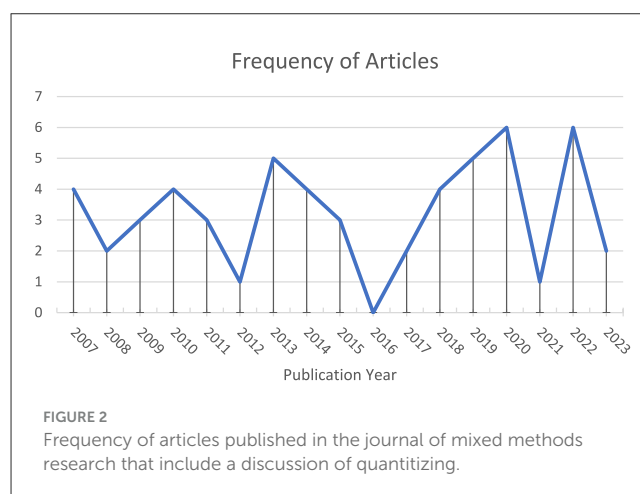
Since Sandelowski et al.’s (2009) highly cited article, several works (e.g., Collingridge, 2013; Isaac et al., 2016; Kerrigan, 2014; Leal et al., 2018; Wao et al., 2011; Weaver-Hightower, 2014) have been published in which *quantitizing* has been explicitly demonstrated—as evidenced by the fact that the title includes the word *quantitizing* or one of its variants (i.e., *quantitize*, *quantitized*, *quantitizes*, *quantitising*, *quantitise*, *quantitised*, and *quantitises*).¹ Interestingly, of the 346 articles (i.e., not including editorials, media reviews, notes, errata) published in *JMMR* at the time of writing (i.e., from Volume 1 and Issue 1 to Volume 18 and Issue 2), 55 have included the word *quantitizing* and/or one of its variants. This frequency indicates that 15.90% (i.e., 55/346) of all published *JMMR* articles to date have discussed/utilized *quantitizing* to some degree. Figure 2 displays the frequency of these *JMMR* articles by year. This figure indicates no linear trend ($p = 0.83$), no quadratic trend ($p = 0.87$), no cubic trend ($p = 0.80$), and no quartic trend ($p = 0.72$).² Simply put, there is no clear publication

1 The decision to use the word “*quantitizing*” and its variants (i.e., *quantitize*, *quantitized*, *quantitizes*, *quantitising*, *quantitise*, *quantitised*, and *quantitises*) in the systematic reviews conducted for the current article (i.e., *Journal of Mixed Methods Research*, Scopus) was made for two main reasons. First, by targeting the term “*quantitizing*” and its variants, the review ensures the inclusion of all studies that specifically address this concept, thereby eliminating false positives. This specificity is essential for collecting consistent information on how *quantitizing* is defined, applied, and evaluated across different works. Second, *quantitizing* is a key process in mixed methods research and is one of the (few) terms that has a shared meaning among mixed methods researchers. Therefore, a focused review on *quantitizing* facilitates better synthesis and comparison of procedures and findings across different studies, allowing researchers to identify common themes, challenges, and effective practices associated with this specific process. Consistent with this assertion, Gough et al. (2017) provide methodological guidance on conducting systematic reviews, discussing the importance of focusing on specific terms to ensure comprehensive coverage. However, it should be noted that focusing only on the term “*quantitizing*” and its variants likely results in false negatives, missing authors (see, for e.g., Bazeley, 2003, 2010, 2017, 2021) who describe the process using different terms (e.g., conversion, transformation). Attempting to identify all authors who discussed or applied the concept of *quantitizing* without using this specific term is beyond the scope of this article because it would require reviewing every single mixed methods research article published in the Scopus database over a 24-year period to determine whether each author used the concept of *quantitizing* despite not using the term. This issue is an example of *terminological variance* or *terminological inconsistency*, which can lead to misunderstandings, and is particularly problematic in interdisciplinary research wherein terminologies might carry different connotations in different fields. Terminological inconsistency also complicates the process of synthesizing research concepts.



pattern with regard to *JMMR* articles in which quantizing has been used/discussed. Going beyond *JMMR*, an analysis of Scopus-indexed works published since 1960 also reveals no clear trend in works wherein quantizing has been used/discussed.

A potential reason why the use of quantizing has not increased over the years might stem from the lack of methodological articles published in this area. Moreover, with a few exceptions (e.g., Collingridge, 2013), methodological works devoted exclusively to the concept of quantizing have tended largely to gravitate around its basic definition, as provided by Tashakkori and Teddlie (1998) and Sandelowski et al. (2009). Additionally, a small but significant body of work has presented arguments challenging the efficacy of quantizing (e.g., Seltzer-Kelly et al., 2012) or presenting useful alternatives to quantizing (e.g., Love and Corr, 2022), which



2 Further, fitting ARIMA (i.e., AutoRegressive Integrated Moving Average) models—which represent statistical models used for forecasting time series data—to the time series data in Figure 2 suggested that the best ARIMA model identified for the data is an ARIMA(0,1,1), which means there are no autoregressive terms ($AR = 0$)—wherein the AR part of the ARIMA model indicates how past values in the series can predict future values; one differencing operation ($I = 1$)—wherein I represents the number of differencing operations of raw observations needed to make the time series stationary (i.e., to stabilize the mean over time); and one moving average term ($MA = 1$)—wherein MA assists in smoothing out the noise in the data. This model indicates the following: (a) There is no pattern of publication frequency that repeats over the 16 years in a way that can directly predict future publication frequency; and (b) the publication frequency is somewhat random but with some predictability when considering the immediate past fluctuation.

might have played a role, however small, in further curtailing its widespread use. Another reason might stem from the justified concerns expressed about the process and outcomes associated with quantizing, some of which were powerfully articulated by Sandelowski et al. (2009), and which will be presented in a subsequent section.

As such, the goal of the remainder of this editorial is to outline a meta-framework—comprising several frameworks and models, as well as both mixed methods research and multiple methods research approaches—for quantizing qualitative data. As a starting point for our meta-framework, six important questions for information collection and problem solving should be answered—known as the Six Ws or 5W1H—namely, Why?,

When?, What?, Where?, How?, and Who? The Six Ws/5W1H is a fundamental concept commonly used in several fields to obtain comprehensive information about a subject or an event. It refers to a set of questions whose answers are considered important in information-gathering or problem-solving. By addressing these six questions, one can form a comprehensive view of a situation, which is crucial for effective decision-making, problem-solving, and understanding. This meta-framework is extremely versatile and can be applied across various fields, from investigative reporting and business analysis to academic research. Each of these questions will be answered respectively in the following six major sections.

Importantly, Sandelowski et al. (2009) concluded their article with a call to action, stating: “This article is a beginning effort, and calls for more efforts, toward that end” (p. 220). Therefore, the following article, in part, is a response to their call by furthering the important dialogue that they initiated. It is designed to serve as a resource not only for mixed methods researchers, but also for quantitative researchers and qualitative researchers, because, as noted by Sandelowski et al. (2009), “Quantitizing is not confined to mixed methods research” (p. 210). The goal is to inspire these researchers to consider incorporating quantitizing into their data analysis strategies when appropriate. By doing so, this article hopes to broaden the analytical tools available to researchers, enhancing their ability to derive meaningful insights from their data.

Why should researchers qualitize?

Quantitizing in mixed methods research serves multiple significant purposes, each enhancing the research process in distinct ways. First and foremost, quantitizing involves using both qualitative analyses (e.g., constant comparison of interview data to yield emergent themes) and, subsequently, quantitative analyses (e.g., descriptive statistics, such as frequencies, associated with these emergent themes) via the conduct of what Onwuegbuzie and Combs (2010) coined as crossover mixed analyses. Broadly defined, crossover mixed analysis refers to the method of applying an analytical technique traditionally used in one research tradition (e.g., quantitative) to data typically analyzed within another tradition (e.g., qualitative) (Combs and Onwuegbuzie, 2010; Greene, 2007; Onwuegbuzie and Combs, 2010; Onwuegbuzie et al., 2011; Onwuegbuzie, 2003; Onwuegbuzie and Teddlie, 2003). Crossover analysis can serve as the central analytic strategy in a study or as a component of various analytic steps. The extent to which crossover analysis is utilized should be guided by the specific research questions driving the study (Hitchcock and Onwuegbuzie, 2020). This technique facilitates a more integrative approach to data interpretation, allowing researchers to draw on the strengths of both quantitative and qualitative traditions to enhance the depth and breadth of their findings.

When optimally employed, crossover analysis in general and quantitizing in particular is consistent with Onwuegbuzie's (2017) $1 + 1 = 1$ formula, which represents fuller integration of qualitative and quantitative research approaches (see also Onwuegbuzie and Hitchcock, 2019; Onwuegbuzie et al., 2018). Particularly, opting to quantitize during the conceptualization stage of the mixed methods

research process might motivate the researcher(s) to collect, to analyze, and to interpret a diverse array of data types, thereby yielding full integration (Onwuegbuzie, 2022, 2023; Onwuegbuzie and Hitchcock, 2019, 2022). Creamer (2018) aptly notes, “in the highest-caliber mixed methods studies, the qualitative and quantitative strands are often so cleverly and iteratively interwoven that it becomes an exercise in semantics to disentangle the two” (p. 100). As will be discussed later, quantitizing under the $1 + 1 = 1$ integration meta-framework not only enhances the depth of the research but also strengthens the coherence and richness of the results by intricately integrating different data types.

Second, quantitizing acts as a bridge, facilitating the integration and more comprehensive analysis of the qualitative and quantitative data (Onwuegbuzie, 2003; Onwuegbuzie and Teddlie, 2003). As such, this process allows for a fuller examination of all data, enhancing pattern recognition and the extraction of meaning (Miles and Huberman, 1994; Miles et al., 2014; Sandelowski et al., 2009). When systems thinking, achieved through quantitizing, is merged with pattern-matching from qualitative data analysis, it enables researchers to gain a deeper and more comprehensive understanding of a phenomenon (Cao, 2007). Furthermore, quantitizing can help to verify interpretations stemming from the qualitative data, ensuring a rigorous and transparent research process wherein the meaning-making process is clarified. Employing quantitizing at the conceptualization stage optimizes and clarifies analysis, enabling the recognition of complexities, contradictions, (ir)regularities, peculiarities, or idiosyncrasies in data that might otherwise remain obscured and uncommunicated (Morse and Niehaus, 2009).

Third, quantitizing can significantly contribute to the methodological robustness of a study. In particular, it can enable the empirical integration of qualitative data with quantitative datasets (Driscoll et al., 2007). This transformation is not just about juxtaposing different data types but about merging them to create a cohesive understanding (Driscoll et al., 2007). By converting qualitative data into a format amenable to statistical analysis, researchers can assimilate insights from diverse data collection methods, thereby enriching the analysis and strengthening the conclusions drawn. By employing quantitizing, researchers can attain a more detailed and nuanced comprehension of their data, as well as can help to clarify any confusion of meanings that might have stemmed from the qualitative data, thereby unlocking the potential for advanced statistical insights and more extensive generalizations. In addition, quantitizing can help qualitative findings to be placed in a more appropriate context.

Fourth, quantitizing can enhance the clarity and applicability of research findings. It translates complex qualitative insights into quantifiable data, making the findings more accessible and actionable for broader applications, including clinical and translational research efforts aimed at community betterment [Clinical and Translational Research Institute, 2024; Mace and Critchfield, 2010]. By facilitating new communication patterns and promoting behavioral changes, quantitizing can play a crucial role in translating research from basic discoveries (i.e., T1 research) to translating the research findings into daily practice (i.e., T2 research) to translating the research findings to the widespread community and clinical applications (i.e., T3 research; Abernethy and Wheeler, 2011; Ivankova et al., 2018; Woolf, 2008).

Fifth, quantitizing can enhance the empirical accuracy of the descriptive insights provided by qualitative approaches. It allows researchers to delve into minute details or to expand their focus to broader contexts (Willems and Raush, 1969). This increase in empirical precision is beneficial for improving the subsequent meta-inferences.

Sixth, quantitizing can foster innovation within the research process. Moreover, it can encourage researchers to approach data creatively, enhancing the interpretive richness and multivariate nature of the data (Onwuegbuzie and Dickinson, 2008; Tufte, 2006). This creative, critical, and reflexive engagement with data not only improves the depth of analysis but also increases the transparency of the findings. Furthermore, from a quantitative research perspective, quantitizing can act as a form of reliability check, such as by comparing the quantitized qualitative data with other quantitative data. In qualitative research terminology, this approach is considered a form of triangulation (Denzin, 1978) or, as Newman and Benz (1998) described, a method for assessing structural relationships.

In summary, as can be seen, there are several rationales for quantitizing. Indeed, this list of rationales is not exhaustive. However, hopefully, in this section, sufficient motivation has been provided for researchers at least to consider quantitizing when conducting mixed methods research studies. In essence, quantitizing is a multifaceted technique that extends beyond simple data conversion. It is a critical tool in the mixed methods research arsenal that enhances data integration, interpretation, transparency, and application, fostering a more nuanced and impactful understanding of research phenomena. This approach not only can help address the complexities inherent in diverse data types but also can enrich the dialogue between qualitative depths and quantitative precision.

When should researchers quantitize?

Quantitizing is a strategic technique that researchers should consider utilizing when it has the potential, even if only partially, to address one or more of their research questions. The nature of the research questions themselves plays a crucial role in determining the suitability of quantitizing. For instance, using the typology conceptualized by Plano Clark and Badiee (2010), because quantitizing is applied to qualitative data, it is particularly relevant for *dependent research questions*—those that rely on outcomes derived from other questions—rather than for *independent research questions*, which relate to each other but do not depend on one another's outcomes. Furthermore, quantitizing techniques are applicable not only to *predetermined research questions* established at the onset of a study based on literature, practice, personal inclinations, or disciplinary considerations, but also to *emergent research questions*, which are new or modified research questions that develop during various phases of the research process (e.g., design, data collection, data analysis, or interpretation phases).

Quantitizing is especially pertinent to *general overarching mixed methods research questions*, which are broad inquiries addressed via both quantitative and qualitative research approaches (Plano Clark and Badiee, 2010). It is also useful for *hybrid mixed methods*

issue research questions, which split a single research question into two distinct parts, each addressed by different research approaches (Plano Clark and Badiee, 2010). Additionally, quantitizing is crucial for *mixed methods procedural/mixing research questions*, which represent narrow questions that direct the integration of the qualitative and quantitative strands of the study. This is in contrast to *separate research questions*, wherein the quantitative and qualitative research questions remain distinct and unconnected.

The framework developed by Greene et al. (1989) offers a valuable way to conceptualize the goals of quantitizing, which can vary depending on whether the technique is applied in a single-stage or multiple-stage context. Single-stage quantitizing involves applying quantitizing techniques at one stage of the research process, whereas multiple-stage quantitizing entails the use of these techniques across two or more stages. In single-stage quantitizing, three of Greene et al.'s (1989) five goals are particularly relevant:

- *Complementarity*: Seeking to elaborate, to illustrate, to enhance, and to clarify findings from qualitative data with results from quantitized qualitative data, or vice versa.
- *Development*: Utilizing results from the quantitizing process to aid findings from qualitative data, enhancing the depth and understanding of those findings.
- *Expansion*: Broadening the scope and range of the study by employing multiple analytical strands, thereby enriching the study phases with findings from both qualitative data and quantitized results.

In multiple-stage quantitizing, the remaining goals of Greene et al. (1989) are critical:

- *Triangulation*: Comparing findings from quantitized data with results from other quantitative datasets to validate or to challenge the results.
- *Initiation*: Identifying paradoxes and contradictions that arise when comparing findings from quantitized data with quantitative results, potentially leading to a re-framing of the research questions.

In summary, quantitizing should be considered a versatile and integral part of mixed methods research, adaptable to various research questions and capable of fulfilling multiple research goals, thereby enriching the research process and outcomes.

When should researchers not quantitize?

Although quantitizing is a valuable method in mixed methods research, there are specific contexts wherein it might be less beneficial or even counterproductive. It is crucial to emphasize that the purpose of this section is not to discourage the use of quantitizing entirely, but to provide clarity on situations wherein the technique might compromise rather than enhance the integrity of the data.

Researchers should avoid quantitizing when the intent is merely to transform qualitative data into quantitative form without regard for the richness and complexity of the original data. In such cases,

quantitizing might lead to oversimplification and loss of depth in understanding the data's underlying narrative, particularly when there is no substantive alignment between the qualitative insights and the quantitative framework (Sandelowski et al., 2009). This can happen if the qualitative data are being manipulated or *forced* into numerical categories simply for the sake of comparison with existing quantitative datasets. This process might diminish the authenticity and richness of the qualitative findings, which are meant to capture nuances that numbers alone cannot convey.

Further, it is inappropriate to use quantizing as a superficial method to compare qualitative findings to existing quantitative data, especially when there is no substantial justification for such comparison. In these cases, quantizing inadvertently could undermine the qualitative analysis by imposing arbitrary or mismatched numerical structures on data that require a more nuanced interpretation.

However, this caution is by no means a blanket rejection of quantizing. On the contrary, when used appropriately, quantizing enhances mixed methods research by allowing qualitative insights to inform and to be informed by quantitative analysis, creating a more integrated and comprehensive approach. Researchers, especially beginning researchers (e.g., doctoral students), should approach quantizing thoughtfully, ensuring that its application aligns with the research questions and the nature of the data, and should not shy away from using this powerful tool when it is methodologically justified. In essence, the $1 + 1 = 1$ integration formula (Onwuegbuzie, 2017, 2022, 2023; Onwuegbuzie and Hitchcock, 2019, 2022) underscores the importance of integration rather than juxtaposition. Quantizing should not be viewed as a unidirectional or mechanical process but rather as a dynamic, iterative one that enriches the research through the thoughtful blending of qualitative and quantitative insights.

What should researchers quantize

The technique of quantizing entails transforming qualitative data into quantitative form (i.e., numerical codes) that can, in turn, be subjected to quantitative (i.e., statistical) analyses (Miles and Huberman, 1994; Sandelowski et al., 2009; Tashakkori and Teddlie, 1998). The sources of qualitative data suitable for conversion into numerical codes for quantitative analysis encompass the following four major groups as identified by Leech and Onwuegbuzie (2008): talk, observations, documents, and images (e.g., drawings, photographs, videos).³ Each of these sources

provides a rich vein of qualitative data that, when quantized, can be systematically analyzed to reveal patterns and insights not readily apparent through qualitative analysis alone. This approach allows researchers to bridge the interpretative depth of qualitative research with the statistical rigor of quantitative methodologies, enhancing the comprehensiveness and robustness of their findings.

The actual types of qualitative data that can be quantized include codes, categories, sub-themes, themes, figures of speech, meta-themes, and narratives (i.e., prose or poetry). In the context of qualitative research, coding is a fundamental process wherein data elements—whether spoken words, phrases, or visual images—are encapsulated into succinct labels that capture their essence. A *code* can describe any unit of data, ranging from a brief utterance to an intricate image, across various media including still or moving visuals, drawings, photographs, or videos, presented in diverse sizes and durations. It represents the smallest point of meaning extracted from an object. Whether conveyed in physical or virtual spaces, codes distill the fundamental meaning from a data excerpt. Saldaña's (2021) identification of 33 coding strategies produces an array of code types, such as an *emotions code*, which discerns the underlying emotional states of participants.

When similar codes are aggregated, a *category* emerges, offering a broader interpretation of the data snippets. Moving up the abstraction ladder (Cartwright, 2012), a *subtheme* elevates the discussion by synthesizing these categories into a more cohesive narrative element, often encapsulated in a phrase or sentence. A *theme* further abstracts these ideas into significant elements or concepts that reveal patterned responses or meanings within the dataset. As such, it represents a higher level of abstraction or categorization than a subtheme. More specifically, it is an extended phrase or sentence that characterizes a major element, idea, or concept—representing some level of patterned response or meaning within the data set. Themes articulate major insights that are crucial for understanding the data's deeper layers.

Additionally, a *figure of speech* represents a specialized category of theme. These include a variety of rhetorical devices such as metaphors, which directly reference one concept by mentioning another; antitheses, which juxtapose functionally opposite ideas; hyperboles, which employ exaggeration for emphasis; analogies, which transfer meaning between subjects; metonymies, which involve the use of closely associated concepts interchangeably; puns, which play on multiple meanings of words; onomatopoeias, which mimic real sounds; and similes, which make direct comparisons. These devices can range from a single word to extended phrases, adding stylistic depth and enriching the narrative.

A *meta-theme* is an overarching phrase or sentence that encapsulates multiple themes, providing a higher order of interpretation and insight. Finally, in the context of research, particularly in social, behavioral, and health sciences, a *narrative* weaves together a logical and coherent story from selected codes,

³ Talk can be individual (e.g., individual interviews) or group-based (e.g., paired depth interviews, focus group discussions, critical dialectical pluralist focus group discussions), face-to-face (e.g., interviews, focus group discussions) or virtual (e.g., online focus groups, chatroom discussions, listservs), synchronous (e.g., SMS, text) or asynchronous (e.g., emails), and verbal (i.e., voice of each interviewee) or nonverbal (e.g., proxemics, kinesics, paralinguistics, chronemics; cf. Onwuegbuzie and Abrams, 2021, in press). Observations can be emic-based (e.g., onsite observations) or etic-based (e.g., Geographic Information Systems), interactive (i.e., live observations) or non-interactive (i.e., past observations), first hand (e.g., by the researcher) or second hand (e.g., by someone else). Documents can be non-digital

(e.g., articles, books, newspapers) or digital (e.g., blogs, tweets, Facebook, emails, chat rooms). Finally, images can be still (e.g., drawings, paintings) or moving (e.g., videos), 2-dimensional (e.g., drawings, paintings) or more than 2-dimensional (e.g., movies), non-virtual (e.g., drawings) or virtual (e.g., I-phone, I-Pad, Youtube, TikTok, Panoramio, Flickr, iMovie, Instagram).

categories, subthemes, themes, and/or meta-themes. Although typically presented in prose, narratives also can be creatively expressed in poetic forms, offering a unique lens through which to view and to interpret the data.

It should be noted that the process of quantizing qualitative data can differ based on the type of data being transformed. For instance, the prevalence of each code can be determined by counting their frequencies. In contrast, for categories, the frequencies of codes within each category can be calculated, and the categories can be analyzed by the proportion of codes they contain relative to the total number of codes. For sub-themes, the occurrences of each sub-theme within the data can be counted, and their distribution across different contexts or groups analyzed. Regarding themes, their presence across data sets can be measured, or a Likert-format scale can be used to rate their intensity or significance. The usage of each figure of speech can be counted and analyzed to understand their impact or frequency in the text. Meta-themes can be quantized by counting how often they appear or are referenced across different data sets (e.g., focus group discussions, individual interviews), and their relative prominence can be compared. Narratives (i.e., prose or poetry) can be quantized by breaking them down into codes, themes, or other units, and then analyzing the narrative length, complexity, and frequency of specific elements.

Overall, quantizing these various forms of qualitative data can transform rich, descriptive information into a format amenable to statistical analysis. This transformation not only allows for a broader scale of analysis but also enhances the ability to communicate findings clearly and to apply them in practical settings, thereby bridging the gap between qualitative richness and quantitative rigor.

Where should researchers quantize?

Quantizing can be effectively applied to qualitative data collected from both offline and online environments. Online environments encompass various forms of situated communication that occur through platforms like Facebook, X, Instagram, Snapchat, WhatsApp, Pinterest, WeChat, Reddit, blogs, wikis, forums, and listservs, as noted by Gerber et al. (2017). Moreover, in the era of big data, as discussed by Gerber et al. (in press), the potential to quantize virtual data is growing at an unprecedented rate. This expanding scope reflects the increasing complexity and volume of digital interactions, providing rich qualitative datasets for quantitative analysis and enabling deeper insights into human behavior and societal trends.

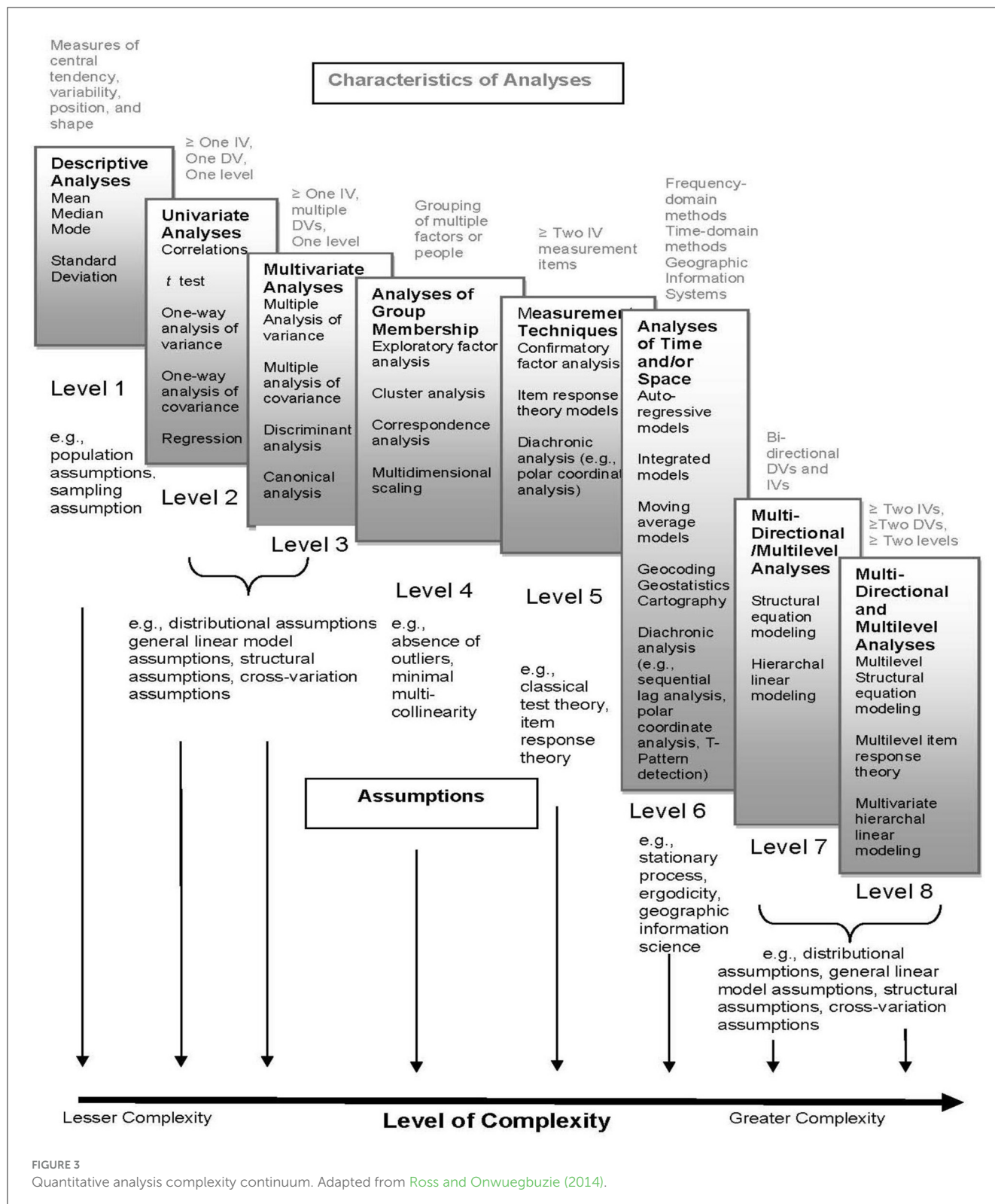
The ability to transform intricate qualitative data sources into quantifiable information allows researchers to apply statistical tools and machine learning algorithms that can identify trends, predict outcomes, and model behaviors on a scale previously unimaginable. Such advancements significantly enhance the analytical power of researchers across disciplines, offering the means not only to track but also to anticipate changes in cultural patterns, social dynamics, and communication practices. As a result, quantizing becomes a crucial technique in the toolkit of researchers, equipping them

with the capabilities necessary to navigate and to interpret the vast landscapes of digital data.

How should researchers quantize?

To date, in the context of mixed methods research, the process of quantizing largely has remained elementary, as evidenced by Onwuegbuzie and Corrigan's (2018) meta-prevalence rate study, which involved identifying the prevalence of mixed methods research approaches across 46 prevalence rate studies between 1994 and 2015 that represented an array of fields and disciplines. Typically, this has involved straightforward enumerations—counting occurrences of codes, categories, sub-themes, themes, figures of speech, meta-themes, and narratives—often represented simply through frequency counts or employing basic descriptive statistics. This rudimentary approach to quantizing aligns with the findings presented by Ross and Onwuegbuzie (2014). Their research reveals a consistent trend: when quantitative methods are integrated with qualitative research, there is a prevalent use of less complex analytical techniques. Specifically, within the framework of the eight distinct levels of quantitative analysis complexity illustrated in Figure 3, studies predominantly employ only the first three levels. These comprise descriptive analyses, univariate analyses, and, less frequently, multivariate analyses. This pattern underscores a cautious, perhaps conservative, utilization of quantitative complexity in mixed methods research, suggesting an opportunity for a deeper, more nuanced engagement with quantitative techniques to enrich qualitative findings. And a useful starting point for engaging in a wider variety of quantitative analyses is via the use of quantizing.

Categorizing the types of quantitative analyses into eight levels of complexity, as shown in Figure 3, offers several benefits in the context of quantizing qualitative data. First, it provides a clear and organized framework for researchers to understand and to select the appropriate quantitative analysis based on the complexity of their data and research questions. This helps in systematically planning and conducting analyses. Second, by categorizing the analyses, researchers, especially those who might not be as familiar with the array of quantitative analyses, can grasp more easily the progression from simple to complex analyses. This can facilitate learning and application of appropriate quantizing techniques. Third, the continuum helps in matching the level of complexity of the analysis to the nature of the data. For instance, simpler descriptive statistics might be sufficient for basic quantizing, whereas more complex multivariate analyses might be necessary for exploring relationships within and between multiple variables or groups. Fourth, different types of data (codes, categories, sub-themes, themes, figures of speech, meta-themes, and narratives) require different analytical approaches. The continuum ensures that researchers can choose methods that yield appropriate quantization of each type of data, maintaining the integrity and richness of the original qualitative data. Fifth, using a standardized framework allows for consistency in data analysis across different studies. This can enhance the comparability of findings across various research studies and disciplines. Sixth, by progressing through levels of complexity,



researchers can uncover deeper insights and more nuanced understandings of their data. For example, moving from simple frequency counts to multilevel structural equation modeling allows for a more sophisticated exploration of underlying patterns and relationships. Finally, documenting the analytical process using

a complexity framework enhances the transparency and rigor of the quantizing process. In turn, this can improve the credibility and reproducibility of the findings. In summary, the benefit of categorizing quantitative analyses into levels of complexity lies in providing a structured, understandable, and rigorous approach to

quantitizing qualitative data, thereby enhancing the quality and clarity of research outcomes.

A valuable entry point for expanding the scope of quantitative analyses in mixed methods research is via the practice of quantitizing. By expanding the quantitizing process, researchers will be able to apply a broader array of sophisticated statistical techniques to qualitative information, thereby unlocking deeper insights and revealing patterns that might otherwise remain obscured. This approach not only will enrich the analytical depth of mixed methods research studies but also will enhance the rigor and generalizability of the findings, paving the way for a more integrated and comprehensive understanding of complex and complicated research phenomena.

To this end, in what follows, I present a four-level, meta-model of quantitizing that encapsulates a dynamic and intricate process far surpassing any existing conceptual frameworks. This meta-model delineates a stratified approach, meticulously structured to unfold across multiple levels. Each successive tier in this hierarchy represents an evolutionary step within the quantitizing process, guiding researchers through a systematic progression from foundational data categorization to complex analytical synthesis.

This meta-model represents a methodical and structured process, developed to illuminate the nuanced pathways by which qualitative data metamorphose into quantifiable insights. It is a paradigmatic blueprint, charting the course from raw narrative to numerical precision, and it promises to refine our understanding of the empirical world through the refined lens of quantitative clarity.

Level 1 quantitizing

Level 1 quantitizing, or first-level quantitizing, comprises the following four classes of quantitizing: **d**escriptive-based quantitizing, **i**nferral-based quantitizing, **m**easurement-based quantitizing, and **e**xploratory-based quantitizing. It is from the initials of these four foundational classes that the term *DIME-driven* quantitizing has been coined—elegant in its simplicity, yet profound in its significance. The DIME acronym serves not only as a mnemonic, but also as a metaphor for the value and precision inherent in this approach.

Descriptive-based quantitizing

Descriptive-based quantitizing involves converting qualitative data into quantitative metrics specifically to describe the characteristics of the data. This approach applies statistical techniques to summarize and to convey the patterns found in qualitative responses. Descriptive-based quantitizing includes the following four key groups of descriptive measures to outline these patterns effectively: measures of central tendency, measures of variation/dispersion, measures of position/relative standing, and measures of distributional shape. These measures are integral to the process of deriving meaning from data.

Measures of central tendency (e.g., mean, median, and mode) are used to describe the central point or typical value within a dataset. By quantitizing qualitative data to these metrics, researchers can determine the most typical or prevalent responses or themes within the data. Measures of variation/dispersion (e.g., range, interquartile range, standard deviation, and variance) help to describe how spread out the data points are within the dataset,

giving insights into the consistency or diversity of qualitative responses. Measures of position/relative standing (e.g., percentiles, quartiles, *z*-scores, and *t*-scores) describe the position or ranking of individual data points within the overall data distribution of the qualitative responses. These measures help researchers understand how individual responses or themes compare to the overall group, highlighting outliers or particularly representative cases. Measures of distributional shape (e.g., skewness, kurtosis) provide insights into the symmetry and tail heaviness of the distribution of the qualitative data, important for understanding the underlying characteristics of the data.

In essence, descriptive-based quantitizing uses these statistical tools to provide a comprehensive statistical summary of qualitative data, making it possible to capture and to communicate the essence and nuances of the data in a structured, quantifiable form. This method is particularly useful in the initial stages of data analysis, wherein understanding the general trends and patterns is crucial.

The following examples of descriptive-based quantitizing illustrate how qualitative data can be transformed into quantitative metrics using various descriptive statistical measures, specifically, measures of central tendency, dispersion, position, and distributional shape. These examples span a variety of research contexts, demonstrating the flexibility of quantitizing in different fields and types of data collection, from interviews to focus groups. By applying these techniques, researchers can summarize qualitative data in a structured manner, revealing underlying patterns, trends, and distributions in the dataset. This allows for a deeper, more nuanced understanding of the data while preserving its richness.

Quantitizing qualitative data from survey data using frequency counts

The first example represents an article that ended up being the most downloaded article published in the *American Educational Research Journal* from 2007 to 2011. Onwuegbuzie et al. (2007) examined the 912 university students' perceptions of characteristics of effective college teachers who were administered a questionnaire asking them to identify and to rank between three and six characteristics that they believed effective college instructors should possess or demonstrate, as well as to provide a definition or description for each characteristic. A qualitative analysis, specifically constant comparison analysis, of these responses yielded nine themes, which are summarized by the acronym *RESPECTED*: **R**esponsive, **E**nthusiast, **S**tudent-centered, **P**rofessional, **E**xpert, **C**onnector, **T**ransmitter, **E**thical, and **D**irector. These themes were quantitized as follows:

if a student listed a characteristic that was eventually unitized under a particular theme, then a score of 1 would be given to the theme for the student response; a score of 0 would be given otherwise. This dichomotization led to the formation of an interrespondent matrix (i.e., Student $\times$ Theme Matrix; Onwuegbuzie, 2003; Onwuegbuzie and Teddlie, 2003). Both matrices consisted only of 0 and 1 s. (p. 127)

This inter-respondent matrix then was subjected to descriptive-based quantitizing. In particular, "By calculating the frequency of

each theme from the inter-respondent matrix, percentages were computed to determine the prevalence rate of each theme" (p. 127), which led to the numerous insightful findings, such as that student-centeredness was the most prevalent theme (i.e., 58.88% endorsement rate).

Quantitizing qualitative data from interviews using means as a measure of central tendency

For the second example, let us suppose that a researcher conducted a study examining the experiences of 100 first-time mothers. These mothers were interviewed about the challenges that they faced during their 1st year of motherhood. Using some form of qualitative analysis, their responses were categorized into the following five major themes: "sleep deprivation," "emotional support," "breastfeeding difficulties," "time management," and "partner involvement." Each participant's response was scored for the presence (1) or absence (0) of each theme, yielding a binary inter-respondent matrix. The mean frequency of each theme then was calculated to identify the most commonly mentioned challenges. For example, if the "sleep deprivation" theme had a mean score of 0.85, this would indicate that 85% of the mothers discussed sleep deprivation as being a key challenge.

Using measures of variation/dispersion to quantitize focus group responses

For the third example, let us suppose that a researcher conducted a study of high school students' attitudes toward environmental conservation. Specifically, let us suppose that 10 focus groups were conducted that yielded a total of 80 students. After a thematic analysis, the students' responses were categorized into themes such as "recycling," "energy conservation," "climate change awareness," and "sustainable practices." These themes then were quantitized using measures of standard deviation and interquartile range to assess the variability of student engagement with each topic. The "recycling" theme had a standard deviation of 0.12 across focus groups, indicating consistent discussion across all groups, whereas "climate change awareness" had a higher standard deviation of 0.45, reflecting a more varied emphasis across groups.

Quantitizing open-ended survey responses using measures of position/relative standing

For the fourth example, let us suppose that a researcher conducted a survey of employee satisfaction in a multinational company. Let us suppose further that open-ended responses from 500 employees about their job satisfaction were coded into five major themes: "work-life balance," "career development opportunities," "management support," "salary satisfaction," and "team collaboration." Each response was assigned a score based on the presence or absence of these themes. To analyze further these responses, the data were converted into percentiles. For example, the "work-life balance" theme ranked in the 80th percentile, meaning that 80% of respondents mentioned it as a key factor in their job satisfaction, whereas "team collaboration" ranked in the 30th percentile, suggesting that it was less frequently mentioned.

Applying measures of distributional shape to quantitize narrative data

For the fifth example, let us suppose that a researcher conducted a study investigating patient experiences with chronic illness that involved analyzing narratives from 200 patients. These narratives were coded into four themes: "treatment satisfaction," "doctor-patient communication," "access to care," and "emotional resilience." Using measures of skewness and kurtosis, researchers analyzed the distribution of these themes. The "treatment satisfaction" theme showed a positive skewness of 1.5, indicating that most patients had positive responses, but a few reported extreme dissatisfaction—using Westfall and Henning's (2013) criteria, wherein skewness coefficients between 1 and 2 suggest moderate asymmetry, whereas higher values represent more extreme asymmetry. The "doctor-patient communication" theme had a kurtosis of 2.3, suggesting that most patients had moderately similar experiences, with few outliers reporting exceptionally good or bad communication experiences—using Westfall and Henning's (2013) criteria, wherein kurtosis coefficients close to 3 indicate normal distribution, with lower values (<3) suggesting a flatter (i.e., platykurtic) distribution and higher values (>3) indicating a distribution with more outliers or extreme values (i.e., leptokurtic distribution).

Inferential-based quantitizing

Inferential-based quantitizing involves transforming qualitative data into estimations or predictions via methods such as general linear model (GLM) analysis—for example, the correlation coefficient, independent samples *t*-test, analysis of variance (ANOVA), multiple analysis of variance (MANOVA), canonical correlation analysis, structural equation modeling (SEM), and hierarchical linear modeling (HLM)—tailoring the data for more predictive utility. The purpose of inferential-based quantitizing is to make inferences about a larger population from a sample. This approach enables researchers to extend conclusions beyond the immediate data set to broader contexts, which can be essential in validating hypotheses and supporting generalizations. For instance, in educational research, inferential-based quantitizing might involve coding and quantitizing qualitative responses from a focus group of teachers discussing educational technologies. The quantitized data then could be used to perform a logistic regression to predict the likelihood of technology adoption based on factors such as age, experience, and attitudes. The results could be generalized to suggest broader trends across schools or regions, providing that the sample is representative.

The following examples illustrate how inferential-based quantitizing enables researchers to transform qualitative insights into quantitative data that can be analyzed using various inferential techniques. Through methods such as canonical correlation analysis, multiple regression, ANOVA, logistic regression, and structural equation modeling, researchers can explore deeper relationships and test hypotheses across larger populations. By doing so, researchers can make predictions, examine relationships, and draw conclusions that extend beyond the immediate sample, thereby enhancing the generalizability and predictive power of their findings. This approach allows for a more comprehensive understanding of complex phenomena while preserving the richness of the original qualitative data.

Using canonical correlation analysis to examine the relationship between demographic variables and qualitatively derived themes

Circling back to the Onwuegbuzie et al.'s (2007) investigation, these researchers conducted a canonical correlation analysis in order to examine the relationship between the nine quantitized themes and the eight demographic variables (i.e., gender, race, level of student, preservice teacher status, age, GPA, number of credit hours taken, and number of offspring). Among the numerous results stemming from this analysis was the finding that

gender, race, age, level of student, preservice teacher status, number of offspring, and number of credit hours are related in some combination to enthusiast, student centered, professional, ethical, expert, and director. Of the demographic variable set, only GPA did not appear to play a role in the prediction of the themes. (p. 140)

In essence, inferential-based quantitizing transforms qualitative insights into quantitative data that can be analyzed statistically to draw conclusions about larger populations, providing a powerful tool for substantiating research findings in mixed methods research studies.

Using multiple regression to predict employee job satisfaction based on qualitatively derived themes

For the second example, let us suppose that researchers conducted a study exploring the job satisfaction of employees in a multinational company. These researchers conducted semi-structured interviews with 200 employees. Qualitative responses were coded into themes such as “work-life balance,” “career development,” “management support,” and “work environment.” These themes then were quantitized, and a multiple regression analysis was performed to predict overall job satisfaction. The researchers used the presence of these quantitized themes as independent variables to predict the dependent variable of job satisfaction scores from a quantitative survey. Results indicated that “management support” and “career development” were the strongest predictors of job satisfaction, accounting for 40% of the variance in the satisfaction scores. This finding would suggest that enhancing management support and career development programs could improve job satisfaction across the organization.

Performing ANOVA to compare student engagement across different learning styles

For the third example, let us suppose that researchers conducted an educational study wherein they interviewed 150 high school students about their engagement levels in different learning environments (e.g., group work, individual projects, and technology-assisted learning). The qualitative responses were coded and quantitized, categorizing engagement into three themes: “high engagement,” “moderate engagement,” and “low engagement.” Researchers then performed a one-way ANOVA to compare engagement levels across three different learning styles: visual, auditory, and kinesthetic. Let us suppose further that the analysis revealed a statistically significant difference in engagement levels, with visual learners reporting the highest engagement in technology-assisted learning [$F_{(2,147)} = 6.32, p < 0.01$] that

represented a large effect size ($\eta^2 = 0.14$). This inferential analysis would allow the researchers to conclude that, for these high school students, technology-assisted learning is particularly effective for visual learners.

Logistic regression to predict health behaviors from qualitatively coded themes

For the fourth example, let us suppose that researchers undertook a health behavior study wherein they conducted focus groups with 120 participants discussing their experiences with adopting healthy habits. The qualitative responses were coded into themes such as “exercise frequency,” “dietary choices,” “emotional support,” and “time management.” These themes then were quantitized, and a logistic regression was conducted to predict whether participants adopted a healthy lifestyle (binary outcome: 0 = no, 1 = yes) based on the coded themes. Let us suppose further that the logistic regression model showed that “exercise frequency” and “emotional support” were statistically significant predictors of adopting a healthy lifestyle ($p < 0.05$), whereas “time management” was not a statistically significant predictor. This inferential-based quantitizing would allow the researchers to predict the likelihood of a healthy lifestyle being adopted based on the presence of certain qualitative factors in participants' narratives.

Structural equation modeling to analyze the relationships between workplace stressors and burnout

For the fifth example, let us suppose that researchers conducted in-depth interviews with 100 nurses to explore the sources of workplace stress and how these stressors contributed to burnout. Qualitative data were coded into stressor categories such as “workload,” “emotional strain,” “interpersonal conflict,” and “lack of autonomy.” These categories then were quantitized and used in a structural equation modeling (SEM) analysis to examine the relationships between these workplace stressors and burnout levels (measured by a standardized burnout scale). Let us suppose further that the SEM analysis revealed that “emotional strain” had the strongest direct effect on burnout ($\beta = 0.65, p < 0.001$), whereas “lack of autonomy” had an indirect effect, mediated by “workload.” This inferential approach would allow the researchers to generalize the relationships between stressors and burnout to the broader nursing population, providing actionable insights for healthcare administrators.

Measurement-based quantitizing

Measurement-based quantitizing involves converting qualitative data into quantitative data specifically for the purposes of measurement, including the development of instruments and score-validation of constructs. This approach typically involves the systematic transformation of qualitative observations into quantifiable scales or metrics that can be empirically tested and score-validated. It allows researchers to measure complex constructs that are not directly observable but can be inferred from qualitative data. Techniques such as Rasch modeling and item response theory (IRT) are commonly used in this process. These techniques help in assessing the properties of the measurement tools, including their score reliability (consistency of the scores yielded by the instruments) and item functioning (how individual

items contribute to the overall measurement), ensuring that the instruments and constructs are robust and accurately reflect the variables they measure.

Consider a study aimed at understanding the barriers to exercise among middle-aged adults. Researchers might initially conduct qualitative interviews to gather detailed descriptions of perceived barriers. Using measurement-based quantizing, these barriers could be categorized and transformed into a survey instrument with scaled items measuring each barrier's perceived impact. The survey then could be administered to a larger population to score-validate the scale and quantitatively assess the prevalence and impact of each barrier, ultimately contributing to targeted interventions.

Returning to the Onwuegbuzie et al. (2007) study, although the authors did not do this, based on their large sample size (i.e., $n = 912$), they could have conducted a Rasch analysis to identify the themes' prevalence or rarity across responses, thereby revealing their relative difficulty or ubiquity. Alternatively, they could have conducted a 2-parameter IRT model to identify not only the themes' prevalence, but also their efficacy in differentiating among participants' qualitative responses.

The following additional examples demonstrate how measurement-based quantizing, using techniques such as Rasch modeling and various forms of IRT, transforms qualitative data into scales that can be empirically tested. These techniques particularly are useful in developing and score-validating instruments that measure complex constructs derived from qualitative insights. By applying these models, researchers can assess the difficulty, discrimination, guessing, and carelessness parameters of the measurement tools, ensuring that the constructs being measured are reliable, valid, and reflective of the complexities of the qualitative data. This process allows for a more precise and robust measurement of phenomena that are not directly observable but can be inferred through systematic quantizing.

Rasch modeling to measure teaching effectiveness

For the first example, let us suppose that researchers undertook a study on teaching effectiveness. They conducted qualitative interviews with 500 students who described the traits of highly effective teachers. The responses were coded into themes such as "classroom engagement," "clarity of instruction," and "empathy." Using Rasch modeling, these themes were transformed into a scale with items measuring each trait. Rasch analysis was applied to assess the scalability and difficulty of each item, identifying which traits were consistently rated as being more challenging for teachers to achieve. Let us suppose further that the results indicated that "classroom engagement" had a higher item difficulty compared to "empathy," meaning that it was less frequently observed by students but highly valued when present. Rasch modeling would allow the researchers to create a linear scale to assess teaching effectiveness based on student perceptions.

Two-parameter IRT to measure resilience in healthcare workers

For the second example, let us suppose that researchers conducted focus groups with healthcare workers to explore the challenges that they face in maintaining resilience during crises. The qualitative data revealed several key factors, including

"emotional support," "work-life balance," "personal coping strategies," and "institutional support." These factors were transformed into items for a resilience scale. Using two-parameter IRT, researchers quantified both the difficulty (how challenging it was for healthcare workers to embody each factor) and discrimination (how well each item distinguished between high and low resilience levels). Let us suppose further that the analysis demonstrated that "institutional support" had a high discrimination parameter, meaning that it was a strong predictor of resilience, whereas "emotional support" had a lower difficulty parameter, indicating that it was a commonly available resource. This would allow the development of a refined instrument to measure resilience in healthcare settings.

Three-parameter IRT to measure public perceptions of climate change

For the third example, let us suppose that researchers undertook a study on public perceptions of climate change. They conducted interviews with 1,000 participants to understand the various factors shaping their views. The interviews were coded into themes such as "scientific trust," "personal responsibility," "economic impact," and "government action." These themes were quantized and used to develop a survey measuring public concern over climate change. Using three-parameter IRT, the researchers assessed difficulty, discrimination, and guessing (the likelihood that respondents with low knowledge might guess a correct answer). Let us suppose further that the results indicated that "scientific trust" was highly discriminative of climate change concern, with a moderate difficulty level, but "government action" had a higher guessing parameter, suggesting that some respondents might not fully understand the item but answered in alignment with social expectations. This model would help to refine the measurement of public perception by addressing potential guessing biases.

Four-parameter IRT to measure ethical decision-making among professionals

For the fourth example, let us suppose that researchers undertook a study investigating ethical decision-making among professionals. These researchers interviewed 300 participants from various industries. The interviews were coded into themes like "personal integrity," "corporate policies," "peer influence," and "legal considerations." These themes then were quantized and used to create a scale measuring ethical decision-making. Using four-parameter IRT, the researchers evaluated difficulty, discrimination, guessing, and carelessness (the probability that respondents might not be paying full attention when answering). Let us suppose further that the analysis revealed that "personal integrity" had a high difficulty and discrimination value, meaning that it was challenging but crucial for ethical decision-making. However, the "corporate policies" theme showed a higher carelessness parameter, suggesting that some participants might not take corporate policies into account when making ethical decisions. This would allow the researchers to refine their instrument by accounting for potential carelessness in responses.

Overall, measurement-based quantizing is a critical bridge between qualitative explorations of complex constructs and their rigorous, systematic quantification, enabling deeper insights and

broader applications in scientific research. This methodological approach not only enriches the precision and interpretability of qualitative data, but also extends the reach of these findings into domains traditionally dominated by quantitative analysis. By transforming nuanced, subjective responses into quantifiable metrics, researchers more effectively can compare, replicate, and build on their findings, ultimately contributing to the advancement of knowledge across diverse disciplines.

Exploratory-based quantizing

Exploratory-based quantizing refers to the process of transforming qualitative data into quantitative data for the purpose of exploring new insights, uncovering underlying patterns, discerning group memberships, and identifying potential relationships within the qualitative data. This is achieved through methodologies like exploratory factor analysis, cluster analysis, or correspondence analysis, each aiming to uncover underlying patterns or structures within the data. This approach is particularly useful in the early stages of research when hypotheses are not yet clearly defined, and the goal is to generate new hypotheses and theories based on the data. In a social science study, researchers might conduct detailed interviews to collect qualitative data on community attitudes toward a new public policy. Through exploratory-based quantizing, the researchers could code responses into quantitative data and apply cluster analysis to identify distinct groups within the community based on their attitudes. This could reveal unexpected patterns, such as specific demographic groups that are particularly supportive or critical of the policy. These findings then could be used to refine further studies or to develop targeted communication strategies.

The following additional examples illustrate how exploratory-based quantizing transforms qualitative data into quantifiable metrics, enabling the use of exploratory techniques like principal components analysis (PCA), exploratory factor analysis (EFA), cluster analysis, multidimensional scaling (MDS), and correspondence analysis to uncover patterns, relationships, and groupings within the data. These methods allow researchers to delve deeper into the qualitative responses, revealing hidden structures and connections that might not be immediately apparent. By applying these techniques, researchers can generate new insights and hypotheses, laying the foundation for further research and theory development in a variety of fields, from consumer behavior to education and mental health. This process helps to bridge the gap between exploratory qualitative work and the more structured, data-driven approach of quantitative research.

Principal components analysis to identify the hierarchical structure of themes pertaining to characteristics of effective college teachers

For the first example, returning to the study by [Onwuegbuzie et al. \(2007\)](#), the researchers conducted a PCA on the nine RESPECTED themes, after transforming the zero-order correlation coefficients to tetrachoric correlation coefficients. This step was crucial to tailor the PCA to the specific characteristics of the binary data (i.e., “1” vs. “0”). The analysis identified four meta-themes—communicator (43.7% of characteristics per meta-theme), advocate (81.0%), responsible (41.1%), and empowering (59.6%)—which were collectively referred to by the acronym CARE. This CARE

model, when combined with the nine RESPECTED themes, led to the development of the CARE-RESPECTED Model of Effective College Teaching.

Exploratory factor analysis to identify dimensions of consumer preferences

For the second example, let us suppose that researchers undertook a study examining consumer preferences for sustainable products. They conducted in-depth interviews with 300 participants to explore their attitudes toward eco-friendly packaging, ethical sourcing, and product durability. The qualitative responses were coded into themes and transformed into quantitative data. Using EFA, the researchers sought to identify the underlying dimensions of consumer preferences. Let us suppose further that the EFA revealed three key factors: “Environmental Responsibility,” “Product Quality,” and “Brand Trust,” which explained 65% of the variance in the responses. These factors then could be used to develop a comprehensive framework for understanding consumer motivations related to sustainability, guiding further studies and product development.

Cluster analysis to group participants by mental health coping strategies

For the third example, let us suppose that researchers undertook a study focused on mental health. These researchers conducted semi-structured interviews with 500 participants discussing how they cope with anxiety and depression. The interviews were qualitatively analyzed and coded into specific coping strategies, such as “exercise,” “meditation,” “social support,” and “self-care routines.” After quantizing the data, the researchers applied cluster analysis to group participants based on their use of these strategies. Let us suppose further that the analysis revealed three distinct clusters: “Holistic Copers,” who emphasized meditation and self-care, “Active Copers,” who relied on physical activity and social support, and “Passive Copers,” who primarily used minimal strategies. These insights would help researchers better understand coping behavior patterns and tailor future mental health interventions to the specific needs of each group.

Multidimensional scaling to explore perceptions of workplace diversity

For the fourth example, let us suppose that researchers undertook a study wherein they interviewed 200 employees from a variety of industries to investigate their perceptions of workplace diversity initiatives. The qualitative responses were coded into themes, such as “inclusivity,” “equal opportunity,” “cultural representation,” and “workplace harmony.” After transforming these themes into quantitative data, the researchers applied MDS to map the relationships among the different perceptions. Let us suppose further that the MDS plot revealed that “inclusivity” and “equal opportunity” were perceived as being closely related, whereas “cultural representation” and “workplace harmony” formed another distinct cluster. This exploration would help researchers identify the nuanced ways that employees viewed diversity efforts, guiding further inquiry into specific areas for organizational improvement.

Correspondence analysis to uncover relationships in educational research

For the fifth example, let us suppose that researchers undertook a study investigating the teaching styles of high school educators. These researchers conducted open-ended interviews with 100 teachers to understand their instructional approaches. The qualitative data were coded into categories, such as “student-centered teaching,” “lecture-based instruction,” and “technology integration.” These categories were quantitized, and correspondence analysis was conducted to examine the relationships between teaching styles and demographic variables, such as years of experience and subject area. Let us suppose further that this analysis revealed that teachers with more than 10 years of experience were more likely to use “lecture-based instruction,” whereas younger teachers tended to favor “technology integration.” Correspondence analysis would uncover these associations, providing valuable insights into how teaching practices evolve over time and across subject areas.

Thus, exploratory-based quantitizing is a powerful tool in mixed methods research, enabling researchers to delve into qualitative data with quantitative tools to uncover new patterns and relationships that can guide future research directions and decision-making. This integrative approach not only amplifies the analytical capabilities of researchers, but also fosters a more comprehensive understanding of data by bridging the methodological divide. With exploratory quantitizing, subtle nuances and complex dynamics within the data are revealed, offering a richer, more detailed landscape for academic inquiry and practical application.

Level 2 quantitizing

Level 2 quantitizing, or second-level quantitizing, comprises spatial-based quantitizing and time-based quantitizing. Each of these types of second-level quantitizing will be described in the following sections.

Spatial-based quantitizing

Spatial-based quantitizing refers to the process of transforming qualitative data into quantitative forms that specifically include spatial (geographical) components. This approach can be used in studies wherein the spatial distribution of the phenomenon of interest is significant and can help in understanding patterns, relationships, or trends that are influenced by geographical variables. For instance, spatial-based quantitizing can be achieved by quantitizing qualitative data based on their geographical attributes, such as proximity, area, density, or distribution across a map. Spatial-based quantitizing can involve the use of tools like Geographic Information Systems (GIS) to visualize the quantitized qualitative data on maps. This would allow researchers to see patterns that might not be apparent from the raw qualitative data alone, such as clustering of phenomena, variation across different regions, or the influence of geographical features on social or environmental factors. Techniques such as spatial analysis, clustering, or heat mapping can be used to interpret spatial relationships involving the quantitized data. For instance, researchers might analyze the concentration of certain themes or subjects within interview responses or survey responses to one

or more open-ended items by location, or might examine how community sentiments vary across different urban or rural areas.

As an illustration, Onwuegbuzie et al. (2020) investigated challenges experienced by 1,932 students at Stellenbosch University that hindered their ability successfully to learn online during the emergency remote teaching that began in April 2020 due to the COVID-19 pandemic via an online questionnaire that they completed. The researchers’ analysis of their responses to an open-ended question led to the identification of seven (challenge) themes that categorized the students’ challenges during the COVID-19 pandemic. As was the case for Onwuegbuzie et al.’s (2007) study, each of the seven themes was quantitized by assigning a “1” to participants whose responses represented that theme, and a “0” to all others. This quantitizing led to what Onwuegbuzie (2003) referred to as an inter-respondent matrix of themes that consisted of “1s” and “0s.” Subsequently, each theme was mapped across the nine provinces of South Africa, revealing insightful patterns. For instance, the GIS map generated from these quantitized data showed that a significantly higher proportion of students experiencing issues categorized under the Internet Connection theme (i.e., that characterized students’ challenges related to Internet connectivity) resided and worked remotely in Eastern Cape—the poorest province—compared to other provinces.

Spatial-based quantitizing thus bridges the gap between qualitative richness and quantitative precision, enabling researchers to harness the power of spatial analysis in understanding complex datasets where location is a key factor.

Time-based quantitizing

Time-based quantitizing refers to the process of converting qualitative data into quantitative forms that emphasize temporal aspects. This approach is particularly relevant in studies wherein the timing, sequence, or duration of events is crucial to understanding the dynamics and developments within the data. Time-based quantitizing helps researchers to measure and to analyze changes over time, to capture patterns of behavior, and to understand the sequence of events or phenomena in a structured, numerical format. It involves integrating time-related information into the quantitizing process. This could mean quantifying the length of time an event takes, the sequence in which multiple events occur, or the intervals between events. Such integration can provide insights into trends, cycles, or durations that are important for the study. Techniques such as time series analysis can be used to forecast future events based on past data, to analyze seasonal variations, or to detect trends and cycles. For studies focused on the occurrence and timing of events, event history analysis or survival analysis can be used. This method deals with the timing of specific events (e.g., failure times) and can accommodate data that are right-censored (i.e., when an observation ends without the event occurring). In psychological research, time-based quantitizing might be used to study the progression of a psychological condition over time. By quantitizing the frequency and intensity of symptoms reported in qualitative interviews at regular intervals, researchers can apply statistical methods to analyze changes in symptom patterns, to correlate them with treatment interventions, or to predict future outcomes.

Returning to Onwuegbuzie et al.'s (2020) study, although the researchers did not examine time-based data, they could have done so by asking the same open-ended question (i.e., What challenges are you experiencing that are hindering your ability to learn online during the COVID-19 pandemic?) at multiple time points during the pandemic. The themes that emerged at each time point then could have been quantitized (e.g., using the dichotomization process [i.e., "1" vs. "0"] described earlier) and then consolidated into a single inter-respondent matrix. This consolidated inter-respondent matrix then could have been used to conduct time-based analyses that included the following:

- *Logistic Regression for Repeated Measures*: This method identifies predictors of thematic prevalence, carefully accounting for the complex correlations among repeated observations from the same participant.
- *Survival Analysis*: Used to analyze time-to-event data, along with its discrete-time counterpart, which assesses the probability of theme emergence within specific intervals.
- *Generalized Estimating Equations*: This approach uncovers the evolving impact of predictors over time, providing insights into their dynamic effects.
- *Generalized Linear Mixed Models (GLMM)*: These models accommodate the complexity of variations between participants, effectively managing diverse individual data points.
- *Mixed Models for Binary Outcomes*: This technique examines themes over time, capturing both fixed and random effects to delineate trends at the population level as well as individual differences.

In summary, time-based quantitizing transforms rich, qualitative temporal data into structured quantitative formats, making it possible to apply statistical analysis tools to understand complex temporal dynamics and relationships within the data. This approach is essential for any research wherein time is a pivotal factor in understanding the phenomena under investigation.

Level 3 quantitizing

Level 3 quantitizing, or third-level quantitizing, comprises cross-sectional-based quantitizing and longitudinal-based quantitizing. Each of these types of third-level quantitizing will be described in the following sections.

Cross-sectional-based quantitizing

Cross-sectional-based quantitizing involves conducting a cross-sectional study wherein data initially are collected or observed in a qualitative format (e.g., interviews, focus group discussion, observations, open-ended survey responses). Then, these qualitative data are quantitized. These newly quantitized data then are analyzed to draw conclusions about the prevalence, associations, or distributions of certain variables within the population at that specific point in time.

This approach allows researchers to utilize the strengths of both qualitative and quantitative methodologies to collect rich, contextual data about a population and then to apply statistical techniques to analyze trends or patterns at a particular moment.

The result can provide a broad, statistically informed snapshot of the research topic, enriched by the depth and detail typically associated with qualitative research.

Longitudinal-based quantitizing

Longitudinal-based quantitizing refers to the process wherein qualitative data collected in a longitudinal study are systematically converted into quantitative data. This allows researchers to utilize qualitative methods to collect rich, detailed qualitative data at multiple time points. Quantitizing techniques then are applied to transform these data into a format that can be quantitatively analyzed. Statistical methods are employed to examine how coded categories change over time, to identify trends, and potentially to infer causal relationships. This approach enables researchers to leverage the depth of qualitative data along with the analytical power of quantitative methods to track and to analyze changes over time in a structured, numerically robust way. For example, a study might involve collecting annual interview data from participants about their health behaviors, followed by coding responses into quantitized data that tracks shifts in health attitudes and practices across the study period.

In essence, longitudinal-based quantitizing is a methodological strategy that marries the detailed, context-rich insights of qualitative research with the temporal analysis capabilities of longitudinal quantitative research, offering a potent tool for understanding how phenomena evolve over time. This integrative approach not only enhances the depth and clarity of data interpretation but also facilitates the examination of dynamic changes and trends within complex datasets, thereby allowing researchers to draw more nuanced and informed conclusions about the underlying processes driving these changes.

Level 4 quantitizing

Level 4 quantitizing, or fourth-level quantitizing, comprises retrospective quantitizing and prospective quantitizing. Each of these types of fourth-level quantitizing will be described in the following sections.

Retrospective quantitizing

In retrospective quantitizing, the initial qualitative data might have been collected for other purposes or in a naturalistic setting without a priori intentions of quantitative analysis. For example, this could involve clinical notes, interview transcripts, or open-ended survey responses collected in past studies. Retrospective quantitizing then would involve applying quantitizing techniques to these existing qualitative data; researchers can retrospectively code and quantify the data. This might include categorizing textual responses into numerically analyzable data or scoring narrative descriptions based on intensity, frequency, or presence of certain themes. The quantitized data then can be analyzed to uncover trends, patterns, or relationships that were not originally quantitized during the initial data collection phase. This approach allows researchers to utilize existing qualitative data to perform new quantitative analyses without the need to conduct fresh data collection, which can be particularly useful in contexts wherein prospective data collection is challenging, costly, or impractical. It provides an opportunity retrospectively to analyze

and potentially to uncover new insights from past qualitative data using quantitizing techniques, expanding the utility and value of previously collected data.

In Figure 4, it can be seen that an arrow goes from retrospective quantitizing to both cross-sectional-based quantitizing and longitudinal-based quantitizing, which indicates that retrospective quantitizing can comprise both cross-sectional-based quantitizing and longitudinal-based quantitizing. This dual categorization of retrospective quantitizing is explained by understanding that the term “retrospective,” which indicates that the study data already exist and, thus, can be extracted for quantitizing. Retrospective quantitizing can involve cross-sectional quantitizing if it involves quantitizing existing data at one point in time. Also, it can involve longitudinal quantitizing if it involves quantitizing existing data across multiple time points to observe changes over time.

Consistent with this conceptualization of retrospective quantitizing, in the context of research designs, for example, Andrade (2022) explains that research designs simultaneously can describe studies as being both retrospective and cross-sectional, or retrospective and longitudinal. This dual categorization depends on how the existing data are utilized—either as a single snapshot (i.e., cross-sectional) or over multiple time points (i.e., longitudinal; Andrade, 2022).

Prospective quantitizing

In prospective quantitizing, researchers start with a clear plan to collect qualitative data that they intend to convert into quantitative data. This plan would be integral to the research design and involve predetermined methods for how qualitative data (e.g., interview transcripts, observations, open-ended survey responses) will be systematically coded into quantitative formats. Data would be collected prospectively, meaning that researchers would collect qualitative information as events unfold or as they interact with study participants over time. This ongoing collection could be structured in a way to facilitate subsequent quantitizing, such as using semi-structured interview techniques that align with a pre-defined coding scheme.

Once the data have been collected, the qualitative information would be converted into quantitative form according to the initial plan. These quantitized data then could be used to perform statistical analysis to identify trends, patterns, and possibly causal relationships, providing robust insights into the dynamics of the study's focus. This prospective quantitizing allows researchers to blend the depth and richness of qualitative data with the rigor and scalability of quantitative analysis, planned from the outset of the study. This prospective approach to quantitizing can enhance the precision and applicability of research findings, especially in fields wherein both contextual and measured data are crucial for understanding complex phenomena.

Conclusions regarding the DIME-driven model of quantitizing

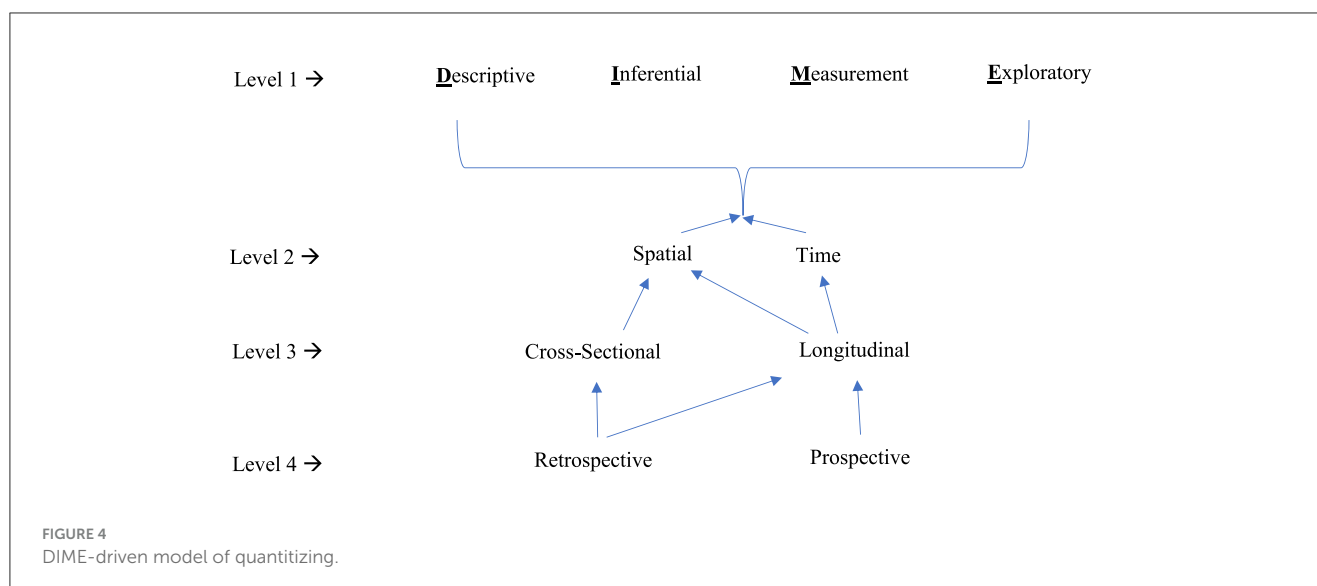
The DIME-driven model of quantitizing is hierarchical, wherein each subsequent level incorporates and builds on the

methods and insights of the preceding levels. Specifically, Level 4 subsumes Level 3 as a special case, which, in turn, subsumes Level 2, and Level 2 subsumes Level 1. This hierarchical structure ensures that each level adds complexity and depth to the quantitizing process, providing a comprehensive framework that moves from basic descriptive quantitizing to more complex analytical tasks involving spatial, temporal, and prospective/retrospective analyses.

Overall, as can be seen, each level in the DIME-Driven Model progressively builds on the previous one, incorporating additional dimensions of analysis (spatial, temporal, cross-sectional, and longitudinal) and increasing the complexity and sophistication required for quantitizing qualitative data. This structured approach allows researchers to select the appropriate level of analysis based on their research questions and the nature of their data, enhancing the depth and rigor of their quantitative analysis. Specifically, Level 2 involves complex spatial analysis techniques and the integration of geographic data, adding a spatial context to the quantitizing process, as well as adds the challenge of accounting for temporal dependencies and changes over time, requiring advanced statistical models to analyze trends and patterns. Level 3 requires analysis techniques to control for cross-sectional differences and to ensure that comparisons are valid across different groups, as well as adding complexity through the need to handle longitudinal data structures, requiring techniques that can account for repeated measures and temporal dynamics. Finally, Level 4 involves complex historical data analysis, requiring techniques accurately to interpret and to quantitize past events and conditions, as well as adding complexity through the need for designing studies that accurately can capture and quantitize future data, often involving predictive modeling and forward-looking analysis techniques.

This four-level model of quantitizing not only systematizes the process of transforming qualitative data into quantitative analysis but also enhances the capability to handle complex data sets and to derive meaningful interpretations that are statistically robust and empirically informative. By methodically escalating through increasingly sophisticated levels of data analysis, the model facilitates a deeper integration of qualitative nuances within a quantitative framework. This progression enables researchers to uncover hidden patterns, to validate theoretical constructs, and to extend their findings to broader applications with greater confidence and precision. Ultimately, this comprehensive approach enriches scientific inquiry in general and mixed methods research in particular by bridging the qualitative-quantitative divide with rigor and creativity.

This DIME-driven model is a paradigm shift, elevating the practice of quantitizing to a realm of heightened sophistication and multidimensional analysis within the sphere of mixed methods research. By embracing this hierarchical model, scholars and researchers are afforded a beacon that navigates the often-nebulous terrain of data transformation, providing clear milestones and checkpoints along the scholarly expedition of mixed methods research. This model not only pioneers new frontiers in methodological rigor but also embodies a visionary standard for future explorations in the realm of data integration.



Who should quantitize?

Quantitizing holds broad appeal due to its versatility across various research methodologies, making it a valuable tool not only for mixed methods researchers but also for those primarily engaged in either qualitative research or quantitative research. Mixed methods researchers, for instance, find quantitizing particularly useful as a means to enrich and to expand on their quantitative findings, seamlessly integrating this technique into the latter stages of their studies.

Similarly, qualitative researchers stand to gain from adopting quantitizing techniques to structure their data more systematically. This approach allows them to enhance the rigor of their analyses without necessarily transforming their studies into mixed methods research. By incorporating quantitizing within their existing qualitative frameworks, they can deepen their analytical capabilities and derive quantifiable insights from their data collections.

Quantitative researchers also benefit from the application of quantitizing techniques, especially when they engage in methods that necessitate the analysis of qualitative data. An example of such an approach is qualitative comparative analysis, which involves a systematic examination of similarities and differences across cases (De Block and Vis, 2019). This method serves as a powerful theory-building tool, enabling researchers to make connections among established categories and to refine and to test these categories further. Thus, quantitizing not only bridges the gap between qualitative and quantitative domains but also enhances the depth and scope of research across the spectrum.

The role of research philosophy in the process of quantizing

In order to conduct a nuanced analysis of whether researchers representing major research philosophies should engage with quantitizing, it is crucial to consider how well the fundamental principles of these philosophies align with the procedures and implications of quantitizing. This approach involves a

thorough examination across the spectrum of research traditions, encompassing qualitative, quantitative, and mixed methods-based philosophies. Such an examination is essential to determine the degree of compatibility between each philosophy's core assumptions and stances and the quantitizing process.

Tables 1–3 in the subsequent discussion provide a detailed exposition of this analysis. Each table systematically outlines the assumptions and stances of the most prevalent research philosophies within the qualitative, quantitative, and mixed methods research domains, respectively. Additionally, these tables assess the propensity of each philosophy to embrace quantitizing. This assessment is based on how effectively quantitizing can integrate with the epistemological, ontological, axiological, and methodological components of these philosophies without compromising their integrity and objectives. By exploring these dimensions, these tables provide a comprehensive overview, thereby facilitating a deeper understanding of which researchers can appropriately and effectively apply the process of quantitizing within the landscape of research methodologies.⁴

Qualitative research-based philosophies

Table 1 illustrates the propensity of each qualitative research philosophy to embrace quantitizing, as influenced by its epistemological, ontological, axiological, and methodological underpinnings. The assessments in this table reflect the assumptions and stances of each philosophy on understanding

⁴ It should be acknowledged that a researcher can holding alternative understandings of reality at the same or contiguous times by making Gestalt switches. However, unless the Gestalt switching involves one or more of the three sets of research philosophies in Tables 1–3 that do not align well with the process of quantitizing (i.e., postmodernism, poststructuralism, and many forms of phenomenology), holding alternative understandings of reality at the same or contiguous times should not prevent a researcher from appropriately utilizing quantitizing when it serves to illuminate the research question(s) at hand.

human experience and social reality. This table reveals that researchers who value empirical, generalizable data for advocacy or broader social analysis are more likely to incorporate quantitizing readily. Conversely, those deeply committed to subjective, individual, and context-specific understandings tend to reject quantitizing—or, at least, are less likely to incorporate it—viewing it as fundamentally incompatible with their epistemological and methodological approaches.

Consistent with this observation, the qualitative philosophies whose proponents are most likely to embrace quantitizing appear to be critical theory and feminist theory. Critical theory is compatible with quantitizing when it serves to expose social inequalities or power imbalances. As such, critical theorists may quantitize to bolster arguments for social change, making this approach somewhat more amenable to integrating quantitizing when it serves their emancipatory goals. Similarly, feminist theory is compatible, and feminist theorists may quantitize effectively to highlight and to challenge gender inequalities. Quantitizing data can be used to demonstrate systemic issues, such as pay gaps or statistical discrepancies in healthcare, which align with feminist goals.

In contrast, the qualitative research-based philosophy whose proponents are least likely to embrace quantitizing appears to be symbolic interactionism. Although not completely opposed to quantitizing, symbolic interactionism places a strong emphasis on understanding individual and group interactions at a detailed, interpretive level. Quantitizing techniques are less common but might be used to some extent to generalize findings from qualitative analyses. Even more opposed to quantitizing are the qualitative philosophies of postmodernism, poststructuralism, and phenomenology in many of its various forms. Proponents of postmodernism and poststructuralism are highly skeptical of grand narratives (i.e., metanarratives) and the reduction of complex social phenomena to simple explanations or categorizations. These perspectives fundamentally critique the structures and power dynamics embedded within traditional methods of knowledge production, including quantification, which they view as an attempt to impose order and linearity on inherently disorderly and fragmented realities. Phenomenology, in general, aims to delve deeply into the lived experiences and perceptions of individuals, seeking to capture the essence of these experiences without dilution or abstraction. Quantitizing, by its nature, abstracts and generalizes individual experiences into numerical data, which opposes the phenomenological commitment to capturing the depth and nuance of direct personal experiences. Nevertheless, aside from these exceptions, the vast majority of qualitative research philosophies do not prevent researchers operating under them from engaging in quantitizing when it assists in addressing the underlying research question(s).

Quantitative research-based philosophies

Table 2 illustrates the propensity of each quantitative research philosophy to embrace quantitizing, as influenced by its epistemological, ontological, axiological, and methodological underpinnings. This table shows that each philosophy's approach to quantitizing qualitative findings varies, primarily based on its ontological commitments and epistemological approaches. Philosophies that prioritize objectivity and empirical verification

are more likely to embrace quantitizing. In contrast, those that value subjective human constructs or mental processes are generally less inclined to do so. Additionally, the acceptance or rejection of quantitizing by proponents of these philosophies also depends on their perspectives on the nature of mathematical entities, the origins of mathematical knowledge, and their values concerning mathematics and knowledge acquisition.

Consistent with this observation, the quantitative research philosophies whose proponents are most likely to embrace quantitizing appear to be Platonism (i.e., mathematical realism), formalism, logicism, objectivism, empiricism, and postpositivism. Advocates of Platonism strongly embrace quantitizing because it aligns with the discovery of eternal, objective, immutable mathematical entities that are thought to exist independently of human thought. Proponents of formalism highly value precise and systematic manipulation of formal systems and symbols, aligning closely with the goals and methods of quantitizing. Logicism, because it reduces mathematics to logical structures, it inherently values the clarity and rigor that quantitizing can provide, wherein quantitizing supports logical deduction and the establishment of universal truths. Objectivists, with their strong emphasis on rationality and empirical evidence, highly value quantitizing as tools for discovering and verifying objective reality, as well as for validating mathematical and scientific theories. Empiricists strongly support quantitizing because of its basis in empirical verification of theories through observable phenomena, which often involves quantifying data. Postpositivists value empirical verification and scientific methodologies, making them highly supportive of quantitizing as a means to validate and to refine theories against observable data. Proponents of these philosophies who highly embrace quantitizing typically value objective, measurable, and empirically verifiable data. They appreciate the precision, clarity, and empirical grounding that quantitizing provides. In fact, they regard quantitizing as an integral part of exploring, understanding, and validating mathematical entities and theories.

In contrast, the quantitative research philosophies whose proponents are least likely to embrace quantitizing appear to be intuitionism, psychologism, fictionalism, nominalism (mathematical constructivism), and anti-realism. Proponents of intuitionism place emphasis on personal, intuitive understanding rather than on external validation methods such as quantitizing. They view mathematics as a mental construct and place significant value on intuitive understanding and mental constructions rather than over empirical or external validation (e.g., measured or derived from physical reality). They might view quantitizing as an unnecessary or misleading step if it implies the existence of an external mathematical reality. Instead, they focus on constructive proofs and the mental processes of mathematicians. Advocates of psychologism focus on understanding mathematical knowledge as a product of human thought and cognitive processes, likely preferring qualitative insights into cognitive functions and how mathematical thinking arises over quantitizing. They might view quantitizing as being too detached from the psychological processes that it deems essential for understanding mathematical concepts. Moreover, they might reject quantitizing if it is perceived as attempting to objectify what are essentially subjective cognitive constructs. Proponents of fictionalism, although they use

TABLE 1 Most common qualitative-based research philosophies: assumptions and stances and the likelihood of embracing the quantizing process.

Research philosophy	Ontology	Epistemology	Axiology	Methodology	Likelihood of quantizing	Rationale
Social constructionism (Berger and Luckmann, 1967; Leeds-Hurwitz, 2009; Lock, 2010; Schwandt, 2000)	Reality is socially constructed.	Knowledge is created within social contexts.	Values are openly acknowledged and scrutinized.	Common approaches include discourse analysis, ethnographic studies, and narrative research.	Generally skeptical	Perceived as reducing the richness of social phenomena.
Social constructivism (Palinscar, 1998; Rust et al., 2005; Vygotsky, 1962, 1978)	Reality is constructed through human mental activity and social interactions.	Knowledge is constructed individually but mediated socially.	Values the subjective experience and perspective of the researcher and participants.	Prefers qualitative approaches such as interviews and case studies.	Usually limited	Prioritizing individual meaning-making which is difficult to quantify. Focusing on depth over breadth in data.
Radical constructivism (Glaserfeld, 1995; Steffe and Thompson, 2000)	Knowledge and reality are personally constructed, not discoverable; rejecting an objective reality.	Understanding is subjective, shaped by experiences.	Highly reflexive about the influences of the researcher's biases; Highly individualized perspective on values.	Emphasizes qualitative approaches that explore individual experiences; Introspective and reflective qualitative methods.	Rarely embraced	It contradicts the emphasis on individual subjective experiences.
Critical theory (Habermas, 1984; Tyson, 2023)	Social reality is shaped by power, economics, and social forces.	Knowledge is a social product, influenced by material conditions and power dynamics. Knowledge is a tool for emancipation and critique.	Committed to emancipation and challenging status quo, as well as to social justice and change.	Qualitative approaches aimed at uncovering power structures and exploring individual experiences.	Open to quantizing	If it serves critical insights and emancipatory goals.
Feminist standpoint theory (Cabrera et al., 2020)	Reality is seen through the lens of women's experiences.	Knowledge is situated; marginalized perspectives offer a more complete view of reality. Knowledge is derived from the lived experiences of marginalized groups.	Values the experiences and voices of the marginalized. Advocacy and empowerment are central.	Qualitative, focusing on the experiences of women and other marginalized groups; often narrative and ethnographic.	Limited use	If it supports advocacy goals.
Feminist theory (Disch and Hawkesworth, 2016; hooks, 2000)	Social reality is gendered and constructed through power relations. Gendered perspectives are central to understanding reality.	Emphasizes the importance of gender as a category of analysis. Knowledge is influenced by gender power relations.	Committed to revealing and challenging gender inequalities.	Qualitative, incorporating diverse women's voices.	Can be embraced	If it supports feminist objectives and serves to highlight inequalities.
Critical race theory (Delgado and Stefancic, 2023; Ladson-Billings and Tate, 1995; Lynn and Dixon, 2021)	Holds that racism is an ingrained feature of society, structurally embedded within systems and institutions.	Emphasizes the validity of experiential knowledge from marginalized groups, using narratives and storytelling to uncover racial injustices.	Values social justice and aims to dismantle racial hierarchies.	Primarily employs qualitative methods like storytelling, counter-storytelling, and analysis of cultural artifacts.	Limited use	Cautious use of quantizing because it might reduce complex social issues to numerical data, potentially obscuring the depth of racial issues. Primarily used to support or to highlight qualitative findings.

(Continued)

TABLE 1 (Continued)

Research philosophy	Ontology	Epistemology	Axiology	Methodology	Likelihood of quantizing	Rationale
Postmodernism (Jameson, 2014; Taylor and Winquist, 2002)	Questions the stability of the social world and denies a single, unifying reality. Skeptical of grand narratives; reality is fragmented and pluralistic.	Knowledge is contingent, fragmented, historically situated, constructed, and varied.	Often rejects grand narratives; values plurality and diversity of interpretations. Challenges meta-narratives and totalizing explanations.	Prefers qualitative methods that emphasize complexity and contradiction; Diverse, often deconstructive or ironic.	Typically resists quantizing	Instead, valuing multiplicity and the deconstruction of categories. Generally opposed due to its challenge to singular truths.
Post structuralism (Dillet, 2017; Williams, 2022)	Reality is constructed through discourse; structures are both enabling and constraining. Structures and human relationships are fluid, not fixed.	Knowledge is produced within specific historical and cultural contexts. Knowledge is constructed through discourses and language.	Critically examines how power affects knowledge production.	Uses textual analysis, discourse analysis and other qualitative methods.	Seldom of interest	Focus is on deconstruction of texts and discourses and on how narratives and knowledge are constructed.
Symbolic interactionism (Blumer, 1969; Carter and Fuller, 2015)	Reality is constructed through social interactions and the use of symbols.	Knowledge is constructed through social interactions. Knowledge comes from the interpretation of these interactions.	Emphasizes understanding the subjective meanings and symbols individuals use. Often implicit, focusing on subjective meanings.	Uses qualitative methods such as observational studies and grounded theory; interpretative qualitative methods.	Occasionally of use.	When the goal is to generalize findings.
Phenomenology: (Moustakas, 1994) At least 29 phenomenological-based philosophies: Descriptive phenomenology (Giorgi, 2009; Todres and Holloway, 2004) Interpretive phenomenology (Tuohy et al., 2013) Reflective/Transcendental phenomenology (Husserl, 1970) Dialogical phenomenology (Herman, 2007) Empirical phenomenology (Mortari et al., 2023) Existential phenomenology (von Eckartsberg, 1998) Hermeneutic phenomenology (Lavery, 2003) Social phenomenology (Chelstrom, 2012) Psychological phenomenology (Giorgi, 1985) Ethnographic phenomenology (Rodgers, 2021) Genetic phenomenology (Lohmar, 2011) Constitutive phenomenology (Sandmeyer, 2008)	In general, the focus is on the lived experience and essence of phenomena.	Knowledge is subjective and grounded in individual experience.	In general, the emphasis is on the importance of the researcher's openness to participants' experiences.	Uses qualitative methods such as in-depth interviews and participant observation.	Rarely used, except for empirical phenomenology (which relies on observations and descriptions that can be quantified; quantizing can enhance the breadth and generalizability of findings), neuro-phenomenology (which involves linking phenomenological accounts with neurological data, often requiring quantitative measures to correlate experiential data with brain activity), eco-phenomenology (to understand better ecological data and patterns that often require quantitative analysis for environmental studies), psychological phenomenology (can incorporate quantizing to explore broader psychological trends and patterns, potentially employing statistical methods to generalize findings)	Most phenomenological approaches and ethnomethodology prioritize qualitative methodologies due to their focus on deep, contextual, and interpretative aspects of human experiences. Quantizing is generally less common and often viewed as potentially detracting from the depth and integrity of the phenomenological inquiry—especially for hermeneutic phenomenology (focused on deep interpretation of texts and experiences, it relies heavily on qualitative analysis to uncover meanings within historical and cultural contexts), existential phenomenology (centers on individual existence and personal experiences, often exploring profound existential themes that are difficult to quantify), transpersonal phenomenology (explores dimensions of human experience that transcend the

(Continued)

TABLE 1 (Continued)

Research philosophy	Ontology	Epistemology	Axiology	Methodology	Likelihood of quantitizing	Rationale
Narrative phenomenology (Maggio, 2016; Shibolet, 2019; Zafran, 2020) Ethical phenomenology (Kirchin, 2003) Ecological phenomenology (Kule, 2018; van der Schyff, 2010; Wood, 2001) Neuro-phenomenology (Featherstone et al., 2013; Peters, 2000) Eidetic phenomenology (Purcell, 2010) Post-intentional phenomenology (Soule and Freeman, 2019; Vagle and Hofsess, 2016) Transpersonal phenomenology (Laughlin and Rock, 2021; Levin, 1988) Intercultural phenomenology (Hong, 2023) Phenomenological anthropology (Schnegg, 2023) Phenomenological sociology (Ferguson, 2006; Overgaard and Zahavi, 2009; Srubar, 1984) Aesthetic phenomenology (Vandenabeele, 2016) Phenomenology of perception (Merleau-Ponty, 2013) Phenomenology of religion (Cox, 2010) Feminist phenomenology (Oksala, 2004) Phenomenology of time (Kortooms, 2002) Political phenomenology (Bedorf and Herrmann, 2019) Phenomenology of embodiment (Moran, 2013)						individual, often delving into spiritual or transcendent aspects that are not easily quantified), reflective/transcendental phenomenology (focus on subjective introspection and essence often leads to a rejection of quantitizing, which is seen as potentially oversimplifying or misrepresenting the depth of lived experiences), dialogical phenomenology (emphasizes understanding through dialogue and relational interactions, wherein the richness of conversational context is more meaningful than quantitative data), ethical phenomenology (centers on moral and ethical dimensions of experiences, which are intrinsically qualitative and subjective, making quantitizing less relevant and rarely embraced), anti-conflationist phenomenology (emphasizes the separation of methodologies to maintain epistemological purity, likely rejecting quantitizing as it could blur the clear methodological distinctions valued by this approach)

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TABLE 2 Most common quantitative-based research philosophies: assumptions and stances and the likelihood of embracing the quantizing process.

Research philosophy	Ontology	Epistemology	Axiology	Methodology	Likelihood of quantizing	Rationale
Platonism (Mathematical Realism; Balaguer, 1998; Tomšič, 2017)	Abstract mathematical entities exist independently of human thought; timeless, non-physical objects.	Knowledge is attained through intellectual intuition and logical reasoning.	Values the discovery of absolute and universal truths.	Deductive reasoning and discovery of eternal truths.	High	Quantizing complements the search for universal mathematical truths.
Nominalism (Mathematical Constructivism; Kerkhove and Van Bendegem, 2012; Szabo, 2003)	Denies the independent existence of mathematical entities; sees them as constructs or labels.	Knowledge is a human construct, dependent on social practices and language.	Values practical utility and coherence.	Constructive mathematics and verification through consistency within mathematical systems.	Low	Prioritizes human-centric constructs over objective quantification.
Structuralism (Sturrock, 2008)	Emphasizes the structures or relationships among mathematical entities, rather than the entities themselves.	Knowledge arises from understanding these structures.	Values insight into the structural aspects of mathematics.	Analysis of relationships and patterns within mathematical systems.	Moderate	Useful for illuminating structural relationships.
Intuitionism (Dummett, 2000)	Mathematics is a mental construct, not reflecting any external reality.	Knowledge is subjective, accessed through mental processes and intuition.	Values the certainty and constructiveness of mathematical proofs.	Constructive proofs, emphasizing processes that can be intellectually grasped.	Low	Due to the focus on mental constructions rather than empirical data.
Formalism (Detlefsen, 2007)	Mathematics is about manipulating symbols according to agreed rules; the symbols don't necessarily represent real objects.	Knowledge is based on mastering these formal systems and operations.	Values logical consistency and rigor in formal systems.	Development and exploration of formal systems, independent of their interpretation.	High	Aligns well with the manipulation of formal systems and precise measurements.
Logicism (Demopoulos, 2013)	Mathematics can be reduced to logical foundations.	Mathematical truths are derived from logical truths.	Values the clarity and undeniable truth provided by logic.	Reducing mathematics to logic to prove mathematical truths.	High	Quantizing supports the objective and universal nature of logical structures.
Empiricism (Meyers, 2006)	Mathematical knowledge is derived from experience and is empirical.	Knowledge is provisional and empirically tested.	Values empirical verification and practical applications.	Empirical observation and experimentation.	High	Crucial for linking mathematics to empirical observations.
Finitism (Ye, 2011)	Only finite mathematical constructs exist; rejects the existence of actual infinity.	Knowledge is about finite procedures and their results.	Values computability and concrete results.	Restricts mathematical practice to finite operations.	Moderate	If the focus remains on finite and tangible outcomes.
Realism (House, 1991)	Mathematical entities exist independently of human knowledge or perception.	Knowledge of these entities is discovered, not invented.	Values the discovery of objective, independent truths.	Objective investigation and logical analysis.	High	It aids in the objective analysis and understanding of mathematical entities.
Anti-Realism (Brock and Mares, 2006; Chalmers, 2009)	Denies the objective existence of mathematical entities outside of human conceptual schemes.	Mathematical truths are dependent on human practices or conceptual frameworks.	Values the practical and explanatory power of mathematics.	Focuses on the usefulness and practical application of mathematical concepts.	Low to moderate	Depending more on its practical utility than on seeking objective truths.
Fictionalism (Fine, 1993; Suárez, 2008)	Mathematical entities are akin to fictional characters; they do not exist.	Mathematical truths are "pretended" for their utility in explaining and predicting phenomena.	Values the usefulness and explanatory power of mathematical constructs.	Utilitarian use of mathematics as a tool for explanation and prediction.	Moderate	Appreciated for its practical benefits rather than its truth.
Psychologism (Crane, 2014)	Mathematics is a product of human thought and psychological processes.	Mathematical knowledge is derived from and limited by human cognitive capacities.	Values the understanding of human cognitive processes in mathematics.	Psychological investigation into how mathematical thoughts and processes develop.	Low	Focuses more on qualitative insights into human cognition.
Objectivism (Peikoff, 1993)	Reality exists independently of consciousness; specific principles govern reality, including mathematical ones.	Knowledge is based on objective observation and rational integration.	Rational inquiry and empirical evidence.	Rational inquiry and empirical evidence.	High	It aligns with the pursuit of objective knowledge through rational and empirical means.
Postpositivism (Phillips and Burbules, 2000; Popper, 2002)	Acknowledges that scientific knowledge is imperfect and theory-laden.	Knowledge is provisional and subject to revision; emphasizes critical testing of theories.	Values rigorous testing, critical thinking, and acknowledges the fallibility of scientific inquiry.	Scientific methods with a recognition of their limitations; uses qualitative and quantitative research.	High	But with a critical stance, recognizing the limits and potential biases of quantitative methods.

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Research philosophy	Ontology	Epistemology	Axiology	Methodology	Likelihood of quantizing	Rationale
Pragmatism-of-the-middle (Johnson and Onwuegbuzie, 2004; Johnson et al., 2007)	Realist and context-sensitive.	Knowledge is gained through actions, experiences, and outcomes.	Values outcomes that are practical and applicable.	Flexible, integrates qualitative and quantitative methods.	Likely embraced	It allows for practical application and enhanced understanding.
Pragmatism-of-the-right (Putnam, 2002; Rescher, 2000)	Moderately realist, recognizing an objective reality with subjective perceptions.	Knowledge is constructed with an understanding of multiple truths.	Values objective and informed research.	Combines qualitative and quantitative to enhance understanding.	Moderately embraced	It aligns with a balanced view of reality.
Pragmatism-of-the-left (Maxcy, 2003; Rorty, 1991)	Strongly anti-realist, emphasizing multiple constructed realities.	Knowledge is socially constructed.	Values diversity and multiple viewpoints.	Prioritizes qualitative methods but is open to integrating quantitative data.	Less embraced	Focus is on depth and complexity of qualitative analysis.
Anti-conflationist (Bryman, 1992; Hammersley, 1992; Layder, 1993; Roberts, 2002)	Clear separation between objective and subjective realities.	Emphasizes distinct knowledge domains.	Values methodological clarity and purity.	Opposes mixing methods that blur epistemological boundaries.	Rarely embraced	Emphasis on maintaining clear methodological boundaries.
Critical realist (Houston, 2001; Maxwell, 2004; Maxwell and Mittapalli, 2010; McEvoy and Richards, 2003, 2006)	Acknowledges a real world that influences, but is distinct from, our knowledge of it.	Knowledge seeks to uncover real underlying structures.	Values deep understanding of social structures.	Uses methods that reveal underlying mechanisms, may mix methods.	Highly embraced	Supports the uncovering of underlying mechanisms.
Dialectical stance (Greene, 2007, 2008; Greene and Caracelli, 1997; Greene and Hall, 2010; Maxwell and Loomis, 2003; Teddlie and Johnson, 2009)	Reality is shaped by dialectical processes.	Knowledge arises from the synthesis of opposing viewpoints.	Values the integration of opposing methods and ideas.	Integrates different methodologies to synthesize new insights.	Highly embraced	Enhances the synthesis of diverse insights.
Complementary strengths (Brewer and Hunter, 1989; Morse, 2003)	Recognizes the specific strengths of qualitative and quantitative realities.	Each method provides unique and valid insights.	Values the integrity of each methodological approach.	Maintains separation of methods to preserve unique contributions.	Less embraced	Focus on preserving the unique contributions of each method.
Transformative-emancipatory (Mertens, 2003, 2007, 2010; Mertens et al., 2010)	Reality is seen through the lens of power dynamics and inequality.	Knowledge is a tool for empowerment and change.	Values research that supports social justice.	Chooses methods that support social change.	Highly embraced	If it aids in promoting social justice and transformation.
A-paradigmatic (Patton, 2002; Reichardt and Cook, 1979)	Does not adhere to any specific reality constructs.	Practical knowledge shapes method choice.	Values pragmatism and utility in outcomes.	Flexible, driven by research questions.	Highly embraced	Supports pragmatic and practical research outcomes.
Substantive theory (Chen, 2006)	Reality interwoven with theoretical frameworks.	Knowledge is deeply contextual and theoretical.	Values theoretical coherence and depth.	Theory-driven, may integrate methods based on theory needs.	Highly embraced	If it enhances theoretical understanding.
Communities of practice (Denscombe, 2008)	Socially constructed realities within professional communities.	Knowledge evolves from communal practices.	Values the practices and traditions of communities.	Adapts methods to fit community practices.	Moderately embraced	Helps in understanding and generalizing community-specific insights.
Phenomenography (Feldon and Tofel-Grehl, 2022)	Focuses on the range of possible experiences.	Knowledge is the variation in perceptions of phenomena.	Values the depth of individual perceptions.	Qualitative, focuses on describing experiences.	Rarely embraced	Emphasis on capturing the richness of individual experiences.
Dialectical pluralism (Johnson, 2012, 2017; Johnson et al., 2014; Tucker et al., 2020)	Multiple kinds of reality acknowledged.	Integrates multiple epistemological perspectives.	Values the diversity of perspectives and methods.	Promotes dialogue among different methods.	Highly embraced	Enhances integration and synthesis of diverse perspectives.
Critical dialectical pluralism (Onwuegbuzie and Frels, 2013; Onwuegbuzie et al., 2024)	Focuses on dynamic social realities influenced by power and inequality.	Knowledge as an instrument for critiquing power structures both within the research study and the population at large.	Values social transformation and empowerment.	Aims to promote social justice through participants assuming the role of participant-researchers and researchers assuming the role of research-facilitators.	Highly embraced	If it serves social justice goals.

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mathematics as a practical tool, do not necessarily see quantitative analysis as reflecting any deeper truth or reality, which might make it less reliant on quantizing. They consider mathematical entities as fictional and primarily useful for their explanatory power. Advocates of nominalism could potentially reject quantizing because they view mathematical entities as social constructs rather than as objective entities that can be quantized. The focus is more on the meanings and uses of mathematical terms within human contexts. Depending on the specific flavor of anti-realism, anti-realists could reject the notion that quantizing reveals any 'true' knowledge about mathematical entities, focusing instead on the usefulness, coherence, and practical applications of mathematical theories rather than on quantitative analysis.

These quantitative research-based philosophies are less likely to embrace quantizing because they often view mathematical entities as subjective or contingent on human thought processes, not as external realities that can or should be quantized. Their proponents often focus on the subjective, constructed, or pragmatic aspects of mathematical knowledge, viewing quantitative methods as less critical or even irrelevant. However, it is important to note that even these philosophies would not completely reject quantizing but would prioritize qualitative approaches. In summary, philosophies rooted in logical, empirical, and scientific methodologies most strongly embrace quantizing, whereas those centered on human psychological or constructivist perspectives are less inclined to do so, focusing more on the qualitative or theoretical aspects of mathematical thought.

Mixed methods research-based philosophies

Table 3 illustrates the propensity of each mixed methods research philosophy to embrace quantizing, as influenced by its epistemological, ontological, axiological, and methodological underpinnings. As was the case for Tables 1, 2, Table 3 shows that these philosophies reflect diverse perspectives on reality, knowledge, method, and values, each shaping the approach to mixing and integrating qualitative and quantitative research methods. Quantizing is variously embraced depending on whether it aligns with the philosophical goals, particularly how it might support or enrich the understanding and outcomes of the research. Each of these philosophies has a unique stance on the use of quantizing alongside qualitative findings, generally shaped by their underlying principles about reality, knowledge, method, and values. Where practical outcomes, integration of diverse methods, or enhancement of theoretical understanding are valued, quantizing tends to be more favorably embraced. Conversely, where the emphasis is on maintaining methodological purity, exploring depth of individual experiences, or focusing on subjective realities, quantizing is less favored.

Consistent with this observation, the mixed methods research philosophies whose proponents are most likely to embrace quantizing appear to be pragmatism-of-the-middle, critical realism, dialectical pluralism, and critical dialectical pluralism. Pragmatism-of-the-middle likely embraces quantizing due to its practical and outcome-oriented approach. It values the integration of methods that can enhance practical applications and outcomes. Critical realists embrace quantizing because it helps uncover deeper truths about underlying mechanisms, aligning with its goal

of revealing the real structures influencing observed phenomena. Both dialectical pluralists and critical dialectical pluralists value the integration and synthesis of diverse methods and data forms, including quantizing, to enrich the dialogue among different epistemological perspectives, with critical dialectical pluralists especially embracing quantizing if it serves social justice goals.

Conversely, the mixed methods research philosophies whose proponents are least likely to embrace quantizing appear to be phenomenography, complementary strengths, and anti-conflationist. Phenomenography focuses on capturing the richness of individual perceptions and experiences primarily through qualitative means. It prioritizes depth over breadth, making quantizing less relevant and seldom embraced. Proponents of complementary strengths, although not completely rejecting quantizing, value the independence of qualitative and quantitative research methods. They suggest maintaining a separation to preserve the integrity of each approach, thereby not favoring the mixing or integrating of data forms. Anti-conflationist advocates likely reject quantizing because it emphasizes the importance of maintaining clear methodological boundaries between qualitative and quantitative research methods. Anti-conflationists argue against mixing methods that could blur epistemological and methodological distinctions, favoring a more principled approach whereby each method retains its purity.

However, it should be noted that proponents of these three philosophical approaches—phenomenography, complementary strengths, and anti-conflationist—are unlikely to reject outright the use of quantizing. Rather, they are more likely to express concerns about an over-reliance on quantizing, cautioning against its potential to overshadow the nuanced insights provided by qualitative analysis. In their view, quantitative methods should serve to augment, rather than to overshadow, the richness of qualitative data.

In summary, proponents of mixed methods research-based philosophies that embrace quantizing generally consider this technique as enhancing the robustness, practicality, and depth of their inquiries. They are driven by objectives that benefit from integrating quantitative rigor into qualitative contexts, such as improving practical applications, uncovering deeper systemic structures, or synthesizing diverse perspectives for richer insights. Contrastingly, philosophies least embracing quantizing often are rooted in maintaining methodological purity, valuing depth of individual experiences, or prioritizing epistemological clarity. These advocates may view quantizing as diluting the philosophical integrity of their methods or as inappropriate given their specific research aims and contexts. Each philosophy's stance on quantizing reflects its underlying assumptions about the nature of reality, the process of knowledge acquisition, the purpose of research, and what is valued as legitimate and important in the research process.

Summary of propensity for quantizing across the three research traditions

Across the diverse landscape of the qualitative, quantitative, and mixed methods research traditions—with notable exceptions such as the qualitative philosophies of postmodernism,

poststructuralism, and many forms of phenomenology—quantitizing generally aligns well with the ontological, epistemological, axiological, and methodological elements of the overwhelming majority of other research philosophies. Although not universally advocated, the compatibility of quantitative analysis techniques with these principles suggests that researchers working within these frameworks can appropriately utilize quantitizing when it serves to illuminate the research question(s) at hand. Particularly, outside of these three sets of research philosophies, this alignment allows quantitizing to play a supportive role, enhancing the empirical robustness and breadth of insights into complex phenomena.

Summary and conclusions

Building on Sandelowski et al.'s (2009) highly cited article, the present article has delved into the evolution and application of quantitizing, a process of converting qualitative data into quantitative formats, which, despite its potential, has not seen an increase in use over the years. This stagnation is attributed mainly to the dearth of methodological articles that explore and refine the approach. In response to this gap, the article introduces a comprehensive meta-framework for quantitizing qualitative data, structured around the 5W1H approach (Why, When, What, Where, How, Who), which serves as a detailed guide for researchers.

The meta-framework incorporates several existing frameworks and models, integrating both mixed methods and multiple methods research approaches to provide a structured yet flexible guide for applying quantitizing across different research contexts. The 5W1H sections of the article systematically address the key aspects of quantitizing, starting with the reasons for its use, the appropriate contexts and timing, and detailing the specific methods and approaches that can be utilized.

One of the pivotal aspects of the meta-framework is the DIME-Driven Model of Quantitizing. This model outlines four levels of quantitizing complexity: Descriptive-based, Inferral-based, Measurement-based, and Exploratory-based, each adding depth and precision to the analysis of qualitative data. The DIME acronym not only simplifies the recall of these categories but also emphasizes the value and precision inherent in the quantitizing process. The utility of this model lies in its ability to enhance methodological robustness and data integration, providing clearer, more actionable insights that are critical in areas such as psychological research, clinical research, and policy development.

The current article ardently advocates for a judicious application of quantitizing, proposing that it be used strategically to augment qualitative analyses. This approach is recommended as a means to enhance the clarity and practical applicability of research outcomes, without detracting from the depth and richness of qualitative data. Further, this article explores the application and value of quantitizing across qualitative, quantitative, and mixed

methods research traditions, demonstrating its broad relevance and transformative potential. It discusses the variable adoption of quantitizing based on differing philosophical perspectives related to ontology, epistemology, axiology, and methodology. Despite the disparities inherent in these philosophical foundations, it is noted that very few research philosophies entirely dismiss the practice of quantitizing.

The article advocates for a balanced use of quantitizing to complement qualitative analyses and to enhance research clarity and applicability without compromising the richness of narrative data. Serving as a comprehensive resource, the aim of this article has been to elucidate the complexities and benefits of quantitizing. It is hoped that it inspires researchers to incorporate this versatile technique into their analytical repertoire, thereby enriching the depth and enhancing the practical applicability of their research findings.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AO: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Therapeutic communication laboratory: integrating mixed methods with digital tools and reflective professional practice

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Communication has been recognized as the matrix in which the helping professionals operate in order to generate changes. In particular, psychotherapy is fundamentally a professional practice based, from its origins, on conversation. This study aims to establish the methodological and instrumental foundations of a therapeutic communication laboratory utilizing a mixed-methods approach. The primary objective is to develop and implement tools and procedures for the effective analysis of psychotherapy session recordings. We present a methodological proposal containing the foundations of a therapeutic communication laboratory which allows a new dialogue between professional practice and empirical research based on observation. We describe the processes of data incorporation and analysis of recorded sessions from a mixed methods perspective (Qual-Quan-Qual). The automation and integration of various digital tools, aligned with this mixed methods approach, are essential to achieve closer collaboration between practitioners and researchers. The incorporation of the transcription and labeling processes of the recordings into analysis tools such as Elan and Theme allows us to advance in these objectives. This approach enhances the training and supervision of psychotherapy professionals and bridges the gap between theoretical intervention models and their practical application. From a research standpoint, it enables the development of a knowledge base and observational instruments to advance the creation of more effective intervention models.

KEYWORDS

therapeutic communication laboratory, conversational analysis in psychotherapy, therapeutic communication, analysis of temporal patterns, mixed methods, observational methodology, motivational interviewing, discourse of change

1 Introduction

The first studies applied to the analysis of the process of therapeutic communication had a marked qualitative character (Ruesch and Bateson, 1951), but if we take a broad perspective of the technological context of the evolution of knowledge in the field, we could observe that technological limitations have played a major role in its advancement. In this paper we want to highlight the opportunities, and the necessary instruments needed for a therapeutic communication laboratory with the implementation of mixed methods, given the nature of the communicative behavior under study (Ruusuvuori, 2010) and how the digital tools that we currently have at our disposal make it possible.

The methodology of conversational analysis (Antaki, 2008) that some authors have proposed to use for the analysis of sessions in psychotherapy (Peräkylä et al., 2012a,b) is a predominantly qualitative methodological perspective. They have highlighted the methodological need to label the different components that come together in the generation of effects of meaning in the conversation, which they wanted to collect in the complexity of the transcription systems used. Paralinguistic elements, silences, rhythm, and speaking turns are important from the start of the conversation, which attempted to record as many details as possible about the timing, tone, intensity, and pronunciation patterns as the conversational sequence unfolded, with speaking turns occurring one after the other.

In this methodological perspective, the adjacency pair (concatenated sequences of the interlocutors) of speaking turns has been the main focus of the analysis of the interlocutors' intervention sequences (Peräkylä, 2019). However, it is clear that additional sequencing patterns beyond the simple concatenation of the interventions must be used. Therefore, in our perspective of mixed methods, we will be able to identify other types of sequencing in the conversational process by using tools like Theme to analyze the temporal patterns of the interlocutors' interventions.

From the perspective of psychotherapy practitioners, a significant qualitative leap was achieved with work initiated at MRI and the so-called Palo Alto School in the latter half of the last century. Indeed, a new reflective practice in psychotherapy, based on the observation of communication occurring in sessions, has emerged since the 1960s, giving rise to systemic family therapies and brief therapies at the Palo Alto School.

It will be in the mythical MRI of Palo Alto that the work of anthropologists, linguists, psychiatrists, psychologists, social workers converge (Bateson and Winkin, 1990), all of them concerned with how efficiency could be promoted in their interventions, and for this they used mainly the Gessell one-way mirror to observe the equipment what was happening inside the room where the psychotherapy sessions were taking place (de Shazer, 1999).

In addition to providing a rich conceptual and practical perspective on how to intervene in the communication process in the most efficient way possible to achieve the desired results of change, this interdisciplinary approach focused on the communication processes that successfully generate (giving rise to the so-called brief therapy) change in patients (Watzlawick et al., 1974).

These contributions to the understanding and efficient intervention in generating change were based from the beginning on observation and listening devices to follow the sessions live. Since then, based on these observation processes of what happens in the psychotherapy room (de Shazer, 1999)¹ intervention models and techniques have been proposed such as motivational

interviewing (Miller and Rollnick, 2015) or solution-focused interviewing (De Jong and Berg, 2008), which are intervention models based on the communication process, and which have been developing different techniques to facilitate change processes. It is also worth highlighting also, the contributions of third generation therapies developed from contextual psychology and the theory of relational frameworks developed in an experimental setting (Törneke, 2017) have also proposed the centrality of language functioning in change processes (Villatte et al., 2016).

These methodological perspectives (conversational analysis) and intervention models based on the language of change and therapeutic communication (reflective practice of psychotherapy professionals based on the observation of what actually happens in the therapeutic conversation) require the incorporation of the technological infrastructure that facilitates the process of reflective practice of professionals, and at the same time, do so with a mixed methods perspective that can collect and take into account, in a systematic way, the multimodal (Stivers et al., 2011) and multidimensional complexity of the object of observation, that is, the communication through which a helping professional promotes processes of change.

2 Components of the therapeutic communication laboratory

The Therapeutic Communication Laboratory proposes to combine observational methodology, as a mixed method, with the methodology of reflective professional practice based on observation. Learning and improving professionally by observing your own practice or that of your colleagues requires the development of observational devices and instruments that facilitate reflection on what really happens in psychotherapy sessions. Currently there is a "gap" between practice and theory, between intervention objectives based on the intervention models followed by professionals and the ways in which they are applied in the conversation process.

In order to overcome this gap, a therapeutic communication laboratory has to facilitate, on the one hand, the process of observing and reviewing sessions, making it less costly in terms of professionals' time, and on the other hand, incorporate the most appropriate tools so that it can be done with a rigorous methodology adapted to the object of observation.

To make this approach possible between the needs of reflective professional practice, systematically incorporating the observation of what really happens in the interaction with clients, we have at our disposal the automation of the transcription processes not only of the verbal content, but also of the automatic labeling tools for intonation (Szekrényes, 2015) or silences that are so important in different therapeutic processes.

For example, we know very well the importance of being able to establish a good therapeutic relationship and the generation of trust and security, etc. And we know that this occurs during the course of the conversation through the different dimensions of communication: the verbal content, that is, what is said, but also and fundamentally how it is said, that is, the intonation, the rhythm of speech, the gestures, the game of the gaze, and others. All of this forms a specific message that is transmitted

¹ "In an equally scientific and modern spirit, another doctor, a certain Salvador Minuchin, drilled another hole in another wall of another city...In a time not very distant and in a place very far in many ways from Vienna, from Palo Alto and from Philadelphia, we looked through the mirror and were amazed at what we saw...We saw a therapist talking to his patient" (de Shazer, 1999).

in the conversational sequence and which are the components of the different conversational operations that the professional performs, whether questions, formulations, through which we carry out the different therapeutic tasks. All these aspects require a technological infrastructure that allows flexibility and ease of use by professionals, since they must be able to incorporate their own therapeutic objectives and notes in a qualitative way, but at the same time provide support to incorporate the multimodal nature and sequential of the conversation. On the other hand, this infrastructure requires the automation of annotation processes, whether of textual or phonetic transcriptions, as well as the rest of the dimensions of communication.

As we can see in Figure 1, the transcription and labeling system combines, in ELAN, manual and automated annotation processes, allowing for great flexibility and facilitating moments of qualitative analysis and integration of automated processes that facilitate a review of the sessions with the least expenditure of time for professionals, while allowing their active participation in the development of annotation and coding systems adjusted to different objectives, whether in the field of supervision, training or research. On the other hand, it allows the development of observational instruments that can be used by researchers following mixed methods, Qual-Quan-Qual (Anguera, 2020), and the methodology of conversational analysis.

As we can see in Figure 2, this technological infrastructure will make it possible to work toward overcoming the gap between professional practice and theoretical intervention models, since it facilitates the reflective practice of professionals and their incorporation into training, coaching, and supervision processes thanks to the flexibility and capacity to integrate different technologies from a mixed methods perspective.

3 Technological infrastructure on the analysis of therapeutic communication

Microanalytical lenses are the technologies that help us process the multidimensionality of communication in its temporal sequentially (Blanchet et al., 2005) and framed in the communicative actions oriented to change that the professional carries out in each case.

These “microscopes” and “X-ray” devices that allow us to X-ray communication are made up of computer programs and procedures for exchanging data analyzed in the light of these different digital tools. It will be on the basis of the creation of annotations and coding carried out with the help of automated labeling systems and complemented by qualitative and *ad hoc* annotations, that with the help of the exchange of these data with other types of temporal pattern processing, we will be able to build a knowledge base that supports learning and improving therapeutic communication skills and generating new knowledge in intervention models.

The different components pivot on ELAN² (ELAN [Computer software], 2023). As explained on its website, ELAN is an annotation tool for audio and video recordings that allows you to add an unlimited number of textual annotations to audio and/or

video recordings. This tool allows the import and export of different formats. Of particular interest to our mixed methods strategy are the exchange possibilities in the textgrid (Praat) formats that allow us, as we will see, to incorporate the results of automatic transcriptions, both orthographic and prosodic, and, on the other hand, the export of all the annotations aligned in time to the Theme program for analyzing temporal patterns.

In this way, ELAN can be used both in a purely qualitative perspective by adding *ad hoc* in the review of role playing in learning processes, or the supervision of real sessions by facilitating the integration of automated processing of the recordings by adding a set of annotations resulting from different transcription procedures, as we will see, not only textual but also phonetic, while facilitating manual annotations by professionals with comments and identification of different, especially significant moments that occurred throughout the session.

It also provides a bridge that allows a fluid transfer between the world of practice (Bavelas, 2011) and that of research and the development of intervention models. through the development of systematic observation instruments to which temporal pattern analysis can be applied to identify statistically significant interaction sequences, true microanalytic lenses that allow us to observe how these patterns manifest by exploring them. again qualitatively. This knowledge base incorporates, through automated registration procedures, labels referring to intonation, along with transcription and other labels that can be added, as demonstrated with the use of the ELAN program, in order to integrate annotations referring to the different dimensions of communication (verbal, paralinguistic, and gestural).

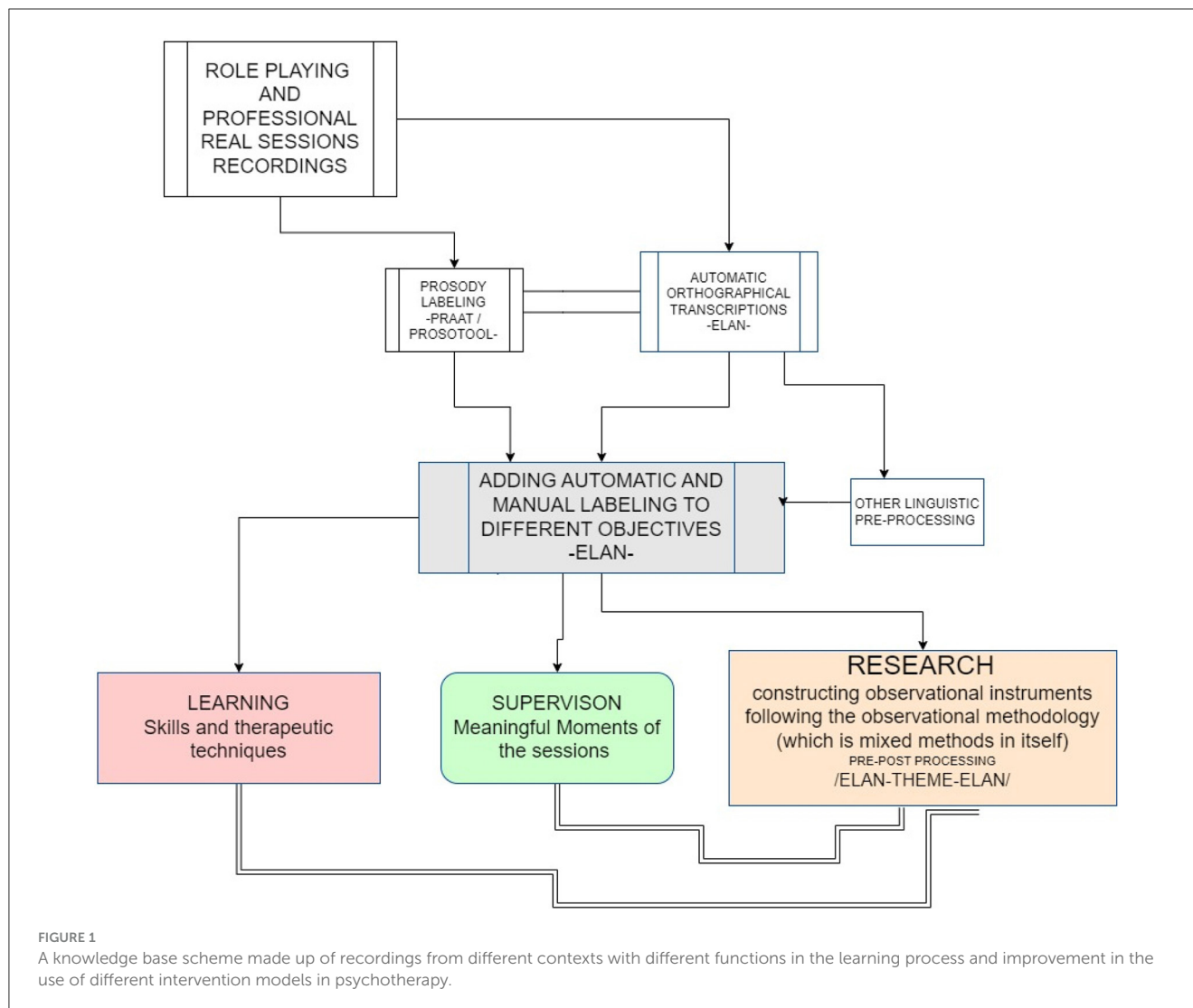
On the other hand, we will see how to integrate transcription and tagging in ELAN with temporal pattern analysis programs (THEME)³ (Magnusson, 1996, 2000, 2020; Magnusson et al., 2016, 2023) that use algorithms to detect temporal patterns in those previously labeled files. They allow us to analyze the most significant patterns in which these labels appear organized and return to the qualitative analysis tools the representative sequences of certain temporal patterns to analyze in depth, generating a continuous movement of discovery, annotation and exploration of the different aspects that can be increase the effectiveness of professional intervention in these conversational sequences.

This back and forth movement between the use of ELAN, qualitative processing *ad hoc* based on the objectives of the annotations (learning contexts, supervisions, or for research purposes in which case, developing a systematized observation instrument that will depend on different objectives of exploration and analysis of the corpus, its analysis with Theme, and subsequently the possibility of returning to qualitatively analyze the temporal patterns detected, is at the heart of the mixed methods that we propose for the therapeutic communication laboratory.

There is consensus on the multimodal (Voutilainen et al., 2010) nature of communicative behavior—and specifically in therapeutic communication—and it is highlighted in other sections of this article. The multidimensionality of communication has been studied by multiple classical and current authors (Bavelas

2 <https://archive.mpi.nl/tla/elan>

3 <https://patternvision.com/>



et al., 2000; Hunyadi, 2020; Hunyadi and Szekrényes, 2020; Mondada, 2013), and this polyhedral character fits perfectly with a mixed methods approach to data collection, management and analysis.

We must take this multidimensional nature into consideration both from the perspective of qualitative analysis itself and from the creation of observational instruments that allow us a Qual-Quan-Qual integration.

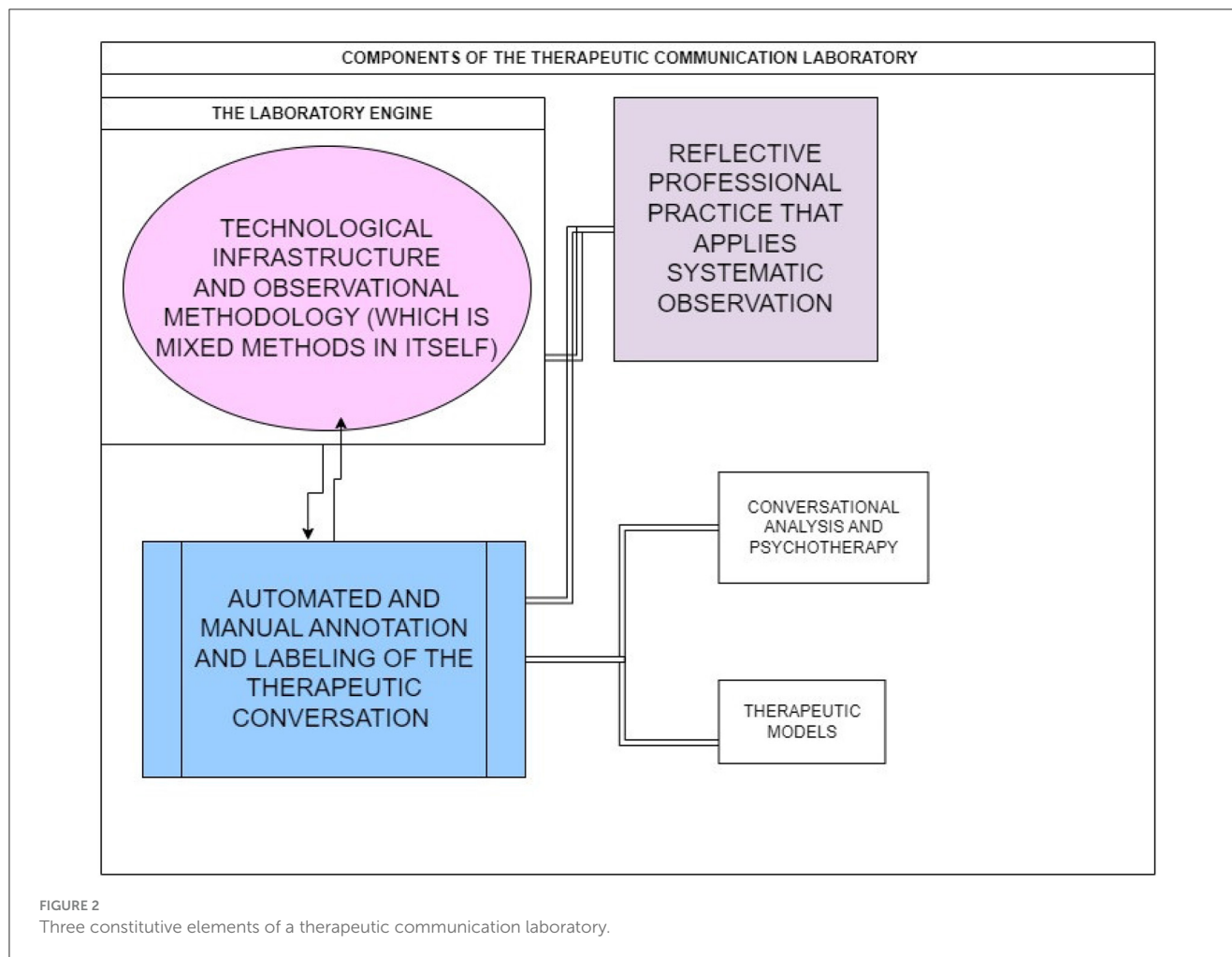
4 Observational instruments and mixed methods

The exponential growth of mixed methods in the last quarter century has put the focus on the integration of qualitative and quantitative elements (Zhang, 2018, 2019; Zhang and Creswell, 2020), which has become the keystone on which discussions and publications continue, leaving behind complementarity as obsolete. Integration, considered as “the interaction or conversation between the qualitative and quantitative components of a study” (O’Cathain et al., 2007, p. 341) is a central axis around which most of the

scientific production of recent years revolves (O’Cathain et al., 2007), and is also a key aspect in mixed methods research (Hitchcock and Onwuegbuzie, 2020, 2022). Moreover, there has been a very significant evolution from a dichotomous approach (qualitative vs. quantitative) to a *continuum* (Onwuegbuzie, 2012; Hitchcock and Onwuegbuzie, 2022), showing a wide arc of possibilities.

In previous works (Anguera et al., 2020; Arias-Pujol et al., 2022) we have referred to the connect way of integration, once proposed by Creswell and Plano Clark (2011), which has shown maximum efficacy to make effective the integration between qualitative and quantitative elements, through the three sequential QUAL-QUAN-QUAL stages, to which we will refer below.

We are interested in the analysis of therapeutic communication, which is part of the interactive habituality between therapist and patient throughout treatment. This aim justifies the suitability of observational methodology, a scientific method characterized by rigor and flexibility, and considered a *mixed method* in itself (Anguera et al., 2023a,b, 2017a,b), which explains its wide applicability in recent decades.



The study of therapeutic communication, characterized by the interest in analyzing the processes of change in the patient, must first address the delimitation of the spectrum of levels of response—in Weick's terms (1986)—, which have subsequently been called dimensions, and which in turn can be unfolded in potential sub-dimensions and in several levels. As specified earlier, therapeutic communication includes turns of speech with its verbal contents, with paralinguistic factors, silences, rhythm, ..., which gives it a polyhedral character. To organize the record, in the first QUAL stage, it is essential to build a customized observation instrument (Anguera et al., 2007), which is the “core” of this process, and which means much more than assigning labels.

First, a decision must be made regarding the dimensions to be considered, which must take into account both the theoretical framework and the situation under study (they can unfold in sub-dimensions of various levels). Together, the dimensions and subdimensions should form the “skeleton” or structure of the observation instrument and depending on the technology used in the recording (only tape recording or video recording) it will be possible to include only verbal behavior and part of the vocal behavior in the first case, or to open up all the possibilities of nonverbal behavior (Mondada, 2007) in the video recordings. The

limits of quantification depends on the adequacy of observational instrument.

The second major initial decision is the segmentation of turns of speech into units, which is an important aspect that will later have an impact on the assignment of codes. Over the years, the location in the molecular vs. molar *continuum* of units has been a debated issue attending to the significance of the granularity to which we subject discourse sentences (Schegloff, 2000), and to the consequences of positioning. From the initial proposal of Krippendorff (2013), the approach we consider most appropriate (Anguera, 2021) is interlocutory segmentation (each turn of speech), and, within each turn of speech adopting the syntactic criterion (a grammatical sentence).

Once both decisions have been taken, and once the structure of the observation instrument and the segmentation criteria are available, it is time to proceed specifically to the development of the instrument. Based on each of the dimensions (or on the most molecularized subdimension, as the case may be), a catalog of behaviors (an open list of communicative behaviors that must be mutually exclusive) or, if possible, a system of categories (a closed list that must be exhaustive and mutually exclusive) will be drawn up. This customized observation instrument will be essential to transform the (qualitative) recording of turns of speech into a

matrix of codes, which will also be qualitative in nature, but which will be systematized in such a way as to allow its quantitative analysis, thus making the integration of mixed methods a reality (Anguera et al., 2021).

The code matrix is irregular, and its structure will be subject to the syntactic rules of the program used to carry out the subsequent quantitative analysis.

The QUAN stage that follows the first QUAL stage has had to make its way. There is a conceptual plurality in mixed methods that can be evidenced from the words of Onwuegbuzie and Combs (2010), who state that “analyzing data in mixed methods is one of the most difficult steps—if not the most difficult step—of the mixed methods research process” (p. 397). In recent years, Onwuegbuzie and Johnson (2021) have developed the *crossover mixed analyses*, which imply that one or more types of analysis associated with one tradition (e.g., qualitative) can be used to analyze data associated with another tradition (e.g., quantitative). Among the multiple options presented in *crossover mixed analyses*, we highlight for its suitability the diachronic analysis—which is quantitative—from qualitative data—which we obtain in a systematic observation record—(Anguera et al., 2021).

In the framework of the diachronic analysis from qualitative data, and which allows us to materialize the QUAN stage, the quantitative analysis that we recommend here is the detection of T-Patterns (TPA) using the THEME program (Magnusson, 1996, 2000, 2020; Magnusson et al., 2016), which presents great possibilities of connection with the ELAN program (Szekrényes, 2019).

The T-Pattern is the core of the model, and its essence lies in the discovery of hidden structures, based on the critical interval between series of points with respect to the time dimension, revealing itself as an extremely valuable analytical tool, which in turn entails a permanent dialogue with the respective conceptual framework. Its non-visible character increases its power of discovery, since the researcher is interested in being able to extract the internal structure that shows the key to the behavior that occurs.

A T-Pattern is defined as the structure formed by a series of events that occur concurrently or sequentially more frequently than would be expected by chance if all the events were distributed independently. This series of events occur in the same order, maintaining temporal distances between them (critical interval) that are relatively invariant to the null hypothesis that each event is independent and randomly distributed at the temporal level (Magnusson, 1996, 2000).

A great advantage of T-Pattern detection is that it is not constrained by implicit assumptions about the distribution of the analyzed behaviors and allows the selection of minimum number of occurrences and significance level, among other parameters, with a clear control over chance findings.

THEME™ (2008) software, throughout the development of its different versions, has allowed the detection of T-Patterns, and the wide applicability deployed has allowed showing self-similarities at different scales, from brain neuronal to social and group interaction.

In recent years, T-Patterns detection has been applied in observational studies in different domains, as shown by two recent systematic reviews (Anguera et al., 2023b; Sáiz-Manzanares et al., 2022), confirming its robustness.

5 Contributions of the HuComTech project to development of a knowledge base of therapeutic communication

As we have already mentioned, in a conversational sequence, verbal content is combined with paralinguistic intonational components and kinesic and gestural components. All of them behave like a pack of information that unfolds over time and form different temporal patterns that are responsible for the generation of sense, meaning and effectiveness of conversational interaction. Hence the need to incorporate into the analysis procedures of therapeutic actions a space-time mesh formed by those components of communication that make up the background in which the different therapeutic communicative actions make sense and operate.

The integration that we propose between observation and qualitative annotation and the eventual development of observational instruments, as described in the previous section is based on the creation of a corpus of therapeutic communication recordings created from different professional practices, namely, role playing in training workshops, real sessions collected for the supervision of psychotherapy professionals or other professional areas of communication that have the generation of change processes as a late motive. This corpus is processed based on different objectives, whether research or exemplification of different types of therapeutic skills, or reflection on how different therapeutic tasks are carried out.

This corpus, whether for a purely qualitative treatment, or for subjecting it to microanalytical analysis procedures through its integration with temporal pattern analysis tools following the perspective of mixed methods, can be transcribed and annotated, preferably automatically, such as we will specify in this paper. For this, automatic transcription and phonological analysis tools are essential to the extent that they save a large amount of manual transcription and annotation time, and therefore, their incorporation into professional practice contexts is much more feasible. On the other hand, this precision in the transcription and the levels of analysis taken into account in the review of the sessions and subsequent coding acquire greater quality and depth.

In the treatment of the corpus, we take as reference what was done by the HuComTech project (Hunyadi, 2011; Hunyadi et al., 2011) of which several of the signatories are authors, has had a pioneering role in the exploration of conversational corpora applying a multidimensional perspective. The multimodal nature of communication served as a research focus that resulted in the creation of the highly elaborate and multidimensional HuComTech. This corpus is based on about 30 hours of formal and informal dialogues with 200 participants with the aim of capturing, describing, and learning about those verbal and non-verbal properties of communication.

From the creation of this corpus, interesting contributions have been made on how we could investigate different aspects that are relevant to the purpose of a therapeutic communication laboratory. One of the aspects that we can explore with this methodology is how different conversational forms indicate different mental states. When engaged in a personal interaction, the interlocutors do

not only convey factual information, they also communicate their attitudes toward both this information and its source, the partner of the interaction. Attitudes can vary from being social/psychological to pragmatic/situational, to active/reactive, and much more. Spoken interactions are not just sequences of grammatically well-formed utterances; personal real/time involvement in a dialogue is realized in a rich, multifaceted, multimodal (Voutilainen et al., 2014) environment with each modality contributing to the holistic nature of the resulting message. The temporally dynamic nature of dialogues means that interactions shape and change their course in real time, with the formal properties of the constituting modalities evolving in parallel with the cognitive processes behind them. Quite noticeably, the grammaticality of a verbal utterance cannot easily be judged following the rules applicable to a temporally static written text—due to their often high degree of fragmentation. Importantly though, we can consider them perfectly fitting the conversation, since this linguistically fragmented speech is just a single component of the multimodal complex.

By studying the linguistic fragmentation of a conversation one can add yet another layer to the understanding and interpretation of the interaction, often hidden behind the spoken word. This was the goal of a study aimed at identifying the patterns of spoken utterances within the HuComTech corpus as well (Hunyadi, 2013). Since automatic morphological and syntactic analysis is always language specific, the AI-based application *magyarlanc*, developed for Hungarian, the language of the corpus, was used for the specific purposes of this study.⁴ The output of the analysis offered a hierarchical syntactic representation of the actual utterance that also included of a number of structurally incomplete sentences. Such chunks of speech, often agrammatical from a strict theoretical nature can in turn shed light on the state of mind of the speaker, including, among others, their assertiveness, uncertainty, presence or lack of cooperativeness, all relative to the given conversation. The CMU Link Grammar⁵ natural language parser, together with its actively developed tool⁶ offers an easy to use platform for a basic syntactic analysis of sentences with an output showing existing as well as missing links within the sentence. These missing links can then serve as indications of structural incompleteness possibly associated with some developing state of mind.

These qualities can be supported by observing other layers of linguistic structure as well. One of the most outstanding of them is prosody. Prosody includes intonation, intensity and duration. The automatic annotation of intonation (cf. *ProsoTool* mentioned earlier) offers a stylized representation of the tunes spreading across the utterance which, if associated with word and/or sentence boundaries, can be an important source of information about the state of mind of the speaker. Automatic segmentation of speech into words (word alignment) is available⁷ for a number of languages after submitting an audio (or video) file together with its orthographic transcription. It has a variety of output formats, including “.eaf” (for ELAN) which can easily

be imported and associated with other, already existing levels of annotation. Intensity data (yet another output of *ProsoTool*)⁸ add extra information to the way the given conversation is performed, shedding light on, among others, the expressed emotions manifested between the interlocutors. Duration data can also be quite informative: a short word followed by a longer pause can indicate hesitation or contemplation, especially following conjunctives, such as *if*, *and* or *but*, *however*, or between parts of a compound.

We understand the conversation process in its space-time deployment, forming a multidimensional mesh on which we must place the necessary lenses to be able to analyze how the different interventions and processes of change are taking place. These lenses are provided to us by these computer tools ELAN, PRAAT, THEME and very fundamentally by the developments of artificial intelligence for transcriptions and automatic labeling of paralinguistic dimensions (*ProsoTool*) (Szekrényes, 2015). Without these instruments it would be very difficult to observe the deployment and effects of professional interventions in the development of the sessions.

6 Motivational interviewing and the language of change

As an example to show the possible integrations of analysis instruments of psychotherapy sessions from this mixed-methods perspective, based on this technological infrastructure, we are using a publicly available recording of a motivational interview.

Motivational interviewing is an intervention model based on language and communication that has developed coding systems⁹ of the different skills that operate in the interview to evaluate the degree to which professionals apply the model.

Motivational interviewing is a collaborative, client-centered intervention model designed to explore and strengthen internal motivation for change. It has been used especially in the treatment of alcohol problems, but it has been extended to other areas of intervention, both psychotherapy and other contexts of professional intervention for the facilitation of change processes (health, educational, social or organizational contexts).

The interventions of the professional in the motivational interview are such as open questions, or formulations such as Reflections,¹⁰ Affirmations, or Summaries through which the

4 <https://rgai.inf.u-szeged.hu/magyarlanc>

5 <https://github.com/opencog/link-grammar>

6 <https://www.link.cs.cmu.edu/link/submit-sentence-4.html>

7 <https://www.clarin.eu/showcase/webmaus-automatic-segmentation-and-labelling-speech-signals-over-web>

8 The tool is available within the framework of the e-magyar project under the name emPros: <https://e-magyar.hu/en/speechmodules/empros>.

9 <https://motivationalinterviewing.org/sites/default/files/miti42.pdf>

10 Reflections “are always offered in response to something the person has said and basically capture and return to the person something they just said. Simple reflections add little or no meaning or emphasis beyond what is said. They repeat the content, perhaps with some rephrasing, but they do not advance assumptions about what the person means. In contrast, complex reflections make a conjecture about the possible meaning beyond what is said” (Miller and Rollnick, 2015, p.560).

person will be guided to generate for himself different forms of language of change aligned with the client values that lead you to commit to change based on your own intrinsic motivations.

It is assumed that the presence of different forms of change language in the person's speech that is manifested throughout the interview will lead him to take the necessary steps to make that change a reality in his life. Therefore, the interviewer's interventions will be aimed at eliciting that type of language in the person interviewed.

From the perspective of conversational analysis, in which we position ourselves, it is necessary to analyze therapeutic communication taking into account how speaking turns are concatenated, and therefore, analyze the interventions of both the professional and the client. In this sense, it is worth highlighting the contributions of linguists such as Laws et al. (2018), Apodaca and Longabaugh (2009), or Amrhein (2004), who have contributed to the motivational interview model with a classification of the different forms of language of change.

7 ELAN annotation and labeling program for the analysis of therapeutic communication

ELAN [Computer software] (2023) is an open source program created and maintained by the Max Planck Institute for Psycholinguistics, which allows us to link different types of annotations, transcriptions and labeling of the different dimensions of communication (paralinguistic or gestural) by linking them to the timeline of audio-visual recordings. As its creators say (ELAN [Computer software], 2023) "a user can add an unlimited number of textual annotations to audio and/or video recordings. An annotation can be a sentence, word or gloss, a comment, translation or a description of any feature observed in the media. Annotations can be created on multiple layers, called *tiers*. Tiers can be hierarchically interconnected. An annotation can either be time-aligned to the media or it can refer to other existing annotations." (see text footnote ²).

On the other hand, it allows us to work either qualitatively, generating *ad hoc* labeling based on the specific objectives we have when viewing the sessions (for example, identifying moments of success, more significant interactions for learning, training or supervision tasks of professionals), but also develop a systematic coding system that allows us to feed a knowledge base that can be used in research or training Programs.

Likewise, it has a very interesting capacity for integration with other tools, especially with the PRAAT program for phonetic speech analysis, which, as we will see in this paper, is very useful in the process of automating transcription and annotations of the paralinguistic dimension and emotional prosody.

Along with these capabilities of integration and alignment in time of the different components to be taken into account in the analysis of therapeutic communication, it is also very suitable for integrating it into research processes with mixed methods and analysis of temporal patterns (Anguera et al., 2023a,b) following the methodology proposed by Hunyadi et al. (2016) and Szekrényes (2019) that allows us to carry out a round-trip movement of integration between the moment of annotation and qualitative

analysis, and analysis of quantitative temporal patterns. For this reason, it is the most appropriate tool to label communication sessions because we can analyze how the different dimensions that make up communication unfold over time, that is, a space-time mesh formed by the words used, the tone, the rhythm, gestures,... and together with these dimensions unfolding in conversational sequences, we align the codings that correspond to the actions carried out by the therapist.

In this paper, our purpose is to show the usefulness and fit of the methodology and tools proposed for the analysis of intervention processes in psychotherapy. In this sense, in the case of motivational interviewing, the integration of the tools presented below allows the joint incorporation of the necessary requirements for methodological rigor and the facilitation of the work of professionals through automation of the processing of recordings and the possibility for them to incorporate their own reflections in future observation instruments.

In the Figure 3, we show how we can manually add the Tiers with therapist annotations depending on the intervention model or the specific objectives of the interventions. In the case of motivational interviewing, we can add where Reflections, open questions, or different modalities of change discourse have occurred. In other intervention models, such as EMDR therapy, we could note where references to Target Identification appear for processing.

8 Automated transcription and labeling of the motivational interview

As we can see in Figure 4, the ELAN program allows us to label the different dimensions of communication, the verbal content of the transcription as well as integrate the automatic labeling carried out with Prosotool (Szekrényes, 2015), a method for automatic annotation of fundamental frequency, in the PRAAT program. The exchange between ELAN and PRAAT is direct so we can work together with these two programs.

ProsoTool requires prior annotation of speaker changes to separately analyze participants' intonation. This step can be automated using available open-source speaker diarization tools like the Pyannote Python module (Plaquet and Bredin, 2023). The resulting speech segments, labeled per speaker, can then be utilized as a multi-tier representation of turn-taking for prosodic and T-pattern analysis. ProsoTool's output consists of categorical labels aligned with the audio, describing the shape (rising, falling, descending, ascending, level) of pitch curves as longer trends in the development of fundamental frequency values. These labels for intonation movements are complemented by positional ones that determine the location of the actual curve within the speaker's relative vocal range (Low1, Low2, Medium, High1, High2).

For automatic transcription, there are publicly available models from OpenAI's Whisper (Radford et al., 2022), known for its high accuracy with the Spanish language. The outputs of speaker diarization, speech recognition, and prosodic analysis can be effortlessly combined in Praat TextGrid format, then imported into ELAN as previously mentioned above.

To implement this processing chain, we utilized a Python-based system developed at the Department of Digital Humanities, Eötvös Loránd University. This system incorporates Pyannote

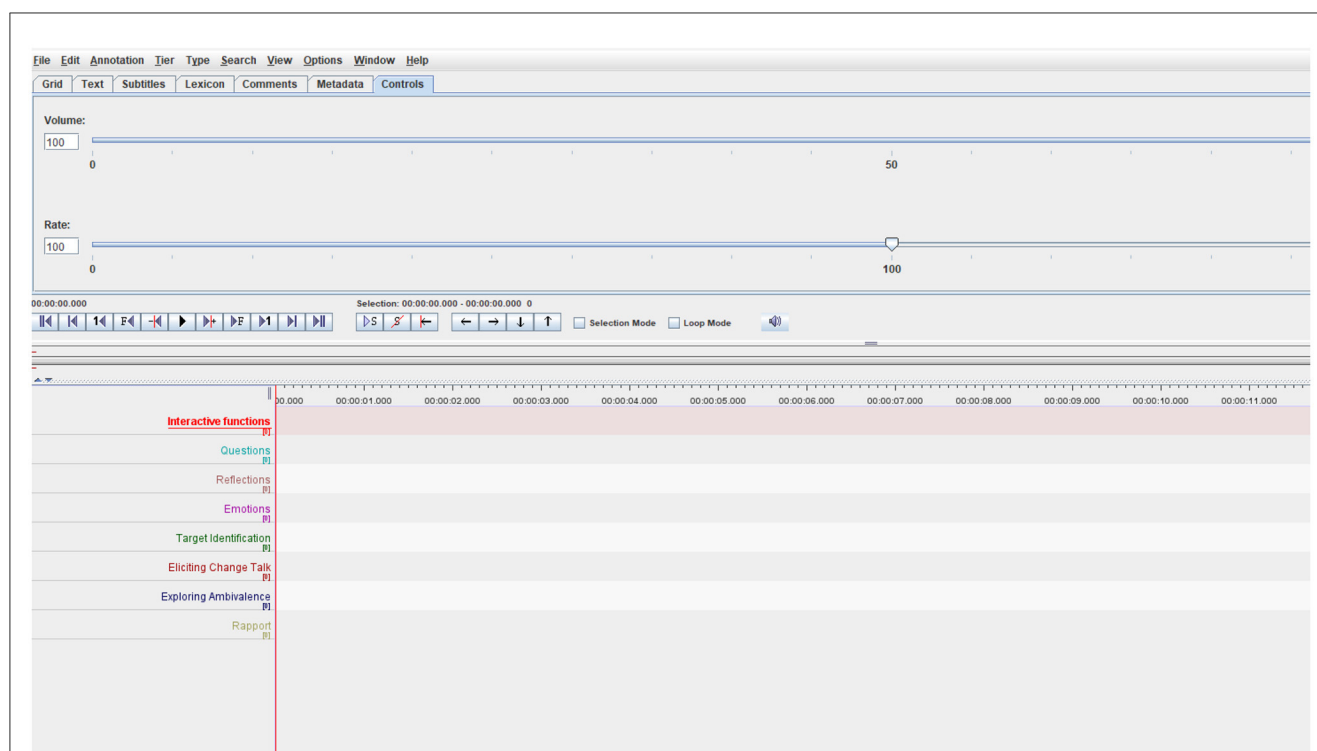


FIGURE 3

A knowledge base scheme made up of recordings from different contexts with different functions in the learning process and improvement in the use of different intervention models in psychotherapy.

(*Speaker-Diarization-3.1*)¹¹ for speaker turn detection and the *openai/whisper-large-v3* model¹² for speech recognition. Following post-processing, the results are provided in multiple formats, including TextGrid, which was used to input data into ProsoTool, an open-source tool available on GitHub.¹³

In the Figure 4 we can see how the different annotations aligned in time contain the different aspects of communication, the verbal content, the silences, the prosodic characteristics of the speech of both the therapist and the client, as well as other labels such as the client's expressions of change speech, of what type, as well as the type of intervention that the professional has carried out. All this information is aligned in time and can therefore be exported to a temporal pattern analysis program to identify the most significant patterns.

The automatic transcription procedures of verbal content and intonation will facilitate the process of qualitative exploration of the session. Therefore, in this first moment, we will be able to explore, analyze and label manually depending on the objectives and context of use (training, supervision or research) of the recording.

Likewise, we can also develop an observational instrument with a system of categories that collect the different dimensions of communication as well as the categories that we want to analyze, whether they refer, as in the case of the motivational interview that we take as an example, to the different types of client expressions,

whether change speech or maintenance speech, and on the other hand, the different types of therapist interventions to determine possible temporal patterns with Theme.

For this, the “back and forth” movement between ELAN and the THEME program (Szekrényes, 2019) is of fundamental importance, since it allows not only to identify possible statistically significant temporal patterns, but also to subsequently analyze some of these patterns in a qualitative way in the ELAN program.

9 Analysis of temporal patterns with THEME

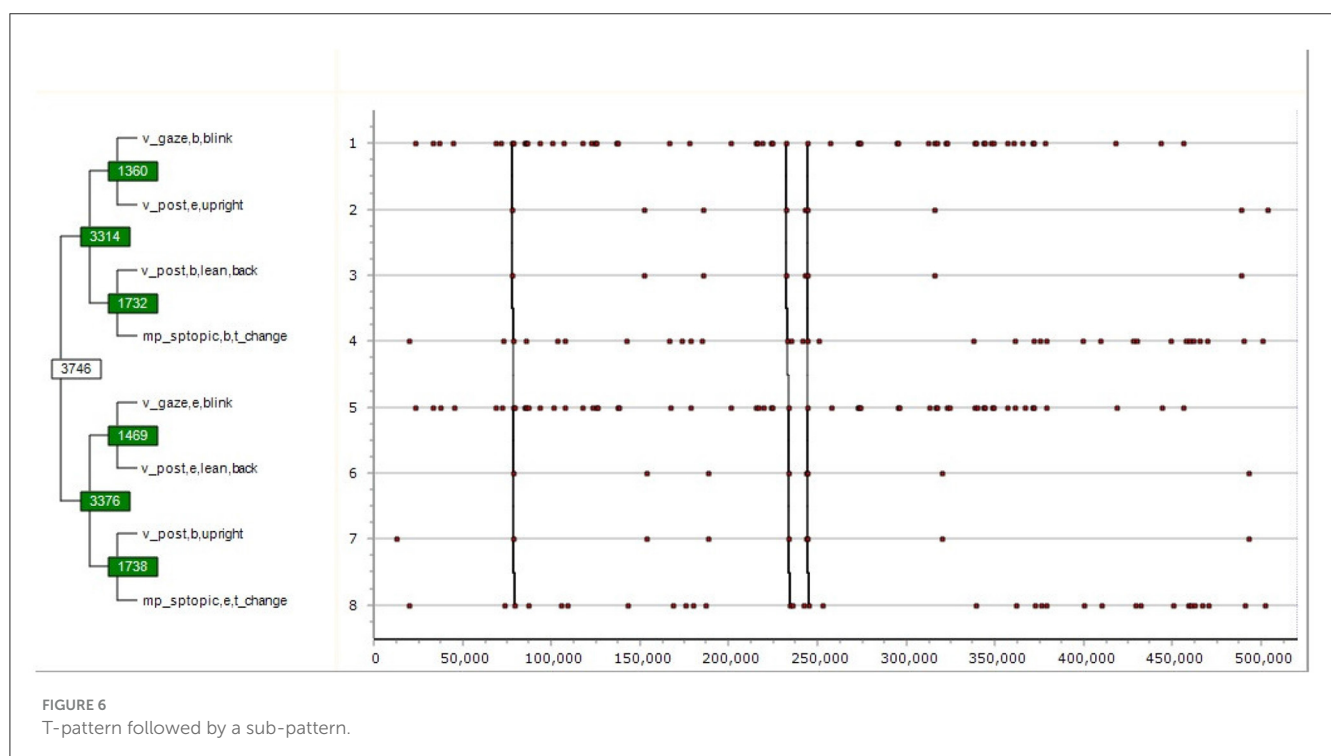
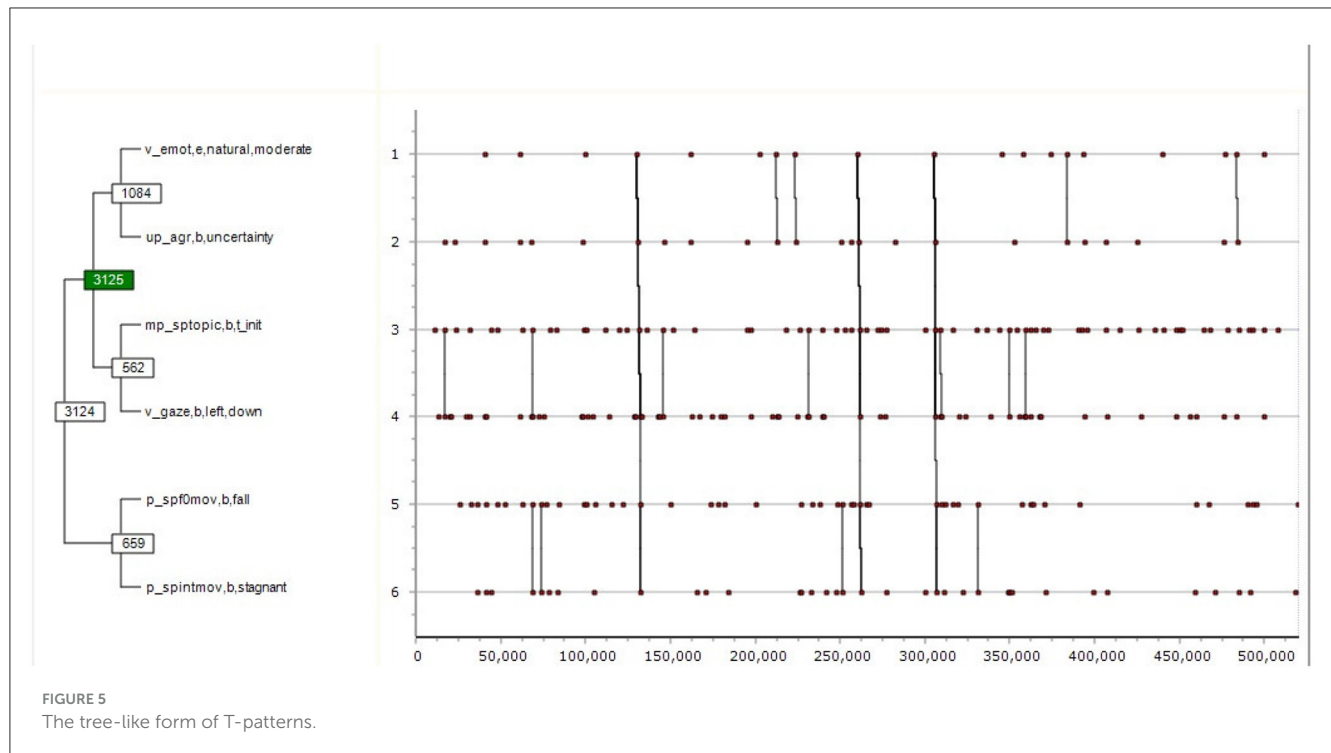
In order to develop a deeper understanding of therapeutic communication, one should start out from the linguistic form and continue to observe and understand the multimodal moments of the interaction, and, finally, go beyond both the verbal and nonverbal stereotypes and arrive at the patient as a single independent individual. It is, undoubtedly, not an easy task, and the therapist's observations and judgements have to be based on as solid data as possible. This is the point where a collection of data in the form of a comprehensive behavioral corpus can be of great importance.

The following three examples are taken from the HuComTech multimodal corpus, in order to demonstrate how a corpus of therapeutic communication will prove to be useful once it is completed. The patterns are all taken from dialogues of a more generic nature using Theme, the research environment especially designed to uncover even such patterns of behavior

11 <https://huggingface.co/pyannote/speaker-diarization-3.1>

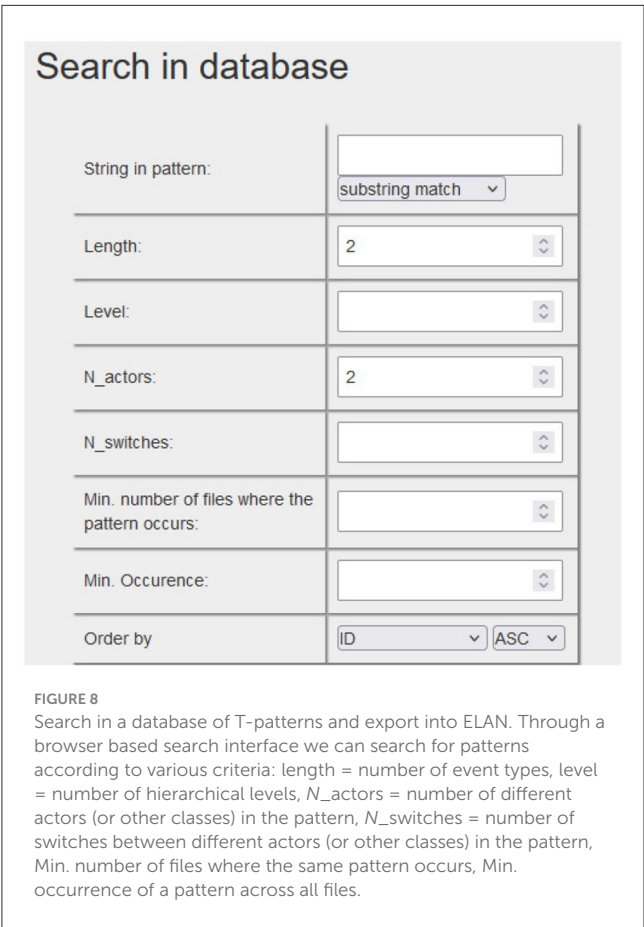
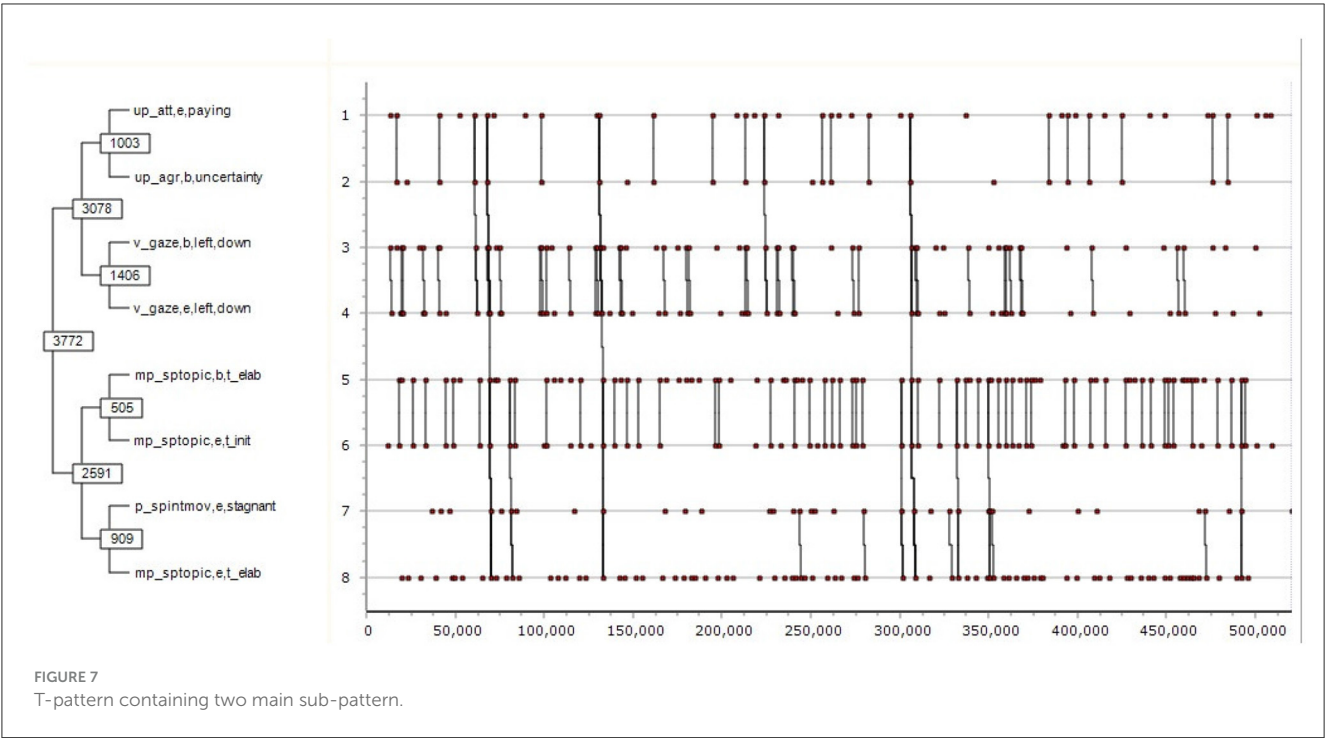
12 <https://huggingface.co/openai/whisper-large-v3>

13 <https://github.com/szekrenyesi/prosotool>



(level 1); then it associates pattern1 with either an event or another first level pattern such as pattern1 to produce pattern2 (level 2), then it continues recursively to the next higher level as long as it finds events or patterns to form a yet more complex pattern. In their graphical scheme, Figures 5–7 represent the same pattern hierarchy found in the form of bracketing in the examples (1) through (3), with the vertical axis standing for the relative time of the constituting sub-patterns, whereas the horizontal axis standing

for the absolute time of the recording. The vertical connected lines show that the complex patterns in (3) and (4) only occur three times each, whereas their sub-patterns have more frequent occurrences. The numbers in the boxes stand for Theme-internal IDs of patterns, whereas green boxes indicate a sub-pattern to have the function of a marker in relation to the next connected sub-pattern. As such, in the case of Figure 5 [also: example (1)] the first half of the complex pattern made of certain emotional,



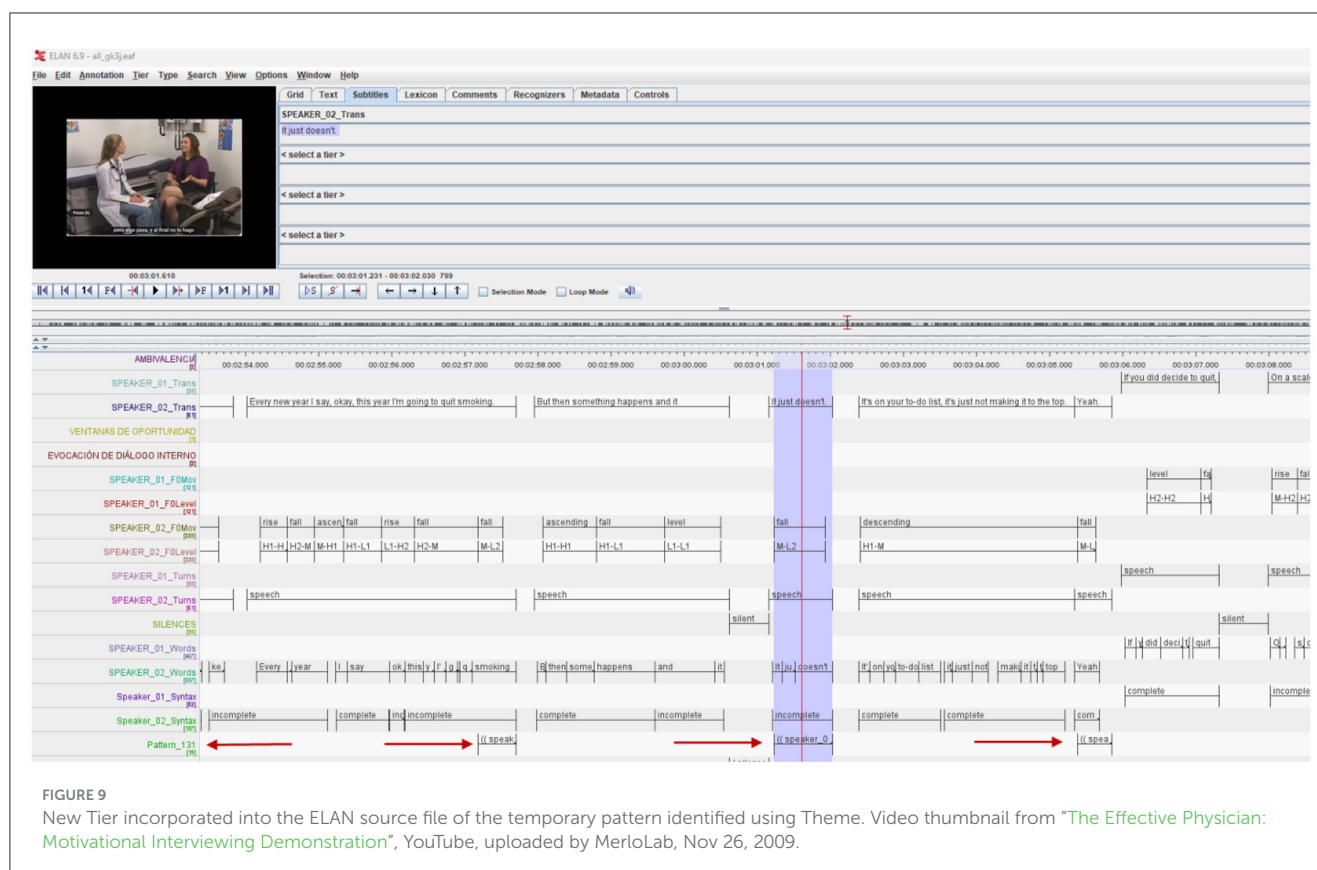
attitudinal and conversational events serves as a marker statistically predicting the occurrences of its second half made of certain prosodic events.

10 Analysis of representative sequences in ELAN

The temporal patterns formed by different types of events that occur over time (textual, paralinguistic, kinesic, or pragmatic annotations, as well as the coding system applied to the interventions of the client and the professional) will be able to be recovered, and in their case, explored in depth qualitatively thanks to the creation (Szekrényes, 2019) of a database that allows exchange between Theme and ELAN formats (see Figure 8).

Finally, we can recover the conversation sequences of the different examples of temporal patterns to explore them with ELAN, incorporating them as a new Tier in the original ELAN file to review them in the context of the recording of the session and the rest of the annotations made in it.

As we can see in Figure 9, from the searches for temporal patterns, we have selected certain patterns that were significant and included incomplete sentences, as defined in the HuComTech project, and we have been able to open the examples of that pattern in a new Tier created in Elan, (in the image below “Pattern_131”) that we can review again in the context of the rest of the annotations and the video with the session in which the temporal pattern is found. As we can see indicated by the red arrows, annotations have been generated in Elan in the recording that exemplify the



temporal pattern detected with Theme, and which can be reviewed and analyzed qualitatively taking into account their context with the rest of the annotations.

11 Discussion

In this article we have presented a proposal for the creation of a technological infrastructure that serves as a basis for the implementation of a therapeutic communication laboratory that assumes a mixed methods perspective that combines methodological rigor and the facilitation of collaboration between psychotherapy practitioners, researchers, and theoretical intervention models.

The incorporation of Theme (temporal pattern analysis algorithms) in Qual-Quant-Quan processes is especially important given the sequential nature of the conversation, which is the object of observation and analysis of the intervention in psychotherapy. The double back-and-forth movement between Elan and Theme that we have shown how it works based on an example of a motivational interview and the project HuComTech enhances this integration of qualitative and quantitative moments of analysis, mutually fertilizing each other.

It is worth highlighting the importance of the incorporation of automated transcriptions with artificial intelligence in Elan, and the incorporation of an automated procedure for labeling intonation and prosodic features, which is so important when generating different effects of meaning and constructing shared meanings in the conversation process.

The automation procedures that we have shown in the article make it possible to put into practice what we have called “reflective professional practice” based on observation. One of the most important impediments for psychotherapy professionals and, in general, helping professionals, to use this methodology of learning and professional improvement is the time spent preparing and accessing the most significant parts of the recordings. With this system, this handicap is overcome since these are semi-automated processes that facilitate the exploration of the sessions in a fast and operational way. Based on the infrastructure that we have described, we can work in collaboration with different groups of professionals to incorporate this methodology in their training, supervision and participation processes in research projects following this mixed methods perspective. In this way, we propose the generation of a knowledge base in which the needs of different groups of professionals can be easily incorporated into the labeling that we can add. Elan allows us to consider the different dimensions of multimodal communication, together with the labeling of the different modalities of professional intervention that can be added *ad hoc* after a qualitative analysis, but at the same time, can be systematized.

The automation of the annotation processes, up to now, the incorporation of orthographic and phonetic transcriptions, with the diarisation of speaking turns, as well as the temporal segmentation of words, allows new developments for the automatic addition of labels referring to the textual component. Thus, for example, we will be able to automatically label the terms that fall into the semantic domain of what in motivational interviewing has been related to the language of change: Desire, Ability, Reasons and

Need. With the advances in computational linguistics, we can add the semantic domains of the different forms of discourse of change to automatically label them and analyze them in the temporal patterns in which they are distributed.

A wide range of possibilities for use is opened up by using this methodology:

Firstly, to advance in the automation of the automated labeling and the integration of the different multimodal components (textual, phonetic, or gestural) components function in the generation of meaning effects of therapeutic communication: formulations, the power of questions, and speaking turns in the context of the labeling of conversational sequences that are broader than adjacency pairs.

Secondly, to generate *ad hoc* annotation systems created by the professionals themselves based on their own problems and needs that arise in their daily practice, which, on the one hand, make use of the facilities of automated labeling that, with artificial intelligence, we can incorporate into observation instruments, to which they can add their own *ad hoc* annotations.

A wide range of possibilities opens up by implementing the methodology we propose. In the case of motivational interviewing or other therapies such as EMDR, it can be applied to the coding and evaluation systems of the application of the model as well as the identification of the different modalities of the discourse of change on the part of the client, and it can be analyzed from this interactional and mixed methods perspective, being useful not only to advance the proposals of the theoretical model but also in the learning, teaching, and supervision methodologies of the professionals who use it.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions. The article is not a research paper, focus is on methods and merging available research tools. Requests to access these datasets should be directed to info@pacomolinero.net.

Ethics statement

Ethical approval and written informed consent were not required, in accordance with the local legislation and institutional requirements.

Author contributions

FM: Writing – original draft, Writing – review & editing. GJ: Writing – original draft, Writing – review & editing. MA: Writing – original draft, Writing – review & editing. LH: Writing – original draft, Writing – review & editing. IS: Writing – original draft, Writing – review & editing.

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In memoriam

We would like to dedicate this manuscript to our loving friend and coauthor Pr. M. Teresa Anguera, who passed away on January 19th, 2025. She was not only a remarkable professional but also a source of inspiration and guidance to so many of us. Her wisdom, kindness and dedication left an indelible mark on the broader research community. We have lost not just a colleague but a friend, mentor, and role model who will be deeply missed by all who knew them. Teresa impact will not be forgotten, and her legacy will live on in the work we do and the memories we hold dear.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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Corrigendum: Therapeutic communication laboratory: integrating mixed methods with digital tools and reflective professional practice

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The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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