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Women in performance science

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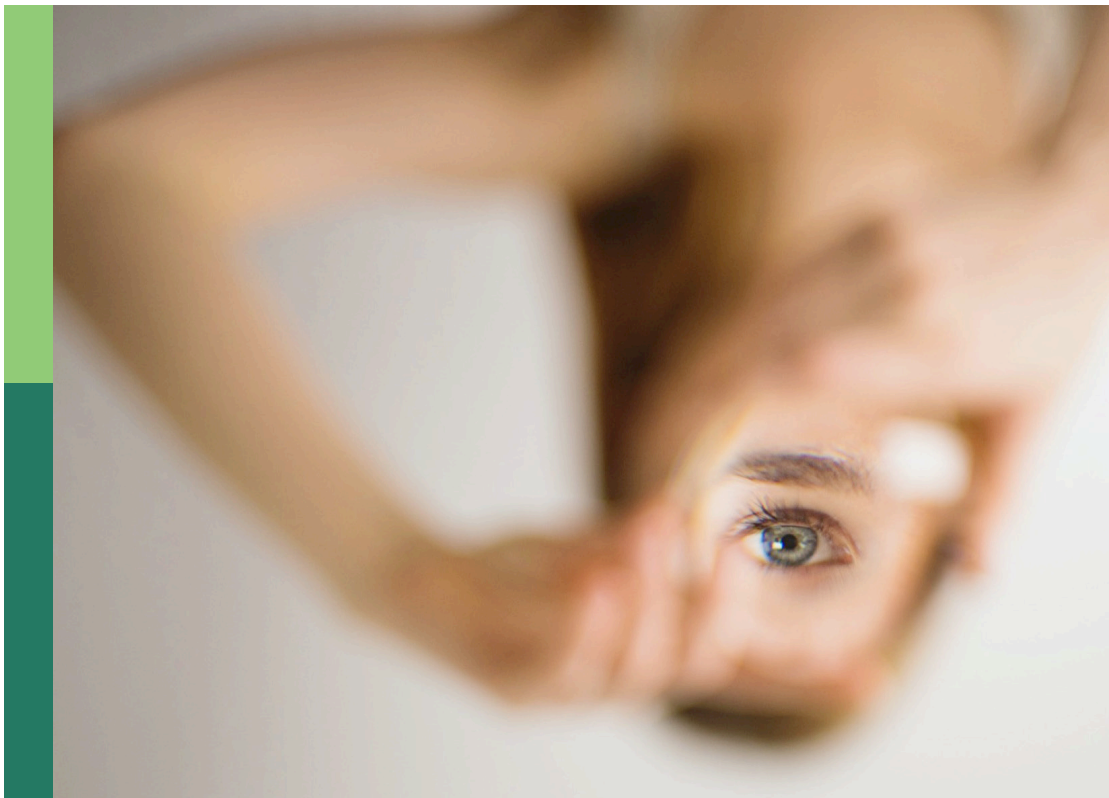

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Women in performance science

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Editorial: Women in performance science

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Editorial on the Research Topic
Women in performance science

We are delighted to present the Research Topic "*Women in Performance Science*" as a platform to promote the work of women scientists in the field of performance science. Women constitute only a minority of global researchers (UNESCO Institute for Statistics, 2020). This disparity stems from the persistent biases and gender stereotypes that dissuade women from pursuing science. Hence, this Research Topic has been launched to showcase women scientists' research across all sub-fields of performance science. Under this Research Topic, we have published 10 articles written by 31 authors from Australia, Canada, Japan, Portugal, the United Kingdom, and the United States. These articles include seven original research articles, two brief research reports, and a systematic review, encompassing diverse academic approaches, including pedagogy, psychology, physiology, and acoustics. A summary of each article is presented below.

Fujimoto and Uesaka examined how learning experiences can either promote or impede interpretive autonomy, and how this, in turn, influences the learning behaviors and wellbeing of eight elite piano and violin students. *Werktreue* internalization served as an analytical framework for the interview data, and its alignment with the self-determination theory emerged through the analysis. The findings suggested that interpretive autonomy fosters self-regulated learning and supports students' wellbeing. Furthermore, this study highlights that nurturing autonomy is essential from the earliest stages of music learning.

Goh et al. investigated gender marginalization within the Australian jazz and improvisation industries. Using a quantitative survey of 124 practitioners, they analyzed how symbolic boundaries reinforce male hegemony. Findings revealed that gender diverse individuals experience the most severe exclusion, while women report distinct challenges regarding work opportunities. Furthermore, awareness of sexual harassment was widespread across all genders. These results underscore the critical need for targeted inclusion strategies and enhanced safety measures to dismantle structural inequities.

Kondo et al. investigated the aspects of opera singing that influence overall performance evaluations by expert judges. They asked four experts to rate the performances of "Caro mio ben" by 10 trained female singers. Acoustic features such as singing power ratio and harmonic-to-noise ratio were also calculated. Consequently,

the subjective rating of vibrato and the objective measurement of singing power ratio emerged as significant predictors of the overall performance score. This study contributes to elucidating the perceptual mechanisms underlying expert evaluations of opera singing.

Moura et al. reviewed solo music performance assessment systems, examining across instruments, rating methods, and target audiences. They highlighted the importance of the context, assessment purpose, and institutional culture, noting that both general and instrument-oriented methods can work effectively. Given that technique strongly shapes performance quality and expression, its weighting in assessment requires careful consideration. A shift from qualitative scales to detailed rubrics can improve the feedback for examiners and students. Finally, tailoring assessment tools for beginner, intermediate, and advanced students is important.

Perrier et al. examined the wellbeing of 16 professional female musicians using the self-determination theory. Participants reported mostly positive effects of being a musician, with autonomy and everyday experiences of mastery strongly supporting wellbeing. Lack of control and limited practice time created stress and reduced feelings of competence. Balancing work and life, especially decisions about having children, was a major challenge. Musicians developed resilience through self-compassion, organizational skills, and maintenance of focus. A deep love for music and transcendent performance experiences provided profound emotional and psychological satisfaction.

Sayers investigated pedagogical strategies for improvisation in North Indian classical music. Using audio-visual analyses of lessons in India, this study examined how oral transmission facilitates skill acquisition. Rather than being spontaneous, improvisation developed through the rigorous imitation and memorization of structured sequences, where "inexact replication" eventually fostered creative recomposition. These results underscore the cognitive sophistication of oral traditions, demonstrating that memory and implicit learning are fundamental for developing musical competence in non-notated systems.

Stephens-Himonides and Young investigated teacher identity within the Technological Pedagogical Content Knowledge (TPACK) framework. Through a case study of an experienced female music educator, they examined how personal background intersects with technology use in piano instruction. The study revealed that identity significantly shapes pedagogical choices and technology integration. Consequently, the authors argued in favor of extending the TPACK framework to include identity, providing a more holistic approach to supporting technology adoption in education.

Takagi et al. validated the Japanese version of the Kenny Music Performance Anxiety Inventory-Revised (K-MPAI-R). Data were collected from 400 Japanese musicians. An exploratory factor analysis extracted seven factors similar to those of the original scale. The scale demonstrated high internal consistency. Criterion-related validity was confirmed through strong correlations with other anxiety measures. Therefore, the Japanese version of the K-MPAI-R was considered a reliable and valid tool for research on music performance anxiety among Japanese musicians.

Watanabe et al. explored the optimal pre-performance state of professional musicians by examining the impact of memory recall. They asked 36 wind instrument players to recall positive or negative performance memories or imagine routine pre-performance activities. Recalling positive performance memories significantly enhanced subjective performance achievement, emotional arousal, and valence. The results suggested that positive recall fosters sympathetic activation and positive emotions, which collectively enhance performance achievement. This study provided objective evidence of the usefulneess of recalling positive performance experiences for professional musicians.

Yoshie and Morijiri investigated the impact of past and current social support on pre-performance mental states and performance quality among university music students. Students rated the support received from parents, a past teacher, and a current teacher, as well as their pre-performance self-confidence and performance evaluation for a recent major event. Past teacher support uniquely predicted self-confidence and performance quality, suggesting that the teacher support received by middle adolescence is particularly crucial for building student musicians' long-term self-confidence.

In conclusion, the articles within this Research Topic cover diverse topics in performance science, including musicians' wellbeing, pedagogical strategies, performance assessment, and gender equality. We believe that these studies, led by women scientists, will substantially contribute to advancing research in performance science.

Author contributions

MY: Writing – original draft, Writing – review & editing. MV: Writing – original draft, Writing – review & editing. YM: Writing – original draft, Writing – review & editing. JH: Writing – review & editing.

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Beyond the gender binary: a survey of gender marginalization and social boundaries in Australian jazz and improvisation

Talisha Goh[1]*, Cat Hope[1]*†, Louise Devenish[1†], Margaret S. Barrett[1†], Nicole Canham[1†], Robert L. Burke[1†] and Clare Hall[2†]

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Jazz and improvisation have typically been associated with ideals of freedom and liberty; however, in practice these genres are known to be constrained by entrenched patterns of male domination and gender discrimination. Despite a large number of qualitative accounts evidencing persistent sexism and gender exclusion in the field, there exists a lack of empirical data to assess the scale of this phenomenon and substantiate smaller-scale research on gender inequality. In this paper, we employ boundary theory to report on a quantitative investigation of gender marginalization in jazz and improvisation in the Australian context, positioning gender as a symbolic boundary resulting in the social exclusion and marginalization of gender diverse individuals and women. An anonymous survey (n=124) was run over a period of five months, to explore the beliefs, attitudes, and experiences concerning gender, of people participating in Australian jazz and improvisation. A means comparison found that gender was a statistically significant indicator ($p \leq 0.05$) on almost all measures, with gender diverse respondents significantly more likely to report the effects of marginalization than their (cisgender) counterparts. Additionally, the results indicated contrasting forms of musical engagement and marginalization across gender groups, with women perceiving exclusion to a lesser extent than gender diverse practitioners, and differing in their opinions regarding work opportunities. Lastly, a widespread but historically unspoken awareness of sexual harassment in the Australian jazz and improvisation industry was reported by all genders. This paper concludes with three recommendations for future research, policy and practice: 1. Specific targeted strategies are needed to address the manifold and complex forms of marginalization experienced by gender diverse people; 2. Heightened institutional visibility for marginalized groups is needed to change gendered narratives and highlight awareness of inequities; and 3. Enhanced safety measures are critically needed to address sexual harassment throughout the industry.

KEYWORDS

jazz, improvisation, gender, music industry, marginalization, Australia, women, gender diverse

1 Introduction

Jazz and improvisation musical genres are characterized by a spirit of democracy and an ethic of freedom, involving individual and group negotiation of musical boundaries that seem to transcend factors such as race, gender, or social background (Tomlinson, 1991; Monson, 2007; Givan, 2020). However, as we discuss below, growing popular and scholarly discourse and literature recognizes that—far from its equitable and liberating ethos—gender marginalization remains an ongoing and widespread harmful issue for individuals practicing in these genres. This marginalization has been shaped by raced, gendered, and colonialist histories, leaving damaging legacies that can be observed in contemporary practices. For example, jazz and blues histories note that one of the few acceptable means for women's participation in early jazz was as vocalists or "blues women." This legacy continues in present-day gendering of musical roles, where men tend to comprise most jazz instrumentalists, with women primarily engaged as vocalists (Tucker, 2002; Davis, 2011; Kernodle, 2014; Wehr, 2016; Buscatto, 2022a,b; Yuhan, 2024). Competitive forms of virtuosity (such as jazz soloing) and associations between improvisation and masculinity serve as a means of gendered negotiation, and a space to assert a soloist's musicianship and authority (Wong, 2016; Heyman, 2022; Johnson, 2022; Buscatto, 2022a,b; Nicols, 2024). Rustin-Paschal extended this premise in an account of Charles Mingus Jr. through examining how performances of "jazzmasculinity" shaped encounters with multiple figures in his life, explaining that such (black, cisgendered) masculinities were characterized by "expertise, discipline, and the mastery of self, others, and the music," as well as "innovation, collaboration, expertise, and emotionality" and "an ability to nurture" (2017, p. 98, 128). Further, studies of contemporary musicians have emphasized that traits associated with the "jazzman" archetype continue to be performed by musicians of all genders and are still viewed as highly desirable within these communities today (Tucker, 2002; McAndrew and Widdop, 2021; Hall and Burke, 2022). Given its historical background and continuing "troubled relationship with gender" in contemporary practice, the ideals of justice and social equity that purport to distinguish jazz and improvisation from other artforms differ greatly from the cultural reality of these musical practices (Reddan et al., 2022, p. xiv).

This study examines how gender shapes the experiences and perceptions of individuals in Australian jazz and improvisation music industries. The gendered histories and cultures associated with these artforms have positioned masculinity as a symbolic boundary that continues to inform behaviors and attitudes toward individuals in contemporary practice, as well as participation and progression in jazz and improvisation music communities. Symbolic boundaries are determined by markers of socially constructed, in-group identification, that are used as a means of identity and cultural formation, and encompass attributes such as appearance, behaviors and attitudes, and patterns of consumption (Lamont and Molnár, 2002). Jazz and improvisation musicians, for example, might be identified through markers such as authoritative and powerful (cisgender masculine) physicality, extensive knowledge of musical catalogues, use of technical language, ideals of high/loud/fast virtuosity, as well as characteristics of emotional sensitivity, confidence, (hetero)sexual virility, and self-assured "cool" aloofness (Rustin-Paschal, 2017; Teichman, 2020; Boeyink, 2022; Devenish et al., 2024). Although symbolic boundaries are necessarily subjective and context-dependent, Lamont and Molnár argue that they are used to enforce real social boundaries, or the "objectified forms of social differences manifested in unequal access to and unequal distribution of resources (material and nonmaterial) and social opportunities" (2002, p. 168). Symbolic boundaries thus have different impacts upon individuals and groups in society; while they are important components of identity formation and belonging, they are also dependent upon distinctions between "in" and "out" groups, and can be used to enforce and uphold social boundaries through processes of inclusion and exclusion by the dominant or powerful group (Lamont, 2001). In jazz and improvisation, a sphere in which markers of musical credibility are conflated with social constructions of masculinity, internalized symbolic boundaries manifest in the preservation of a gendered social boundary through the exclusion and marginalization of individuals who do not fit into the hegemonic jazzmasculine ideal. Research of these social boundaries in the creative industries has tended to focus on issues of gender visibility and representation, marginalization due to stereotypes, and the gendered inequities within musical workplaces as a subset of the wider creative industries. As we discuss below, this exclusion and marginalization has been evidenced by a plethora of inquiries conducted by academic, government-affiliated, and industry bodies, that affirm a gendered symbolic boundary positioning women and gender diverse individuals as an out-group of Australian music and performing arts industries.

1.1 Representation

In Australian music and performing arts more broadly, imbalances in gender representation have been well documented. Numerous music industry reviews have found that women and gender diverse workers are underrepresented at the highest levels such as board membership or leadership positions, but overrepresented in lower support roles (Banks and Milestone, 2011; Browning, 2016; Cooper et al., 2017; Edmond, 2019). A similar picture has emerged in analyses of musical programming, commissions, and awards (Hope, 2022). In response, various organizations and festivals have taken initiatives to redress the lack of gender diversity, and new initiatives continue to improve diverse visibility (Browning, 2016; Cooper et al., 2017; Raine, 2019; McCormack, 2020; Tenth Muse Initiative, 2022). Although the effectiveness of these schemes in systemically addressing issues of underrepresentation is debated (Edmond, 2019), it is evident that there is high demand for representation; further, diverse representation across the broader Australian music and performing arts industry has great potential to impact jazz, improvisation, and popular music genres, which are highly influenced by commercial and market trends (Raine, 2019; McAndrew and Widdop, 2021). A number of qualitative artistic responses have also addressed this issue, such as saxophonist Cheryl Durongpisitkul's work *A Pinky Promise* (including a movement entitled *Diversity Poster Girl*), performed by the Monash Art Ensemble in 2022. Although gender representation may appear to be a large step toward gender equity, it entails an accompanying increase in responsibility and emotional labor placed upon visible practitioners. Through the appearance of gender parity through representation, masking gender inequities under assumptions of meritocracy thus risks further marginalization of gender diverse and women practitioners in jazz and improvisation (Gill, 2014; Edmond, 2019). That is, without the structural and social changes to support it,

representation alone cannot solve problems of jazzmasculine hegemony and gender exclusion.

1.2 Marginalization

Although there are attempts within the music industries to address issues of representation, some scholars argue that positive discrimination and other strategies to mitigate underrepresentation do little to change marginalizing behaviors that occur as a result of gendered social boundaries, and may unintentionally reinforce them (Gill, 2014; Edmond, 2019). In workplace studies, marginalization "represents the relegation of people (or groups of people) to a less powerful or included position within a society, and experiencing marginalization is a critical barrier to securing decent work" (Duffy et al., 2016, p. 132). A number of studies have focused on the effects of marginalization on individuals who do not fit into the jazzmasculine construct, finding that the gender identity of these outsider individuals tends to take precedence over intellectual and artistic contributions when superficial attempts at inclusion are made by practitioners holding positions of power (Wehr, 2016; Suzuki, 2022). Issues that result from this include tokenism, or the inclusion of "exceptional" women or gender diverse artists in male-dominated canons and repertoire on the condition of conforming to acceptable gender stereotypes such as jazzmasculinity (Tucker, 2002; Wehr, 2016), gendered expectations of labor within and beyond musical groups (Wehr, 2016; Buscatto, 2022a,b), and the devaluation of women and gender diverse musicians' authority, capability, and musical contributions (particularly in the case of jazz vocalists, who tend to be women) (McAndrew and Widdop, 2021; Heyman, 2022; Buscatto, 2022a,b). Research conducted in the Australian scene supports the premise that the instrumental/vocal binary constitutes a gendered symbolic boundary among performers, resulting in gendered forms of marginalization (Hargreaves, 2013; Hargreaves and Forbes, 2022); for example, "vocalists…are often compared negatively to instrumentalists in terms of knowledge and application of jazz theory and musicianship") (Istvandity, 2016, p. 75). Such marginalization serves to reinforce hierarchies of power, such as the objectification of jazzwomen as sex-objects or emotional laborers (Wehr, 2016), the valorization of "real" instrumental musicians, and equivalent assumptions of meritocracy within canons of jazz and improvisation (Whyton, 2010; Edmond, 2019; Buscatto, 2022a). Additional identities and factors—such as family or cultural origin, socio-economic status, disability status, or sexual orientation—also contribute to the individuals' experiences of marginalization, often having a cumulative intersectional effect (Crenshaw, 1989).

1.3 Structural inequities

At a structural level, jazz and improvisation may be viewed as a particular microcosm of the wider creative and cultural industries, as it is characterized by a heavy reliance on formal and informal networks, indistinct boundaries between work and non-work, low remuneration (if any) for long hours of highly-skilled work, precarious modes of employment, and resulting cultures of competition (Gill, 2002). This has accumulated a particular set of inequities less often seen within traditional employment and organizational arrangements, with compounding effects on out-group exclusion and marginalization. For example, long and unpredictable hours are particularly unwelcoming to workers who are not men, as they are expected to take on the bulk of household and caring responsibilities (Banks and Milestone, 2011; Buscatto, 2022a). Further, the industry networks which are a vital means of obtaining job opportunities, tend to be homosocial and exclusionary, leading to the oft-cited "boys club" (Hennekam and Bennett, 2017; Buscatto, 2019). Concerningly, the culture of precarity and competitive individualism has also contributed toward the normalization of sexual violence and harassment within the music and creative industries, as victims risk career or reputational damage for speaking out (Hennekam and Bennett, 2017; Crabtree, 2020; MAPN Consulting and Support Act, 2022). Consequently, "serial perpetrators [of sexual violence and harassment] are often an open secret and are not always held to account" (MAPN Consulting and Support Act, 2022, p. 9). The invisible structures that govern the industries inhabited by musicians make it difficult for individuals to identify and voice instances and experiences of marginalization, leading to the reification of "unspeakable inequalities" within neoliberal cultural and creative spaces, in which "the new laboring subjectivity seems to demand a repudiation of structural inequalities" (Gill, 2014, p. 517).

1.4 Survey rationale

Given the challenges in identifying the specifics involved in gender marginalization and the ambiguities surrounding cultural and creative work, it is not surprising that rigorous quantitative investigations into the subject have been scarce. Due in large part to a lack of funding or support within institutional contexts, the few English-language academic articles dedicated to gender issues in jazz and improvisation have tended to be one-off unfunded investigations conducted by lone early-career women, many of whom had experienced gender marginalization as practitioners themselves (Canham et al., 2022). This sporadic interest in minimizing gender marginalization's effects has resulted in difficulties maintaining long-term change in Australian music industries (Edmond, 2019). Although many studies of the Australian music and greater performing arts industries have explored gender marginalization in terms of descriptive statistics, inferential investigations are needed to determine the scope of the problem, identify the most pressing issues, and the groups that experience them. Our survey represents the only quantitative investigation of gender marginalization in Australian jazz and improvisation to date that we are aware of, and so presents a unique opportunity to bridge gaps between academic and industry investigations and inform policy in the area, which is often dependent upon statistical investigations. In turn, this will aid in galvanizing the industry from tacit awareness of the issue to meaningful action. This survey aimed to identify gendered perceptions of marginalization by taking an exploratory statistical approach to determine if factors of age, educational attainment, and ancestry might also be predictors. Although we view gender as a symbolic boundary influencing in and out-groups in jazz and improvisation, we considered it important to address the experiences of those who identify beyond the gender binary, who remain an under-researched group in wider workplace studies (McFadden and Crowley-Henry, 2016).

2 Materials and methods

This survey aimed to identify gendered perceptions of marginalization through an exploratory statistical approach, considering factors such as age, educational attainment, and ancestry. As there are many ways in which symbolic boundaries contribute to marginalization of out-group individuals, the survey design drew on intersectional feminist theories to address equality through democratic artistry and feminist musicology (McClary, 1991; Citron, 1993; Green, 1997). Marginalization impacts people differently according to the intersection of other structural inequalities, such as sexuality, race, ethnicity, class, age, and geography (Crenshaw, 1989; Hooks, 2015). A key component of the survey's conceptualization, structure, and questions were the authors' lived experiences and expertise as musicians and researchers in jazz, improvisation, and performing arts, particularly as most of the research team identified as members of the gender out-group. Additionally, the research team spanned a diverse range of career stages, means of artistic engagement, and industry experience, with specialist knowledge in fields such as gender studies, career counseling, musicology, sociology, narrative inquiry, music education, and artistic research methods. These knowledges were considered throughout the formulation of the survey; for example, the statements discussed in the Results section were shaped by Authors 2, 3, 5, and 6's status as active practitioners in jazz, improvisation, new, and Western art music. As well as assessing its positionality, the team was mindful of the disruptive impacts of the COVID-19 pandemic on the Australian performing artists at the time of survey development, and questions were included where theory and literature pointed to a likelihood of possibility, such as in the case of sexual harassment (Hennekam and Bennett, 2017; Crabtree, 2020).

Using the Qualtrics platform, an initial pool of over 60 items was generated by the research team over a period of 4 months. This was reduced and condensed in line with survey research that recommends a maximum completion time of 20 min, the estimated average attention span for adults (Revilla and Ochoa, 2017). In total, 45 questions were used in the sector survey. The survey included 7 overarching sections, as follows:

> Part 1: Explanatory Statement and Consent form (1 question)
> Part 2: Tell us about yourself (8 questions)
> Part 3: Education and training (7 questions)
> Part 4: Practice (8 questions)
> Part 5: Engagement with jazz and improvisation (13 questions)
> Part 6: Motivations and gendered experiences (7 questions)
> Part 7: Follow up and contact details (1 question)

Of the 7 sections, Parts 4–6 contain questions generated specifically for this survey with the remaining items covering demographic or background information. Feedback was sought from expert reviewers in the field to ensure the appropriateness of items and choice of tick-box answers, leading to several iterations of the questionnaire before it was sent out. Most questions (39 of 45) could be answered quickly, utilizing a multiple-choice, tick-box, drop-down selection, sliding-scale, or 5-point Likert scale format, and an open-ended "other" response was offered if the respondent did not identify with any of the categories suggested. Three questions required short 1–2 word typed responses, and three required larger open-ended responses. All questions were optional, meaning that respondents could proceed to the next question without answering. Under half (18) were governed by conditional logic, relying on the provision of a previous answer to show. For our purposes, and given that women and gender diverse musicians face challenges in accessing jazz and improvisation in a professional capacity (Buscatto, 2022a), the surveys were aimed at those who engage with the industry in any capacity, working from a model of inclusion rather than exclusion. This was reflected in the format and wording of our survey questions; for example, we asked participants to describe their artistic identities rather than limiting them to tick-box categories.

The survey was open for a period of 5 months from November 2021 to April 2022. Key industry bodies from around Australia, each with a large practitioner subscription database, were approached to distribute the survey URL in their mail-outs or newsletters. Musicians and workers known to the researchers were also contacted to spread the survey link within their networks, comprising a snowball sample. As an ethical consideration, a list of mental health and gender-specific support services was supplied to all respondents before commencing the survey in case they experienced any distress answering the questions. Participants were also given contact information for the research team to voice any questions or concerns, and informed that they could withdraw themselves and their data from the research at any time.

2.1 Data analysis

A series of mean comparisons were conducted for proportions at $p \leq 0.05$ to examine whether factors of education level, age, ancestry, and gender played a role in motivations, participation, perceptions, and experiences in jazz and improvisation. In the Results section below, we report the significant findings from the survey questions relating to perceptions and experiences of marginalization.

3 Results

3.1 Demographic profile of final sample

Overall, a total of 184 responses were gathered; with 129 responses completed sufficiently for inclusion in the final analysis. Of these, five did not provide information about their gender identity. The following data analysis pertains to the final sample of 124 responses.

In alignment with our gender-inclusive practices and our own theoretical framework, respondents were offered an open-ended text box to describe their gender identity, rather than choosing from limiting and prescriptive categories (Barclay and Russell, 2017; Australia Council for the Arts, 2021; Lindqvist et al., 2021; Victoria State Government, 2021). The analysis (Table 1) divided self-described gender identities into 3 broad groups: Women, Men, and Non Binary/Gender Diverse (Cameron and Stinson, 2019). "Women" incorporated responses of "female," "cis woman," and "she/her," while the "Men" categorization incorporated responses of "male," "cis man," and "he/him." Due to the small sample size of the Non Binary and Gender Diverse groups, it was necessary to merge these groups for statistical analysis; this amalgamated group (referred to as "Gender Diverse" throughout this paper) included responses of "Female/Non Binary," "Male/Non Binary," "Transgender woman," "Transgender man," and

TABLE 1 Demographic characteristics of respondents.

		Women *n* (% of total)	Men *n* (% of total)	Gender Diverse *n* (% of total)	Total *n* (%)
Gender identity		57 (46.0)	56 (45.2)	11 (8.9)	124 (100)
Age					
	18–29	20 (16.1)	10 (8.1)	4 (3.2)	34 (27.4)
	30–49	22 (17.7)	23 (18.5)	5 (4.0)	50 (40.3)
	50+	15 (12.1)	23 (18.5)	2 (1.6)	40 (32.3)
	Total	57 (46.0)	56(45.2)	11 (8.9)	124 (100)
Ancestry					
	Identifies Australian or British ancestry	45 (36.3)	46 (37.1)	9 (7.3)	100 (80.6)
	Does not identify Australian or British ancestry	12 (9.7)	10 (8.1)	2 (1.6)	24 (19.4)
	Total	57 (46.0)	56(45.2)	11 (8.9)	124 (100)
Educational attainment					
	High school	3 (2.4)	7 (5.6)	1 (0.8)	11 (8.8)
	Certificate, Diploma or other post-secondary certification	4 (3.2)	0 (0.0)	0 (0.0)	4 (3.2)
	Bachelor	12 (9.7)	7 (5.6)	2 (1.6)	21 (16.9)
	Bachelor (Honors)	4 (3.2)	6 (4.8)	0 (0.0)	19 (15.3)
	Graduate diploma or other graduate certification	7 (5.6)	11 (8.9)	1 (0.8)	10 (8.1)
	Masters	10 (8.1)	14 (11.3)	3 (2.4)	27 (21.8)
	Doctorate	12 (9.7)	10 (8.1)	3 (2.4)	25 (20.2)
	Not stated	5 (4.0)	1 (0.8)	1 (0.8)	7 (5.6)
	Total	57 (46.0)	56 (45.2)	11 (8.9)	124 (100)

"Genderfluid." Of the 124 analyzed responses, 46.0% identified as women, 45.2% identified as men, and 8.9% identified as non-binary or gender diverse. While we acknowledge that our sample may not be representative of the gender makeup of the industry, we note there is no accurate information about that makeup currently available. Further, given that women and gender diverse practitioners tend to understate or underestimate their participation in the professional artistic workforce (Conor et al., 2015; Scharff, 2015; Buscatto, 2022a,b), we argue that incorporating all levels of participation (including self-identified "non-professionals") provides a more accurate picture of gendered engagement in Australian jazz and improvisation.

Participants represented a range of ages, with just over a quarter (27.4%) from 18 to 29 years, 40.3% from 30 to 49 years, and almost a third (32.3%) over 50 years of age. Most were Australian born (84.7%), only spoke English (89.5%), and reported Australian or British ancestry (80.6%). Our sample also contained a high proportion of university-educated respondents, with postgraduate qualifications highly represented (Doctorate 20.2%; Masters 21.8%; Honors, Graduate Certificate, or Diploma 23.4%; Bachelor 16.9%). The remainder (12.1%) indicated they had completed high school with or without a further post-secondary certificate or diploma. By contrast, only half (51.6%) of respondents indicated that at least one of their parents had studied at university. Although respondents lived across Australia, many of our final sample were based in Victoria, despite considerable efforts to garner interest in the survey Australia wide through relevant contacts (Figure 1).

A broad range of musical practices within and around jazz and improvisation genres were indicated throughout the sample (Table 2). Respondents tended to have extensive musical experience (23.4% practicing for over 41 years, 25.8% 31–40 years, 21.8% 21–30 years; 25.8% 11–20 years; and 3.2% less than 10 years), specifically in jazz and improvisation (37.9% practicing more than 21 years since age 18, 23.4% 11–20 years, 17.7% 6–10 years; and 20.2% less than 5 years). More than half (51.6%) of respondents primarily practiced within jazz genres, encompassing styles such as bebop, modern jazz, and contemporary jazz (mean 42.7%, st. dev 29.5). Improvisational genres (including experimental and fusion) were the primary genre practiced by a quarter of respondents (26.6%, mean 28.1%, st. dev 24.3), alongside around a third based in other genres (including classical and pop) (30.6%, mean 29.2, st. dev 24.5).

3.2 Experiences in the workplace

Perceptions of experiences were assessed using a 4-point Likert scale of agreement to a series of statements on working in jazz and improvisation. With regard to the way the respondents were treated within jazz and improvisation communities, gender played a significant factor in all cases. Men almost universally agreed that they felt respected (100%), valued (98.1%), equally considered in terms of artistic input (94.3%), adequately recognized (88.7%), and safe (98.1%) (Table 3). Women were also likely to somewhat or strongly agree with these statements, but to a lesser extent (feeling respected 93.9%; valued 89.8%, equally considered artistically 77.6%; recognized 81.6%; safe 91.8%). Gender diverse respondents were the least likely to agree to all statements, with only 60% feeling

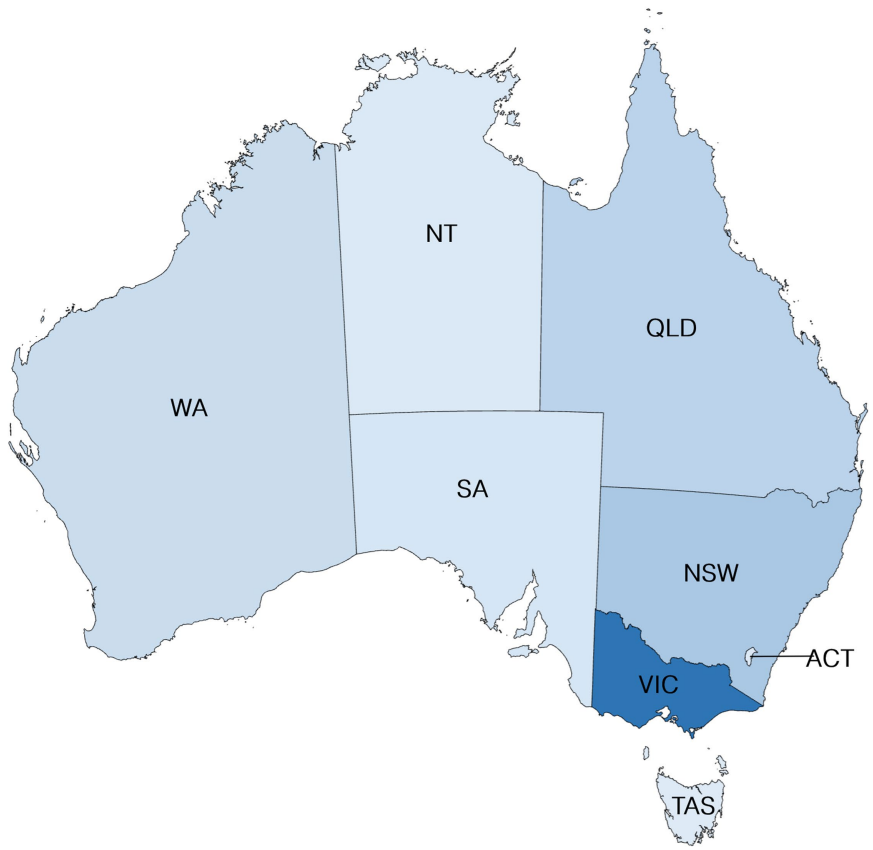

FIGURE 1
Geographical distribution of respondents.

respected and 70% feeling valued by colleagues. Less than half felt their input was equally considered (40%), that they were adequately recognized (40%), or safe (44.4%) in their current workplaces. Concerningly, the gender diverse group was significantly more likely to report different experiences compared to the other two gender groups ($p \leq 0.001$ in all cases).

In addition to gender identity, age was found to have a significant impact on perceptions of working in the industry in general, with older respondents feeling more respected (100.0%, $p \leq 0.05$) and safe (100.0%, $p \leq 0.001$) than 30–49 (respected 91.3%; safe 87.0%) and under-29 age groups (respected 90.0%; safe 86.2%). Overall, however, age was less likely to affect these perceptions than gender. Educational attainment and ancestry did not have an observable effect on these responses.

3.3 Perceptions of equality and diversity

As with the reported experiences working in the industry, gender identity was found to have a significant effect on overall perceptions of equality and diversity throughout the industry (Table 3). Over half of men surveyed perceived diverse representation in the projects they worked on, and less than half of women and gender diverse respondents did (men 58.5%; women 38.8%, gender diverse 30.0%; $p \leq 0.005$). Similarly, male-identifying respondents tended to have a more favorable outlook on the way others were treated in the workplace, with 84.9% agreeing, compared to 73.5% of women and only 40% of gender diverse respondents ($p \leq 0.001$). Age also had an impact on these perceptions; over-50s perceived more diverse representation (66.7%, $p \leq 0.001$) and equality (86.1%, $p \leq 0.005$) than 30–49 year olds (representation 43.5%; equality 67.4%) and under-29 s (representation 30.0%; equality 76.7%) age groups. No significant effects were found for education and ancestry.

3.4 Factors affecting opportunity

Following on from our previous findings on perceptions of diversity and equality, the factors that respondents thought most affected professional opportunities were also found to vary significantly by gender (Table 4). Respondents were asked to check three factors they felt most affected professional opportunities in jazz and improvisation from a range of possible demographic and social factors. Men and gender-diverse practitioners were more likely to look toward others as important determinants of opportunity, sharing the three most cited factors of networks, standards of expertise, and personal relationships. Women, on the other hand, recognized the role of outside roles and responsibilities, citing this factor over personal relationships, though this was not statistically significant (33.3% for outside roles versus 28.1% for relationships). Women were, however,

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TABLE 2 Basis of practice.

		Women *n* (% of total)	Men *n* (% of total)	Gender diverse *n* (% of total)	Total *n* (%)
Years of musical practice (any genre)					
	0–10	2 (1.6)	2 (1.6)	0 (0.0)	4 (3.2)
	11–20	19 (15.3)	10 (8.1)	3 (2.4)	32 (25.8)
	21–30	11 (8.9)	11 (8.9)	5 (4.0)	27 (21.8)
	31–40	15 (12.1)	15 (12.1)	2 (1.6)	32 (25.8)
	41+	10 (8.1)	18 (14.5)	1 (0.8)	29 (23.4)
	Total	57 (46.0)	56 (45.2)	11 (8.9)	124 (100)
Years in jazz and improvisation practice (since age 18)					
	5 or less	17 (13.8)	6 (4.9)	2 (1.6)	25 (20.2)
	6–10	10 (8.1)	8 (6.5)	4 (3.3)	22 (17.7)
	11–20	13 (10.6)	12 (9.8)	4 (3.3)	29 (23.4)
	21+	17 (13.8)	29 (23.6)	1 (0.8)	47 (37.9)
	No response		1 (0.8)		1 (0.8)
	Total	57 (46.0)	56 (45.2)	11 (8.9)	124 (100)
Primary genre practiced*					
	Jazz	28 (22.6)	33 (26.6)	3 (2.4)	64 (51.6)
	Improvisation	14 (11.3)	14 (11.3)	5 (4.0)	33 (26.6)
	Other genres	20 (16.1)	15 (12.0.1)	3 (2.4)	38 (30.6)
Artistic identity*					
	Jazz musician	22 (17.7)	27 (21.8)	5 (4.0)	54 (43.5)
	Improviser	22 (17.7)	25 (20.2)	1 (0.8)	48 (38.7)
	Performer (other)	17 (13.7)	10 (8.1)	3 (2.4)	30 (24.2)
	Instrumentalist	8 (6.4)	6 (4.8)	1 (0.8)	15 (12.1)
	Vocalist	9 (7.3)	2 (1.6)	0 (0.0)	11 (8.9)
	Composer/ Songwriter/Arranger	13 (10.5)	12 (9.7)	2 (1.6)	27 (21.8)
	Other artistic identity	7 (5.6)	10 (8.1)	2 (1.6)	19 (15.3)
	No response	2 (1.6)	–	–	2 (1.6)

*Respondents were able to identify with one or more categories, hence totals do not equal 100%.

significantly less likely to attribute socio-economic factors to professional opportunities compared to the other two groups (women 5.3%; gender diverse 27.3%; men 17.9%; $p \leq 0.05$). Age, education, and ancestry were not found to have significant effects on these responses.

3.5 Inclusion, exclusion, sexual abuse, and safety

General experiences and overall perceptions of the industry were assessed using a 4-point agreement scale to a series of statements regarding inclusion, sexual abuse, and safety (Table 5). While most male-identifying respondents felt respected (94.3%), only three-quarters of women and gender diverse respondents did so (women 79.2%; gender diverse 75.0%). Similarly, men were more likely to feel included (92.5%) than women (62.5%) and gender diverse (50.0%) respondents. These findings were statistically significant ($p \leq 0.05$ for respect; $p \leq 0.001$ for inclusion).

Experiencing or witnessing sexual harassment and abuse was common throughout the industry, with three quarters (75.0%) of women and gender diverse respondents, and more than half (64.2%) of men, seeing or hearing of instances. Alarmingly, almost a third of women (31.3%) and half of gender diverse (50.0%) respondents had experienced sexual abuse or harassment themselves, and this experience was not reported by any men (0%, $p \leq 0.001$). Accompanying this finding, women and gender diverse groups were significantly more likely to feel unsafe because of their gender than men (women 27.7%; gender diverse 75.0%; men 0%; $p \leq 0.001$). Gender diverse practitioners were also significantly more likely to feel unsafe due to factors beyond gender when compared to men and women (gender diverse 50.0%; women 16.7%; men 9.4%, $p \leq 0.005$). Additionally, three quarters of gender diverse respondents felt uncomfortable because of their gender, compared to less than half of women and men (gender diverse 75.0%; women 43.8%; men 18.9%; $p \leq 0.005$). Age, educational attainment, and ancestry were not found to have significant effects on these perceptions.

TABLE 3 Experiences when working in ensembles, projects, and gigs in jazz and/or improvisation ($n = 112$).

	Somewhat/Strongly agree		
Currently, when working in ensembles, projects, and gigs in jazz and improvisation:	Women $n = 49$	Men $n = 53$	Gender diverse = 10
I am treated with respect	93.9%$_a$	100.0%$_a$	60.0%$_b$
People of many different backgrounds are represented	38.8%$_a$	58.5%$_b$	30.0%$_{a,b}$
I am valued by the ensembles and projects I participate in	89.8%$_{a,b}$	98.1%$_b$	70.0%$_a$
My artistic input is considered equally with all other members	77.6%$_a$	94.3%$_b$	40.0%$_c$
I receive adequate recognition for my input	81.6%$_a$	88.7%$_a$	40.0%$_b$
People are treated equally and fairly	73.5%$_a$	84.9%$_a$	40.0%$_b$
I feel safe	91.8%$_a$	98.1%$_a$	44.4%$_b$

Differing lettered subscripts denote significant differences in gender identity groups selecting a given factor at the 0.05 level.

TABLE 4 Most important factors (in top three) impacting professional opportunities in jazz and improvisation ($n = 124$).

	Gender Identity of Participant		
What are the top three factors you think most affect professional opportunities in jazz and improvisation?	Women $n = 57$	Men $n = 56$	Gender diverse $n = 11$
Age	10.5%	10.7%	9.1%
Socio-economic background	5.3%$_a$	17.9%$_b$	27.3%$_b$
Gender identity	15.8%	7.1%	18.2%
Ancestry / Cultural background	3.5%	3.6%	0.0%
Geographic background	5.3%	8.9%	9.1%
Sexuality	7.0%	1.8%	9.1%
Training institution attended	21.1%	30.4%	18.2%
Roles and responsibilities outside of jazz and improvisation	33.3%	21.4%	9.1%
Networks and associations with other people	59.6%$_{a,b}$	69.6%$_b$	36.4%$_a$
Standards of expertise	50.9%	60.7%	36.4%
Personal relationships	28.1%	35.7%	36.4%
Other	12.3%	16.1%	9.1%

Differing lettered subscripts denote significant differences in gender identity groups selecting a given factor at the 0.05 level.

4 Discussion

This study explores the perceptions and experiences of individuals who participate in contemporary Australian jazz and improvisation, examining data along the axes of gender identity, age, educational attainment, and ancestry. In any social setting, symbolic boundaries are meaningful constructions in determining the collective interests, identity, and values of a group. Our study supports the premise that symbolic boundaries can "play an important role in the creation of inequality and exercise of power" through persistent marginalization of individuals who do not fit with in-group markers (Lamont et al., 2015, p. 850). This study provides statistical evidence for perceptions of marginalization on the basis of gender identity, demonstrating some ways in which gendered symbolic boundaries contribute to the exclusion of less powerful out-groups in jazz and improvisation. Further, the data analysis suggests that both gender out-groups experience and view marginalization in different ways, while their gender in-group colleagues report more respectful and inclusive perceptions of their contributions, and more optimistic views of many aspects of their experiences of the industry. For example, women were most likely to see outside roles and responsibilities as having an effect on professional opportunities, and gender diverse respondents were least likely to view networks in this way. The "double-status" of women, as part of the cisgender in-group and the non-male out-group, was reflected throughout their responses, as their reports of marginalization tended to fall somewhere between that of men (as a double in-group) and gender diverse respondents (a double out-group). Interestingly, no statistically significant differences were reported between ancestry groups or levels of educational attainment, with age being a predictor of perceptions of safety and respect to a small degree. Although a number of differences were found between the gender groups of this study, it should be noted that the same size of our survey (57 women, 56 men, and 11 gender diverse respondents) may limit the generalizability of the findings, and further large-scale investigations may expand on the recommendations below. Here, we contextualize three major findings of our survey, with recommendations for how these can inform future research policy and practice in Australian jazz and improvisation.

TABLE 5 Experiences in participation in the jazz and/or improvisation ($n = 109$).

	Somewhat or Strongly agree		
When participating in jazz and improvisation in general:	Women ($n = 48$)	Men ($n = 53$)	Gender diverse ($n = 8$)
I am treated with respect	$79.2\%_{a}$	$94.3\%_{b}$	$75.0\%_{a,b}$
I feel uncomfortable because of my gender	$43.8\%_{a}$	$18.9\%_{b}$	$75.0\%_{a}$
I feel I am included	$62.5\%_{a}$	$92.5\%_{b}$	$50.0\%_{a}$
I experience sexual abuse or harassment	$31.3\%_{a}$	$0.0\%_{b}$	$50.0\%_{a}$
I have witnessed or heard of others experiencing sexual harassment	75.0%	64.2%	75.0%
I feel unsafe because of my gender	$27.7\%_{a}$	$0.0\%_{b}$	$75.0\%_{c}$
I feel unsafe because of factors beyond my gender	$16.7\%_{a}$	$9.4\%_{a}$	$50.0\%_{b}$
My sense of safety affects the jobs/gigs I choose to do	$37.5\%_{a}$	$13.2\%_{b}$	$100.0\%_{c}$

Differing lettered subscripts denote significant differences in gender identity groups selecting a given factor at the 0.05 level.

4.1 Recommendation 1: Deeper understandings and targeted support for gender diverse practitioners

Our findings point to the multifarious ways in which gender diverse individuals are marginalized throughout greater society. Our data suggests that symbolic markers of masculinity are particularly harmful to gender diverse people in Australian jazz and improvisation. When compared to (cis) women and men, gender diverse respondents had statistically significant differences across perceptions of respect, artistic valuation, and recognition when working in the field, and feelings of respect and inclusion from the industry in general, pointing to the complex and myriad ways that gender diverse individuals experience marginalization in everyday life. These findings align with studies of the broader workplace, which have found that gender diverse individuals face unique stressors beyond being openly gender non-conforming at work, including relational factors (e.g., visibility of gender minorities, inclusion in committees, and available networks), and practical factors (e.g., inclusive language use, availability of gender-neutral toilets and change-rooms, voice-related issues, and bullying and harassment) (Boncori et al., 2019). As part of the wider cultural and creative industries, jazz and improvisation workplaces are also complicated by fluid boundaries between work and non-work contexts as social and work spaces tend to overlap, which can lead to ambiguity regarding appropriate and inappropriate behavior in different contexts (Gill, 2002). Although our sample of gender diverse respondents was relatively small ($n = 11$), this data highlights a need for quantitative research specific to gender diverse groups in the cultural and creative industries more broadly, as they have received relatively little attention in existing research (Canham et al., 2022). Means of mitigating the specific forms of marginalization experienced by our respondents, which are situated among other various complex, compounding, and intersecting forms of oppression across many social contexts, would also benefit greatly from further in-depth investigations.

Beyond experiences and perceptions of exclusion, this study points to some of the effects of marginalization on the ways that gender diverse individuals engage with jazz and improvisation. For example, gender diverse individuals tended to cite socio-economic background as an important factor affecting job opportunities, downplaying the importance of standards of expertise and networks compared to cisgender women and men. This difference suggests that economic factors may remain a central limiting factor in gender diverse individuals' engagement in jazz and improvisation; aligning with findings that show almost a third of LGBTQIA+ Australians earn less than a living wage and live below the poverty line (Hill et al., 2021, p. 26). Further, this research has found that due to social exclusion, gender diverse Australians may observe and use different strategies to participate musically, such as in the higher attribution of personal relationships in affecting job opportunities. This finding might suggest that inclusive communities are particularly important to gender diverse musicians, as knowledge of which opportunities are available, welcoming, and safe to them remains a primary concern.

Another more worrying effect of marginalization for gender diverse respondents was that less than half currently felt safe when participating in jazz and improvisation in general, with three-quarters specifying that they generally feel unsafe due to their gender, and half due to other factors. This finding reveals that, though there have been recent efforts to improve gender diverse safety and visibility in the industry, such as best-practice recommendations and the creation of guidelines for music venues, there is still much work to be done. Moreover, the very significant differences in perceptions and feelings of safety depending upon gender highlights the urgent need for different forms of education and awareness when it comes to the health and safety of all who work in the industry. We therefore support calls to enhance these safety measures, noting that contexts beyond formal venues and institutions should also be considered (Music Victoria, 2021; Baker, 2023; Goodwin and Vincent, 2023). As a group that experiences lower wellbeing outcomes than cisgender workers altogether (including gay and lesbian workers), the marginalization of gender diverse individuals in music and performing arts has considerable mental health implications that should be accounted for in future research (Hill et al., 2021; Donaghy and Perales, 2022). Intersections between gender and sexual identities, which fell beyond the scope of the current study, present a further site for investigation, as LGBTQIA+ identities have been presented as "a threat to heterosexuality" (Schilt and Westbrook, 2009, p. 442), or a disruption of the prevailing social boundaries that maintain gendered inequities (Madureira, 2012). In line with broader studies of LGBTQIA+ marginalization (Hill et al., 2021), we recommend that targeted strategies to address the specific forms of marginalization experienced

by gender diverse groups are needed within the Australian jazz and improvisation industry to create positive change.

4.2 Recommendation 2: Make invisible groups visible

The data obtained from this survey indicate differing perceptions of equality, diversity and inclusion between gender and age groups, as older groups and men were more inclined to perceive jazz and improvisation as an equal and fair industry, where they felt respected and safe. These findings on inclusion align with prior organizational studies, which have found that those experiencing greater degrees of out-group marginalization are more likely to perceive the workplace as unfair and non inclusive, and that "majority group members are often unaware of, or take for granted, the privileges associated with their status" (Mor Barak et al., 1998, p. 98). While the older age group in the study did not constitute a majority, it should be noted that they tended to skew male, with over half of the 50+ age group identifying as men, and over half of the 18–29 age group identifying as women. We found that those less aware of—or more hesitant to acknowledge—existing inequities were older male respondents, and this is likely tied to their societal privilege and associated cascading advantage overall. This phenomenon may also be explained by the higher degree of in-group power within the industry, as older, male, workers are more likely to hold higher positions within the industry (Browning, 2016), and thus may hold a more privileged status due to seniority and the social hierarchies inherent in jazz and improvisation. Other possible explanations for ambivalence toward gender inequities in jazz and improvisation concern attrition within the older age group, as out-group workers leaving the field causes an increased homogeneity in the older age group (Edmond, 2019), or differences in perception due to age, as more dramatic differences in industry equity and diversity may be viewed across a longer time span. Within their specific working groups, however, women did tend to feel respected, valued, and recognized, such as in all-women jazz big bands or study programs. This may indicate the benefits of smaller-scale cultural change on the ground level, or collaboration strategies that reduce the effects of gender marginalization (Bennett et al., 2019; Edmond, 2019).

On the whole, while the findings show some ways in which marginalization differs between gender diverse people and women, they also highlight different ways in which each group engages with jazz and improvisation as a result of wider structures of marginalization. The data also suggest that gender diversity in the industry decreases as age increases, supporting prior findings that those belonging to out-groups are aware of their exclusion and marginalization, which may motivate them to leave the industry altogether (Browning, 2016; Cooper et al., 2017; Hope, 2022). In line with recommendations from the Australian popular music industry (Edmond, 2019), we recommend that promoting and celebrating less visible groups, through organizational initiatives or otherwise, will help disentangle jazz and improvisation from constructs of jazzmasculinity and its associated symbolic boundaries and spread awareness of various forms of marginalization to in-groups. Ultimately, such work is needed to transform existing gendered social boundaries, decrease attrition of marginalized groups, and diversify the industry for future generations.

4.3 Recommendation 3: Address safety and harassment issues

An alarming finding from the survey was the high prevalence and knowledge of sexual harassment in the industry. In male-dominated or androcentric spheres such as the cultural industries, sexual harassment is known to be widespread and tends to take on particularly insidious forms (Hennekam and Bennett, 2017; Bridges et al., 2020; Raj et al., 2020). The findings suggest that jazz and improvisation are no exception. Almost three quarters of respondents, regardless of gender, knew of others who had been sexually harassed or abused in the industry, and almost a third of women and half of gender diverse respondents reported experiencing abuse or harassment themselves. Contrastingly, zero instances of harassment were reported by surveyed men. The high rates of knowledge and experiences regarding sexual abuse and harassment among the survey cohort substantiates findings that such behavior is rife within the Australian music industries (Crabtree, 2020; Baker, 2023), and supports the premise that instances of harassment and harassers are widely known as an "open secret" (MAPN Consulting and Support Act, 2022, p. 9).

Recent studies of Australian music note that harassing behaviors include sexist comments, offensive remarks, sexual joking or innuendo in banter, unwanted sexual attention, and sexual assault (Crabtree, 2021), and perpetrators include audience members, peers, managers, or those in positions of power in the industry (Crabtree, 2021; Elmes and Knox, 2022, pp. 29–30). Additionally, a potentially worse prevalence of sexual harassment has been identified within the Australian contemporary music industry, with 72% of women, 39% of men, and 85% of "additional gender" practitioners experiencing at least one instance in their careers ($n = 690$) (MAPN Consulting and Support Act, 2022, pp. 31–34). Given the above knowledge and incidence of harassment, and the fact that many musicians (including respondents of this survey) are known to engage in multiple musical genres (Bartleet et al., 2020), it is unsurprising that the gender diverse respondents and women surveyed were significantly less likely to feel safe within the industry overall when compared to men. Additionally, as discussed in Recommendation 1, gender diverse respondents were particularly likely to feel uncomfortable and unsafe due to their gender, citing safety as a major concern in the jobs or projects they engaged in. In a musical landscape where only 15% of artists of any gender feel safe at work all the time (Elmes and Knox, 2022, p. 27) and 80% of victims do not report harassment (Baker, 2023), the data indicate that harassment remains a large component of gender marginalization. Consequently, we recommend that policy and practice initiatives to address safety and sexual harassment be strengthened. Such initiatives are paramount in mitigating gender-based inequities in the industry and improving the culture of jazz and improvisation (Support Act, 2023).

5 Conclusion

This study provides new theoretical and empirical insights on gender marginalization in jazz and improvisation. Like many musical genres, jazz and improvisation are rooted in historical constructions and practices of gender such that notions of masculinity and musicality have become intertwined. As a result,

masculinity has become a symbolic marker in social and professional contexts centered upon jazz and improvisation in the present day, maintaining a set of very real inequities and the exclusion and marginalization of those who do not fit or conform to the jazzmasculine archetype (Lamont and Molnár, 2002; Rustin-Paschal, 2017). This survey of 124 individuals who participate in Australian jazz and improvisation examined perceptions and experiences of inclusion and exclusion, finding that gender diverse individuals, who are furthest from the jazzmasculine ideal, were significantly more likely to experience marginalization than (cisgender) women, who in turn were more likely to experiences these effects than (cisgender) men. Further, we found evidence that gender groups experience marginalization differently: while gender diverse individuals were significantly less likely than cisgender groups to perceive representation and fairness, as well as feel respected, recognized, and safe, women were more likely to attribute outside roles and responsibilities as a major factor impacting professional opportunities. Harassment and safety were of particular concern, with most respondents having knowledge or direct experience of harassment, corresponding to gendered feelings of safety and the limitation of professional engagement due to safety risk. The survey complements a plethora of descriptive and qualitative investigations in the literature, contributing a statistical viewpoint in the absence of large-scale quantitative investigations regarding gender marginalization within the Australian jazz and improvisation industry. As the spirit of jazz and improvisation is built upon the liberation and transformation of music and people, to ensure these practices can flourish in the 21st century, devotees and institutions must strive toward equity for all.

6 Limitations and direction for future research and practice

A number of limitations must be acknowledged in this research. Firstly, the sample may not be representative of the complete Australian jazz and improvisation sector; for example, although much of the existing literature points to a masculinized population, our sample consisted of almost equal numbers of cisgender women and men, with relatively high levels of education, mostly from backgrounds that can be described as "Anglo-Australian." Although our sample size was small from a statistical standpoint, the jazz and improvisation industry in Australia is known to be a smaller part of the larger music industry in Australia compared to other countries, and the current study represents the largest-scale survey of gender marginalization in the industry that we are aware of. The true number and nature of individuals who participate in Australian jazz and improvisation, in a professional, non-professional, or other capacity remains unknown.

A second limitation concerns the nature of the research, as it was necessary to disclose the gendered nature of the survey to respondents. Due to this disclosure, the research may have attracted a sample that is more sympathetic or aware of gendered issues, or respondents may have been more inclined to respond according to social desirability bias (Krumpal, 2014). Informing respondents of response anonymization is hoped to have mitigated some of this effect (Krumpal, 2014).

Lastly, the landscape of practice is still recovering and changing after COVID-19 devastated much of the performing arts industry in Australia (Rusak et al., 2021; Crosby and McKenzie, 2022). Survey responses were collected from 2021 to 2022, capturing a particular point in time when parts of Australia were emerging from prolonged lockdowns, and the effects of venue restrictions and shutdowns were still very much felt by many respondents. As a result, many of the survey questions specified a time period of reference (either pre-pandemic, or at the time of answering the survey), and findings remain in line with much of the industry research that was conducted before the pandemic, as well as that which is emerging post-lockdowns.

Accounting for factors that have limited this research, the findings indicate a number of avenues warranting further investigation and recommendations for practice. Firstly, the data support the premise that there is an existing culture of gender inequity, marginalization, and sexual harassment in the Australian music industries (Crabtree, 2020), and that implications for safety are paramount. This is particularly important to those who rely on this as a main source of income, as safe conditions remain a priority for workers (Australian Human Rights Commission, 2013). Qualitative investigations to further explore the experiences of marginalization, particularly by gender diverse individuals and women in the industry, will be valuable to developing strategies to mitigate gender marginalization in the future. Secondly, a particular focus on gender diverse and LGBTQIA+ people operating in the cultural and creative spheres is a potential site of further investigation. As a highly marginalized population operating in a precarious and competitive industry, these accounts will be important to developing strategies to improve equity and diversity. Thirdly, although survey numbers were not sufficient to draw statistical conclusions concerning intersectional identities, the effects of multiple marginalized identities upon individuals operating in this industry will potentially reveal additional structural inequities that should be considered in future policies and practices.

Data availability statement

The datasets presented in this article are not readily available because the dataset is restricted for use to the nominated researchers only and is not available to the public. Requests to access the datasets should be directed to Gender Diversity in Jazz and Improvisation research team, https://www.monash.edu/arts/music-performance/genderjazz.

Ethics statement

The studies involving humans were approved by Monash University Human Research Ethics Committee (MUHREC). 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

TG: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing, Supervision, Visualization. CaH: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing. LD: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing. MB: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing. NC: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing. RB: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – review & editing. ClH: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, 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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Solo music performance assessment criteria: a systematic review

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Assessment is a crucial aspect of music performance. In pedagogical contexts, an effective assessment process can measure student achievement and inform instructional decisions that contribute to improving teaching and learning. However, music performance assessment is particularly challenging due to its inherent subjectivity, involving personal expression and interpretation, which can lead to divergent opinions. In this PRISMA systematic review (registration DOI: 10.17605/OSF.IO/CSM8Q), we aimed to delimit and analyze solo music performance assessment systems found in the literature to date, including their corresponding evaluation categories and descriptive criteria, rating methodology, and target audience. A search in three main scientific databases (Web of Science, Scopus, ERIC) was conducted using keywords associated with the topic of assessment in the field of solo music performance. Ultimately, 20 papers were selected and examined, resulting in 26 original assessment systems for analysis. Regarding sample characteristics, we found that studies mainly focused on evaluating high school and university students, with music teachers and faculty members serving as primary evaluators. Many assessment systems were designed to be applicable across various instruments, although some were tailored to specific instruments (e.g., piano, voice) and families (e.g., brass, woodwind). Systems typically structured evaluation around technical, interpretative/expressive, and various musical feature categories (e.g., pitch, rhythm, intonation), further elaborated with descriptive items. While five-point Likert scales were commonly used, recent studies indicated a shift towards rubrics for detailed feedback, which aids examiners' understanding and supports student progress. No differentiation was found in assessment criteria based on students' learning stages, suggesting an area for improvement in refining these assessment methods. This study identifies gaps and proposes improvements in existing assessment systems, providing a foundation for educators and policymakers to enhance curriculum design and instructional practices in music education.

KEYWORDS

instrumental and vocal performance evaluation, judges, rating scales, music pedagogy, music competitions, western classical music, systematic review

1 Introduction

Assessment is an integral dimension of music performance, both in educational and professional contexts. The assessment process is defined by Payne et al. (2019, p. 43) as "the collection, analysis, interpretation, and applied response to information about student performance or program effectiveness in order to make educational decisions resulting in continual improvement." Therefore, achieving effective assessments is of extreme relevance, as they do not only provide an overview of the student's progress in comparison to the expected skills and knowledge projected for a given outcome or learning level, enabling students and teachers to reorganize practices but also reveal areas upon which curricular adaptations can be implemented (Mustul and Aksoy, 2023; Payne et al., 2019; Tabuena et al., 2021).

However, developing reliable systems for music performance assessment presents multiple challenges. First, each musical instrument requires specific skills (e.g., string instrumentalists develop bowing technique, and wind instrumentalists develop breathing technique), demanding that assessment tasks be tailored to each instrument's unique requirements (Russell, 2014). Second, although ensuring jury expertise, human-based performance evaluation models carry high degrees of subjectivity, often due to poor descriptions (Giraldo et al., 2019; Thompson and Williamon, 2003; Wesolowski et al., 2016). Third, many instrumental and vocal assessment systems put emphasis on pitch and tempo accuracy, neglecting other important dimensions such as interpretation and sound quality (Giraldo et al., 2019). Ultimately, performance-oriented education receives less attention that general classroom music education, resulting in limited research in this area. Considering the identified challenges, it is crucial that systematic reviews provide a framework for addressing these issues.

In a preliminary database search, four narrative reviews were found about the topic of music performance assessment: three articles (Lerch et al., 2020; McPherson and Thompson, 1998; Zdzinski, 1991) and one book chapter (Russell, 2014). In such reviews, multiple assessment systems were identified, including generalized systems applicable to all instruments (Mills, 1991; Russell, 2010b, 2015; Stanley et al., 2002; Thompson and Williamon, 2003; Wesolowski, 2012, 2021; Winter, 1993) and instrument-specific systems (Abeles, 1973; Bergee, 2003; Wrigley, 2005; Wrigley and Emmerson, 2013). Russell (2014) highlighted the role of four nuclear evaluation categories, common to most studies, which significantly predict evaluators' assessment accuracy: tone and intonation, articulation, rhythmic accuracy, and interpretation or musical effect. There are other studies, however, presenting a dicotomical distinction between categories related to instrumental and vocal technical skills (e.g., accuracy of notes, of rhythm) and interpretation (e.g., dynamics, suitable sense of styles, sense of performance, bodily communication) (Davidson and Coimbra, 2001; Mills, 1991; Stanley et al., 2002). In fact, a subsequent study demonstrated that both technique and musical expression contributed to increases in assessments of overall performance quality, with technique alone also contributing to rating increases in musical expression (Russell, 2015). Nonetheless, as stated by Lerch et al. (2020), the selection of evaluation parameters is highly dependent on the proficiency level of the students and can also vary depending on the culture and musical style of the music being performed. The reviews also called attention to the wide range of rating scales was implemented across studies (McPherson and Thompson, 1998; Zdzinski, 1991), including qualitative (e.g., in Russell, 2010a, strongly agree/agree/disagree/strongly disagree) and quantitative classifications (e.g., in Thompson and Williamon, 2003, ratings from 1 to 10), as well as a variety of assessment levels (e.g., Mills, 1991, uses four levels, while Wrigley and Emmerson, 2013, use seven levels). Earlier reviews advocated for the need to increase reliability and validity of assessment procedures, highlighting the promising results of more systematic approaches, such as the facet-factorial (Zdzinski, 1991) and the importance of considering the influence of personal, cultural, and social biases on the jury (McPherson and Thompson, 1998). These considerations inspired follow-up research related to judge reliability (Bergee, 2003; Hewitt and Smith, 2004; Smith, 2004, to name a few). The more recent review by Lerch et al. (2020), focused on computerized music analysis, presented an overview of the tools and methods which can be used to automatically assess performance parameters not only for evaluation purposes but also for analysis, modelling, and software development. The authors underscore the relevance of developing accessible and reliable automated systems to improve objectivity in performance assessment, a quest that has been long mentioned (McPherson and Thompson, 1998; Zdzinski, 1991). Russell (2014) also corroborated the potential of technology in music assessment, if its equal availability is ensured for all students.

Hence, the absence of a systematic literature review in solo music performance assessment, coupled with the diverse array of instruments, methods, and rating scales identified in this preliminary research, reinforces the need to delimit and characterize evaluation procedures. This systematic review aims to provide a systematized overview of valuable evidence for academics and educators in this field. It builds on previous studies by critically examining generalized and instrument-specific systems, aiming to integrate their strengths while addressing their limitations. Specifically, its goal is to critically analyze solo music performance assessment systems found in the literature to date, including their corresponding evaluation categories, descriptive criteria, rating methodology, and target audience. We intend to establish a generally accepted set of standards and criteria to measure solo performance quality, if possible, adjusted for different musician populations (e.g., basic and advanced learning levels). The main research question driving this study is "What solo music performance assessment systems are reported and implemented in the literature, and how are they characterized?." This is followed by the specific questions: "What are the main categories of assessment, and which are given the most importance?," "Within each category, what descriptive items/criteria are provided to the evaluators?," "What rating methods are adopted (e.g., qualitative or quantitative, type and size of scales)?," and "How do assessment systems differ between the types of population being evaluated (e.g., children, professionals)?"

2 Methods

This systematic review followed the PRISMA updated guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses, Page et al., 2021). Registration in the OSF (Open Science Framework) was also performed (Registration DOI: 10.17605/OSF.IO/CSM8Q).

2.1 Eligibility criteria

The current systematic review covered studies that developed and/or implemented music performance assessment systems, analyzing their methodological design (categories/items for assessment, criteria, and rating scales). Given the qualitative nature of our research question, we used the PEO framework: Population – music performers and students, including children, adolescents, higher education students and professionals (no limitations were imposed due to the scarce existing research); Exposure – the process of performance assessment was considered as the exposure; Outcome – assessment systems and corresponding categories, items, criteria, and rating scales.

Inclusion criteria were established to focus on peer-reviewed articles and reviews that provide detailed descriptions of music performance assessment systems, ensuring the inclusion of rigorous and validated studies. The language criteria was expanded to include articles written in Portuguese, as this is the native language of all authors and there are multiple journals using it as primary language. Exclusion criteria, such as the omission of articles referring to general music education rather than performance assessment, were applied to maintain the specificity and relevance of our review. Based on these considerations, the specific inclusion and exclusion criteria applied in this review are as follows:

Inclusion criteria adopted:

1 Articles with relevant data on the theme of music performance assessment and with descriptions of the assessment systems;
2 Reviews or original research articles published in peer-reviewed journals;
3 Articles written in English or Portuguese;
4 Articles that report evaluations targeted at performers or music students (children, adolescents, higher education students, professionals).

Exclusion criteria adopted:

1 Articles referring to assessment systems of general music education rather than music performance;
2 Articles that were marked as "retracted";
3 Letters to the editor and grey literature.

2.2 Information sources and search strategy

Web of Science (all databases), Scopus, and Education Resources Information Center (ERIC) were the chosen databases for our literature search due to their coverage of peer-reviewed articles in the fields of education, social sciences, and music performance. These databases are recognized for their extensive indexing of high-quality academic journals, ensuring that our review encompasses a wide range of relevant studies. The electronic search was conducted on March 18, 2024, using the expression: ("music* perform*" OR "music play*") AND [title] (analys* OR assess* OR evaluat* OR rat* OR exam* OR criteri* OR jury OR judge*). The previous keywords were chosen to capture a broad spectrum of terms related to music performance assessment while ensuring specificity to our research focus in instrumental and vocal music performance. Filters were applied to limit the results to research articles and reviews in English and Portuguese.

2.3 Data collection, selection, and extraction

Outputs were exported to a reference manager software (Mendeley; © 2024 Elsevier Ltd), and duplicates were removed. The selection process was conducted following three stages. In the screening stage, two researchers independently analyzed titles and abstracts following the eligibility criteria to exclude irrelevant references. When eligibility was ambiguous, the full text of the reference was obtained. In the inclusion stage, the same researchers critically appraised the full texts of the selected references for eligibility, and all relevant references were included in the review. Also, at this point, an examination of the bibliography of each study was performed to identify additional relevant studies complying with the inclusion criteria (backward citation searching). The screening and inclusion stages were replicated for the citation searching. In the case of disagreement over the eligibility of studies, a discussion was carried out between the researchers until a consensus was reached.

Researchers then extracted the data from the included references into a Microsoft Excel sheet. The following information was retrieved: author, year, journal, aim, type of study, sample characteristics (age, learning level, musical instruments, context of implementation), assessment system characteristics (name, categories, items, preponderance of items in the final score, criteria, rating methods), results, and limitations (if applicable). Following, data synthesis was conducted through both qualitative and quantitative methods to provide a comprehensive analysis of the findings, including the presentation of tables and summarizing the studies' evidence through a qualitative approach.

3 Results

3.1 Study selection

The selection process is summarized in Figure 1, presenting the PRISMA flow diagram.

A total of 1,113 studies were identified and 754 were retained after the duplicate's removal. In the screening stage, 700 publications were excluded because they did not fulfil the criteria for inclusion and exclusion, resulting in 53 publications for full-text analysis. Two publications were not fully available online, so publishers and authors were contacted via email, from whom we did not get a response, resulting in a final number of 51 publications. After careful analysis, 37 studies were excluded: 21 studies presented replications or extensions of assessment rubrics originally presented in other included studies (i.e., applying them to ensembles, student self-evaluation, among others), six studies consisted of theoretical articles which, although regarded performance evaluation, did not provide descriptions of assessment systems, six studies implemented single rating assessment systems without specific dimensions or criteria (e.g., single overall rating from 1 to 100), and four studies did not focus on performance assessment (e.g., were focused on listeners' emotional perceptions).

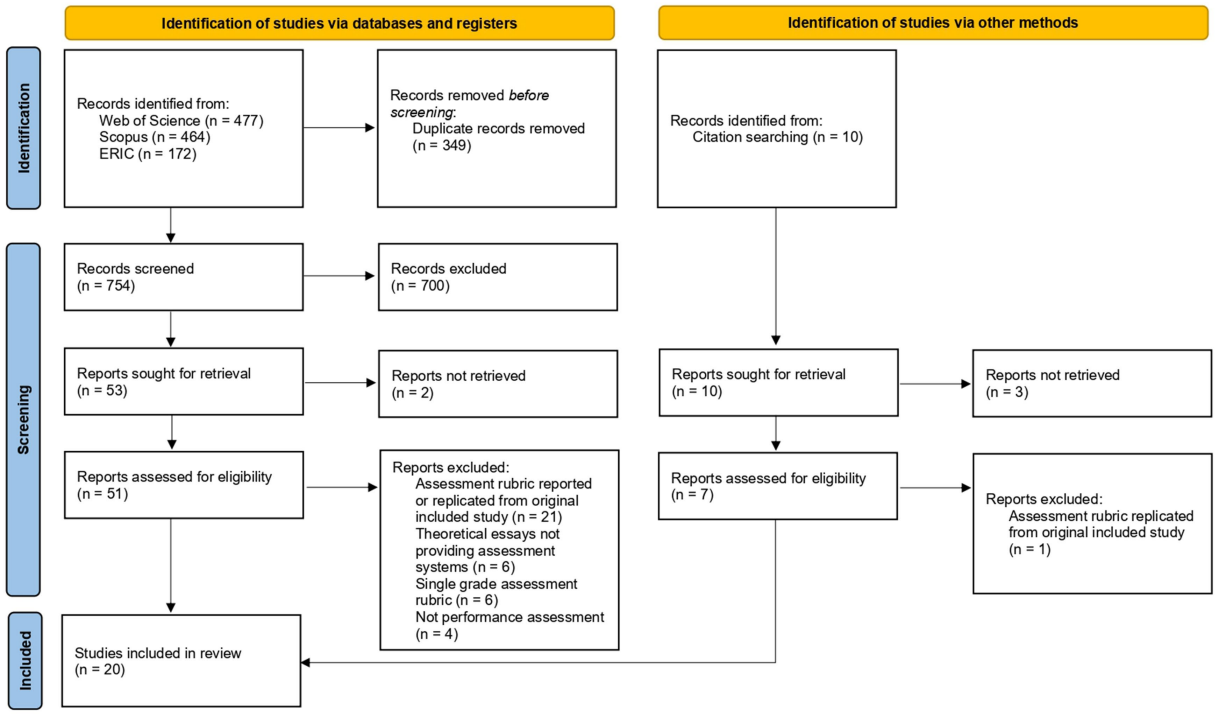

FIGURE 1
Flow diagram (based on PRISMA statement, Page et al., 2021) summarizing the search procedure.

At this stage, we arrived at 14 publications to include in the review. However, through backward citation searching, we identified 10 additional publications potentially meeting our inclusion criteria. Three of these were impossible to retrieve online and the author informed us that electronic copies of the works were not available. Hence, we analyzed the full text of seven publications. One study was excluded because it presented a replication of the assessment rubric used in another included article, leading us to a total of six publications to add to the review. The systematic review included 20 studies: 18 empirical research articles, one theoretical article, and one narrative literature review. Nineteen studies were written in English and one was written in Portuguese.

Out of the three narrative reviews initially found, two were removed from this systematic review considering that one study (McPherson and Thompson, 1998) reported assessment systems already included under their original empirical research articles, and the other study (Lerch et al., 2020) did not provide information on assessment systems and primarily focused on computer-assisted assessment of sound features. However, we kept one review (Zdzinski, 1991) because it presented additional assessment systems that were deemed relevant to our review.

3.2 Sample characteristics

The characteristics of the participants are shown in Table 1.

Across studies, the number of evaluated participants ranged from one (Winter, 1993) to 926 (Saunders and Holahan, 1997), and the number of evaluator participants ranged from three (Álvarez-Díaz et al., 2021) to 67 (Russell, 2010a). Studies reported performance assessments of students from: junior high only ($n = 1$), middle and high school ($n = 4$), grade 8 ABRSM (Associated Board of the Royal Schools of Music) ($n = 1$), upper secondary music students ($n = 2$), superior-level/university music students ($n = 7$), a combination of professionals, university, and high school students ($n = 1$), or not specified/not applicable ($n = 4$). Performances in the following instruments were included: clarinet only ($n = 1$), trumpet only ($n = 2$), piano only ($n = 1$), voice only ($n = 1$), guitar only ($n = 1$), brass ($n = 1$), woodwind and brass ($n = 2$), strings ($n = 1$), a combination of instruments from varied families and voice ($n = 7$), or not specified/not applicable ($n = 3$).

Evaluator participants were instrumental music teachers ($n = 4$), teacher-performer specialists ($n = 3$), faculty members ($n = 6$), a combination of instrumental teachers, graduate students, and faculty members ($n = 4$), a combination of instrumental teachers and nonspecialists with performative experience ($n = 1$), and not specified/not applicable ($n = 2$). The instrumental expertise of the evaluators was voice only ($n = 1$), guitar only ($n = 1$), trumpet only ($n = 1$), brass ($n = 1$), woodwind and brass ($n = 1$), strings ($n = 1$), mixed panel (varied instrumental families) ($n = 6$), or not specified/not applicable ($n = 8$). Nine studies specifically adopted evaluators with high levels of expertise in the corresponding instrument or instrumental family (e.g., brass) being evaluated.

3.3 Assessment systems characteristics

A summary of the 26 assessment systems extracted from the 20 publications analyzed in this review, including names, authors, years

TABLE 1 Details of included studies—characteristics, samples and methods.

Author (year)	Study type	Study description	Evaluators sample	Evaluated sample	Assessment system
Abeles (1973)	Empirical	Construction and validation of scale	Instrumental music teachers (phase 1, $n = 50$; phase 2, $n = 32$)	Junior high students ($n = 100$) Instruments: clarinet	Clarinet performance rating scale (CPRS)
Fiske (1975)	Empirical	Construction and validation of scale	Teacher-performer specialists ($n = 14$) Instruments: brass, non-brass	High school students ($n = 32$) Instruments: trumpet	Fiske scale
Mills (1987)	Empirical	Construction and validation of scale	Music teachers and music specialist students, and nonspecialists with performance experience (phase 1, $n = 11$; phase 2, $n = 29$)	Students at level of Grade 8 (ABRSM) (phase 1, $n = 6$; phase 2, $n = 10$). Instruments: harp, horn, piano, oboe, violin (phase 1); violin, horn, piano, voice, clarinet, harp, oboe, flute, double bass, trombone (phase 2).	Mills scale
Zdzinski (1991)	Narrative literature review	*Literature review kept to retrieve additional assessment systems not found in empirical studies. For the assessment systems reported in empirical research articles, these were preferred.*			Watkins-Farnum Performance Scale (WFPS) (Watkins and Farnum, 1954; Kidd, 1975*)
Bergee (1993)	Empirical	Replication of author-constructed scale (Bergee, 1987; Bergee, 1988**)	University internal and external faculty members (phases 1, 2, and 3, $n = 5$) Instruments: trumpet, horn, trombone, tuba, percussion	University music students (phase 1, $n = 10$; phases 2 and 3, $n = 8$) Instruments: brass (non-specified)	Brass Performance Rating Scale (BPRS)
Winter (1993)	Empirical	Construction and validation of scale	Qualified musicians and music educators ($n = 33$)	NA ($n = 1$, 3 performances) Instruments: piano	Winter Scale
Saunders and Holahan (1997)	Empirical	Construction and validation of scale	Elementary, secondary, and college-level instrumental music teachers ($n = 36$) Instruments: woodwind and brass	Middle and high school students (Grades 9–12) ($n = 926$) Instruments: woodwind and brass	Woodwind/Brass Solo Evaluation Form (WBSEF)
Davidson and Coimbra (2001)	Empirical	Comparison between quantitative and qualitative assessment	Faculty internal and external highly experienced singers/ assessors ($n = 4$) Instruments: voice	2nd year superior-level students ($n = 21$) Instruments: voice	Davidson and Coimbra Scale
Stanley et al. (2002)	Empirical	Interview study and construction of scale	Staff of the Sydney Conservatorium of Music, most with >20 years of performance assessment experience ($n = 15$)	NA *The scales (discussed and created) aimed at superior-level students.*	Sydney Conservatorium Scale Stanley Scale
Zdzinski and Barnes (2002)	Empirical	Construction and validation of scale	Public school string educators, upperclass and graduate string education students, and faculty members ($n = 50$) Instruments: strings	Middle and high school students ($n = 102$) Instruments: strings	String performance rating scale (SPRS)

(Continued)

TABLE 1 (Continued)

Author (year)	Study type	Study description	Evaluators sample	Evaluated sample	Assessment system
Bergee (2003)	Empirical	Adaptation of various assessment methods	Faculty members ($n = 24$) Instruments: brass, percussion, woodwind, voice, piano, strings	Undergraduate and graduate music majors and minors ($n =$ NA) Instruments: brass, percussion, woodwind, voice, piano, strings	BPRS (Bergee, 1993) Nichols Percussion Scale [Nichols, 1991, as cited in Bergee (2003)] CPRS (Abeles, 1973) Jones Voice Scale (Jones, 1986) Original Piano Scale SPRS (Zdzinski and Barnes, 2002)
Thompson and Williamon (2003)	Empirical	Construction and validation of scale	External professional performing musicians with substantial experience of evaluating at conservatory level ($n = 3$) Instruments: piano, cello, clarinet	Superior-level students (Royal College of Music) ($n = 61$) Instruments: keyboards, woodwind, strings, others (i.e., harp, guitar, brass, voice)	Thompson and Williamon Scale
Barry (2009)	Theoretical	Discussion of politics, issues and successful practices regarding music performance assessment	*Note: Although not empirical, the paper presents a discussion of selected performance evaluation tools and procedures that have been used successfully in music-performance settings.*		Piano Accompaniment and Song Leading Checklist (Benson, 1995, as cited in Barry, 2009) Sample rating scale (adapted from Augustana Percussion Exam) Sample Assessment Rubric for a Preparatory Piano Exam
Ciorba and Smith (2009)	Empirical	Construction and validation of scale	Music faculty members ($n = 37$) Instruments: brass, woodwind, guitar, percussion, piano, strings, voice	Music undergraduate students ($n = 359$) Instruments: brass, woodwind, guitar, percussion, piano, strings, voice	Multidimensional assessment rubric
Russell (2010a)	Empirical	Construction and validation of scale	Public school guitar and string teachers, college guitar professors, undergraduate and graduate music education majors, and professional guitar players ($n = 67$) Instruments: guitar, strings	Professional guitar teachers, college undergraduate and graduate majors, and senior high school freshman, sophomore, junior, and senior ($n = 55$) Instruments: guitar *Total of 100 recordings*	Guitar Performance Rating Scale (GPRS)
Wrigley and Emmerson (2013)	Empirical	Construction and validation of scale	Music faculty members ($n = 30$) Instruments: strings, brass, woodwind, piano, voice	Superior-level student exams ($n = 829$) Instruments: strings, brass, woodwind, piano, voice *(n of students not provided, data collected across semesters can include more than one exam per student)*	Performance examination rating scale (PERS)

(Continued)

TABLE 1 (Continued)

Author (year)	Study type	Study description	Evaluators sample	Evaluated sample	Assessment system
Russell (2015)	Empirical	Construction and validation of scale	College undergraduate and graduate music students, university music professors, primary and secondary school music educators, and professional musicians ($n = 58$)	Undergraduate performance and music education majors ($n = 4$) Instruments: French horn, cello, male voice, flute	Aural musical performance quality (AMPQ)
Costa and Barbosa (2015)	Empirical	Construction and validation of scale	Teachers from specialized artistic schools ($n = 9$) Instruments: trumpet	High level 5th musical grade students ($n = 2$) Instruments: trumpet	Scale of evaluation of the musical execution (SEME)
Wesolowski et al. (2017)	Empirical	Construction and validation of scale	Experts experienced in secondary-level instrumental teaching ($n = 13$)	Middle and high school solo and ensemble performances ($n = 75$) Instruments: flute, clarinet, alto saxophone, trumpet, trombone	Music performance rubric for secondary-level instrumental solos (MPR- 2 L-INSTSOLO)
Álvarez-Díaz et al. (2021)	Empirical	Construction and validation of scale	Senior professors of music ($n = 3$) Instruments: piano, viola, clarinet	10 upper secondary students (6^{th} grade of musical studies) Instruments: violin, piano, guitar, percussion, bassoon, flute, tuba	Álvarez-Díaz Scale

*Doctoral thesis unavailable (excluded from analysis). **We were informed by the author that, to his knowledge, these articles, reporting the construction of the scale, are not available in electronic or printed format, hence we included the first available publication mentioning this scale.

of publication, as well as structural characteristics, is presented in Table 2.

Most assessment systems were designed for application across instruments ($n = 11$) but there were also family-specific ($n = 6$), and instrument-specific (clarinet, $n = 1$; guitar, $n = 1$; trombone, $n = 1$; percussion, $n = 2$; voice, $n = 1$; piano, $n = 3$) systems.

The first-level assessment categories ranged from two (Benson, 1995, as cited in Barry, 2009; Stanley et al., 2002; Wrigley and Emmerson, 2013) to 12 categories (Mills, 1987) across studies, although most recurrently three, four or five categories were implemented. Technical-related categories were the most frequent (19 studies used the term technique, whereas others defined it as command of instrument, instrumental control, or instrumental competence). Expressive-related categories were also recurrent, emerging under the terms interpretation (14 studies), expression (5), musical understanding (4), musical communication (1), musicality (3), musicianship (3), and artistry (1). Following, we found tone/timbre/sound quality (15), intonation/pitch/melodic accuracy (14), rhythm (13) and tempo (11), articulation (8), dynamics (6), and phrasing (3). While some studies considered rhythm and tempo as separate categories (e.g., Abeles, 1973), others joined them (e.g., Bergee, 1993). Four studies included an additional category related to overall quality. Eight systems further comprised categories related to presentation, confidence, visual, stage presence, and audience communication. Five systems included one category related to the adequacy of the interpretation regarding the musical style and epoque. Two studies included categories of body communication and posture. Moreover, the Álvarez-Díaz Scale (2021) was the only system to consider the difficulty of the repertoire as a category, and the Woodwind/Brass Solo Evaluation Form (Saunders and Holahan, 1997) provided a reduced version for musical scales' assessment. In instrument- and family-specific systems, idiosyncratic categories were identified, including diction and language facility (for voice), sticking or grip (for percussion), air support, tongue, or vibrato (for winds), memorization, fingering, or pedaling (for piano), and vibrato (for strings).

The most common logic adopted across studies was to select a small set of first-level categories and further expand them into multiple second-level items. However, four studies presented different organizations. Mills' categories (1987) consisted of 12 statements (e.g., performer hardly knew the piece), which were transposed into 12 bipolar items (e.g., the performer hardly knew/was familiar with the piece). Costa and Barbosa (2015) also presented differing categorical terminologies (materials: sensorial and manipulative, expression: personal and vernacular, shape: speculative and idiomatic, value: symbolic and systematic). Nevertheless, these categories become closer to others in their more objective item form (e.g., tuning, sound quality, notion of musical style). The Watkins-Farnum Performance Scale (1954) also derived significantly from other methodologies, as it consisted of 14 exercises of increasing difficulty in varied musical features (e.g., pitch, rhythm, slurring/articulation, among others) which are played orderly by the evaluated participants. Evaluators score each exercise's performance by considering the participants' errors, producing a final score for the test. When participants score zero on two consecutive exercises, they stop the test (see Table 2 for

TABLE 2 Details of assessment systems retrieved from included studies—categories, items and criteria.

Author (year)	Assessment system	Categories	Items	Rating method
Abeles (1973)	Clarinet performance rating scale (CPRS)	1. Interpretation 2. Intonation 3. Rhythm-continuity 4. Tempo 5. Articulation 6. Tone	1.1. Effective musical communication 1.2. The interpretation was musical 1.3 The piece was played in character 1.4 Played with musical understanding 1.5 Played with traditional interpretation 2.1. Thin tone quality 2.2. Played with a natural tone 2.3 There was a lack of tonal color 2.4 The quality of the tone was rich 2.5 Sounded shallow 3.1. Uneven rhythm 3.2. Smoothness in execution 3.3. Melodic continuation 3.4. Insecure technique 3.5. The rhythm was distorted 4.1. Played out of tune 4.2. Flat in low register 4.3. The intonation was good 4.4. Played overall flat 4.5. Tended to be flat 5.1. Played too fast 5.2. Seemed to drag 5.3. Hurried repeated notes 5.4. Played too slowly 5.5. Rushed 6.1. Squeaked 6.2. Free from tonguing noise 6.3. Attacks and releases were clean 6.4. Tonguing produced thunkie sound 6.5. Accents were played as indicated	5-point scale (Highly disagree, disagree, neutral, agree, highly agree)
Fiske (1975)	Fiske Scale	1. intonation 2. rhythm 3. interpretation 4. technique 5. overall	NA	5-point scale (1–5)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Mills (1987)	Mills scale	1. Nervous 2. Performer did not enjoy playing 3. Performer hardly knew the piece 4. No sense of the piece as a whole 5. Dynamics inappropriate 6. Tempi inappropriate 7. Phrasing inappropriate playing 8. Technical problems distracting 9. Performance hesitant 10. Performance insensitive 11. Performance muddy 12. Performance dull	1. The performer was nervous /confident 2. The performer did not enjoy/did enjoy playing 3. The performer hardly knew/was familiar with the piece 4. The performer did not make sense/made sense of the piece as a whole 5. The performer's use of dynamics was inappropriate/appropriate 6. The performer's use of tempi was inappropriate /appropriate 7. The performer's use of phrasing was inappropriate/appropriate 8. The performer's technical problems were distracting/ hardly noticeable 9. The performance was hesitant/ fluent 10. The performance was insensitive/sensitive 11. The performance was muddy/clean 12. I found this performance dull/ interesting	4-point bipolar scale, non-specified levels
Zdzinski (1991)	Watkins-Farnum Performance Scale (WFPS)	The Watkins-Farnum Performance Scale consists of a set of 14 exercises (16–36 bars long) of increasing difficulty varying in pitch, rhythm, slurring/articulation, tempo, expression, pause/fermata and repeats. Participants play the exercises in order, and evaluators note each bar in which an error occurs. Per bar, only one error can be scored, hence the possible scores per bar are either one or zero. The maximum possible score on each exercise is a given standard, and the total points scored equals the standard for the exercise minus the number of bars containing an error. Participants continue playing until they score zero on two consecutive exercises. The total score for the test is the cumulative score for all exercises.		12-point score (Satisfatory to Honors)
Bergee (1993) Original unavailable works: Bergee (1987) and Bergee (1988, 1989)	Brass performance rating scale (BPRS)	1. interpretation/musical effect (items 1, 2, 9, 15–19) 2. tone quality/intonation (items 3, 4, 11, 25, 26) 3. technique (items 5–7, 12, 14, 21) 4. rhythm/tempo (items 8, 13, 20, 22–24)	1. Performer plays mechanically 2. Spiritless playing 3. Intonation is inconsistent 4. Plays all registers in tune 5. Performance is clean 6. Poor synchronization of tongue and fingers (slide) 7. Interval leaps are smooth 8. Rhythm flows 9. Superior interpretation 10. Pitch suffers from poor tone production 11. Good intonation at forte volume 12. Lack of clarity in tongued passages 13. Rhythmically accurate 14. Articulation is clean and not percussive 15. Plays rhythms unmusically 16. Ineffective musical communication 17. Neglects style and expression 18. No contrasts in performance 19. Good spirit and drive 20. Tempo not controlled 21. Precise attacks and releases 22. Loud passages rhythmically unsteady 23. Rhythm is unsteady 24. Plays too hurriedly 25. Sound is thin 26. Sound in upper register is pinched and restricted 27. Dynamics are played	5-point scale (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Winter (1993)	Winter scale	1. Technical 2. Pitch 3. Time 4. Interpretation 5. Overall	1.1. Insecure technique 1.2. Hands well coordinated 1.3. All passages easily executed 1.4. Too heavy handed 1.5. Poor release of notes 1.6. Uneven touch 1.7. Unnecessary finger/hand movement 1.8. Staccato action poor 2.1. Many wrong notes 2.2. Insufficient attention to phrase endings 2.3. Fluent melody lines 2.4. Appropriate balance (melody and chords) 2.5. Fluency impeded by many pauses/stumbles 3.1. Uneven rhythm 3.2. Smooth execution 3.3. Played too fast 3.4. Hurried repeated notes 3.5. Played too slowly 3.6. Accents appropriately performed 3.7. Inconsistent tempo 3.8. Fast passage work needs more control 4.1. Wide dynamic contrasts 4.2. Artistic and skillful execution 4.3. Reflects musical understanding 4.4. Sacrifices style for performance ease 4.5. Sensitive approach to expression 4.6. Haphazard approach to dynamics 5.1. Detailed preparation demonstrated 5.2. Stylistic interpretation 5.3. More hand independence needed 5.4. Played with conviction and sincerity 5.5. Nerves well controlled	6-point scale (HD, D, SD, SA, A, HA) + overall impression (1–10)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Saunders and Holahan (1997)	Woodwind/Brass Solo evaluation form	1. Tone 2. Intonation 3. Technique/Articulation 4. Melodic accuracy 5. Rhythmic accuracy 6. Tempo 7. Interpretation For Scales: 1. Technique 2. Note accuracy 3. Musicianship	Tone (single rating): - is full rich, and characteristic of the tone quality of the instrument in all ranges and registers - is of a characteristic tone quality in most ranges, but distorts occasionally in some passages - exhibits some flaws in production (i.e., a slightly thin or unfocused sound, somewhat forced, breath not always used efficiently, etc.) - has several major flaws in basic production (i.e., consistently thin/unfocused sound, forced, breath not used efficiently) - is not a tone quality characteristic of the instrument Intonation (single rating): - is accurate throughout, in all ranges and registers. - is accurate, but student fails to adjust on isolated pitches, yet demonstrates minimal intonation difficulties - is mostly accurate, but includes out-of-tune notes. The student does not adjust problem pitches to an acceptable standard of intonation. - exhibits a basic sense of intonation, yet has significant problems, student makes no apparent attempt at adjustment of problem pitches. - is not accurate. Student's performance is continuously out of tune Technique/Articulation (Check all applicable): - appropriate and accurate tonguing. - appropriate slurs as marked. - appropriate accents as marked. - appropriate ornamentation as marked - appropriate length of notes as marked (i.e., legato, staccato) Melodic accuracy (single rating): - all pitches/notes accurately. - most pitches/notes accurately. - many pitches accurately. - numerous inaccurate pitches/notes. - inaccurate pitches/notes throughout the music, (i.e., missing key signatures, accidentals, etc.) Rhythmic Accuracy (single rating): - accurate rhythms throughout. - nearly accurate rhythms, but lacks precise interpretation of some rhythm patterns. - many rhythmic patterns accurately, but some lack precision (approximation of rhythm patterns used). - many rhythmic patterns incorrectly or inconsistently. - most rhythmic patterns incorrectly. Tempo (single rating): - is accurate and consistent with the printed tempo markings. - approaches the printed tempo markings, yet the performed tempo does not detract significantly from the performance. - is different from the printed tempo marking(s), resulting in inappropriate tempo(s) for the selection, yet remains consistent. - is inconsistent (i.e., rushing, dragging, inaccurate tempo changes). - is not accurate or consistent. Interpretation (single rating):	5-point scale (1–5) either continuous (single rating selection) or additive (marked boxes up to 5)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
			- the highest level of musicality including well-shaped phrases and dynamics. - a high level of musicality, but has some phrases or dynamic that are not consistent with the overall level of expression. - a moderate level of musicality and musical understanding. - only a limited amount of musicality and music understanding. - a lack of musical understanding For Scales Technique (Check all applicable): - with consistent, even tempo. - at required tempo. - with appropriate rhythmic pattern. - with appropriate articulation as required. - evenly, both ascending and descending Note accuracy (Check all applicable): - all pitches/notes accurately. - most pitches/notes accurately. - many pitches/notes accurately. - numerous inaccurate notes/pitches. - a large number of inaccurate pitches/notes throughout the scale Musicianship (Check all applicable): - accurate articulation, clean tonguing. - adequate breath control/support. - a natural rise and fall of dynamics. - adequate and efficient embouchure formation. - efficient hand/holding position and commendable erect posture	
Davidson and Coimbra (2001)	Davidson and Coimbra Scale	After the qualitative analysis, the authors were able to conclude that assessors based their evaluations on three main categories: body communication, technical accuracy, and artistry.	1. Free comment 2. Grade 3. Post-performance open questions: 3.1. If the assessor knew the student, and if so, in what capacity; 3.2. How well they knew the pieces being presented; 3.3. Whether the assessors felt that the repertoire was appropriate to the candidate; 3.4. What were the major strengths and weaknesses of the performance; 3.5. What impressions were they left with, and were these impressions different to their initial thoughts.	Free comment + 5-point scale (A – E) + Set of *a posteriori* open questions

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Stanley et al. (2002)	1. Sydney Conservatorium Scale 2. Stanley Scale	1.1. Technical 1.2. Musical 2.1. The performance, as a whole, displayed instrumental or vocal control appropriate to the level of examination 2.2. The performance was accurate with respect to rhythm, pitch, articulation, and dynamic 2.3. The performance (where appropriate) was a faithful reading and/or memorisation of the composer's text 2.4. The performance displayed musically effective production, projection and variation of tone 2.5. The candidate communicated well with other performers, demonstrating good ensemble and listening skills and leadership where appropriate 2.6. The performance communicated an understanding of expressive, stylistic, musical and structural issues 2.7. The performance displayed musical creativity, artistic individuality and effective audience communication	For Vocal Studies: 1.1.1. Technical Facility 1.1.2. Musical Accuracy (Note and Rhythm) 1.1.3. Evenness of Tone 1.1.4. Intonation 1.1.5. Purity of Vowel 1.1.6. Breathing/Posture 1.2.1. Style 1.2.2. Musical Communication 1.2.3. Emotional Impact 1.2.4. Concert Presentation, Flow 1.2.5. Language Facility 1.2.6. Ensemble For Winds: 1.1.1. Intonation 1.1.2. Articulation 1.1.3. Accuracy 1.1.4. Dynamic Contrast 1.1.5. Breathing 1.1.6. Tone Production 1.2.1. Phrasing 1.2.2. Musicianship 1.2.3. Creativity 1.2.4. Emotional Impact For Scale 2., NA	Likert Scale (n of levels not mentioned)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Zdzinski and Barnes (2002)	String performance rating scale (SPRS)	1. Interpretation/musical effect 2. Articulation/tone 3. Intonation 4. Rhythm/tempo 5. Vibrato	1.1. Lack of style in performance 1.2. Very musical 1.3. Melodic phrasing 1.4. Subtle nuances lacking 1.5. Dry-too technical 1.6. Appropriate range of dynamics 2.1. Student is using correct proportion of weight 2.3. Clear articulation produced by left hand 2.4. Maintains proper contact point 2.5. Arm weight draws full sound from string and speed with bow 2.6. Tone is full without harshness on forte 2.7. String crossings are controlled 3.1. Pitch was mostly consistent 3.2. Half steps not close enough 3.3. Consistently good intonation on all strings 3.4. Performer was able to adjust pitch 3.5. Played out of tune 3.6. Minor thirds are sharp 4.1. Uneven rhythm 4.2. Excellent rhythm 4.3. Tempo is not stable 4.4. Rhythm was distorted 4.5. Correct rhythms 4.6. Tempo is steady during technical passages 5.1. Full, rich vibrato 5.2. Vibrato is continuous 5.3. Vibrato is even 5.4. Vibrato is irregular	5-point scale (SA, A, N, D, SD)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Bergee (2003)	1. BPRS (Bergee, 1993) 2. Nichols Scale [Nichols, 1991, as cited in Bergee (2003)] 3. CPRS (Abeles, 1973) 4. Jones Scale (Jones, 1986) 5. Original Piano Scale 6. SPRS (Zdzinski and Barnes, 2002)	1. See Bergee (1993) 2.1. Technique/Rhythm 2.2. Interpretation 2.3. Tone Quality 3. See Abeles (1973) 4.1. Interpretation/Musical Effect 4.2. Tone/Musicianship 4.3. Technique 4.4. Suitability/Ensemble 4.5. Diction 5.1. Interpretation/Musical Effect 5.2. Rhythm/Tempo 5.3. Technique. 6. See Zdzinski and Barnes (2002)	Each category was defined by three items to keep evaluations short, but these are not described in the article. Some scale-specific indications are provided: 2.3. For mallet performance, Tone Quality item "drum tone sounded muffled" was adapted to a more general "tone was characteristic." 3. No modification outside of the Articulation subscale was required. Under Articulation, the three items dealing with generalized aspects were used (e.g., "free from tonguing noise") and the two dealing specifically with clarinet articulation ("squeaked"; "tonguing produced thunkie sound") were ommitted.	5-point scale (SA, A, N, D, SD) + 13-point grade (A+: excellent performance in all respects to F: exceedingly poor performance in all respects)
Thompson and Williamon (2003)	Thompson and Williamon Scale	1. Overall quality 2. Perceived instrumental competence 3. Musicality 4. Communication	1.1. Overall rating of performance quality 2.1. Overall rating of instrumental competence 2.2. Level of technical security 2.3. Rhythmic accuracy 2.4. Tonal quality and spectrum 3.1. Overall rating of musical understanding 3.2. Stylistic accuracy 3.3. Interpretive imagination 3.4. Expressive range 4.1. Overall rating of communicative ability 4.2. Deportment on stage 4.3. Deportment with instrument 4.4. Communication of emotional commitment and conviction 4.5. Ability to cope with the stress of the situation	10-point scale (1–10)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Barry (2009)	1. Piano Accompaniment and Song Leading Checklist (Benson, 1995, as cited in Barry, 2009) 2. Sample rating scale (adapted from Augustana Percussion Exam) 3. Sample Assessment Rubric for a Preparatory Piano Exam	Categories are only provided for Scales 2 and 3: 2.1. Basic Skills: 2.1.1. Tone 2.1.2. Style/Dynamics 2.1.3. Intonation/Sticking 2.1.4. Technique 2.1.5. Grip 2.2. Musicianship: 2.2.1. Phrasing/Dynamic Shaping 2.2.2. Tempo/Pulse 2.2.3. Rhythm 2.2.4. Articulation 3.1. Memorization 3.2. Posture 3.3. Tempo 3.4. Dynamics 3.5. Fingering 3.6. Pedaling	Scale 1: 1. 1. uses correct posture and hand position 1.2. Introduces song 1.3. Cues singers to come in … (counting) 1.4. smiles and looks up when cueing 1.5. plays correct chords 1.6. plays chord changes at correct times 1.7. sings along 1.8. uses proper balance between the hands 1.9. plays in steady tempo throughout 1.10. continues in tempo if chords are missed. Scale 2: 2.1.1. Appropriate mallet/stick choices 2.1.2. Accents (not weight) 2.1.3. Student plays accurately with regard to pitch and intonation. Student chooses appropriate sticking for the selections performed 2.1.4. Student has mastered the relevant technical skills required by the selection(s), 2.1.5. Student establishes and adjusts grip effectively 2.2.1. Student phrases appropriately and intelligently, musical interpretation 2.2.2. Appropriate for the style and character of the work 2.2.3. Rhythms are performed with accuracy and musicality 2.2.4. Student accurately and appropriately conveys score markings. Scale 3 (descriptor per level): 3.1. Not yet: Student needs more than two cues or hesitates more than twice; Almost: Student needs no more than two cues or hesitates no more than twice; Meets Standard: Student needs no cues and hesitates no more than once; Exceeds Standard: Student never needs no cues and never hesitates. 3.2. Not yet: Student sits too close to the keyboard; Almost: Student is at a proper distance from the keyboard but does not have feet flat on the floor; Meets Standard: Student sits at a proper distance from the keyboard with feet flat on the floor; Exceeds Standard: Student sits at a proper distance from the keyboard and maintains a straight but fluid upper body. 3.3. Not yet: Tempo lags or rushes more than twice; Almost: Tempo lags or rushes no more than twice; Meets Standard: Tempo follows the markings in the score and stays with the metronome (set by head judge). Exceeds Standard: Tempo follows score markings and includes liberties taken in the period in which the piece was composed. 3.4. Not yet: Dynamics are incorrect more than twice (i.e., forte is not different than piano). Almost: Dynamics are incorrect no more than twice. Meets Standard: Dynamics follow the markings in the score and are clearly differentiated. Exceeds Standard: Dynamics follow score markings and includes liberties taken in the period in which the piece was composed. 3.5. Not yet: Student misses standard fingering more than once; Almost: Student misses standard fingerings once; Meets Standard: Student follows the score's fingerings; Exceeds Standard: Student develops more efficient fingering practice. 3.6. Not yet: Student pedals incorrectly two or more times; Almost: Student incorrectly pedals once; Meets Standard: Student follows the score's pedal markings; Exceeds Standard: Student pedals correctly and artistically.	1. Checklist 2. 5-point scale (0: no evidence, 1: emerging, 2: fair, 3: good, 4: superior). 3. 4-point rubric (Not yet, Almost, Meets Standard, Exceeds Standard).

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Ciorba and Smith (2009)	Multidimensional assessment rubric	1. Musical Elements (proficiency with and accuracy of musical elements, including pitch, rhythm, text articulation, and score accuracy) 2. Command of Instrument (represents the student's ability to control his or her instrument with musical intent) 3. Presentation (presentation demonstrates a lack of sensitivity to musical expression)	Qualitative descriptors (one selection per category): 1. 1 – Accuracy of musical elements does not meet minimal expectations (many noticeable mistakes); 2 – Accuracy of musical elements meets minimal competency (a few noticeable mistakes); 3 – Accuracy of elements is achieved most of the time; 4 – Accuracy of elements is proficient and well established; 5 – Precise demonstration of musical elements is demonstrated. 2. 1 – Command of instrument is below minimum expectations (demonstrates little technical control of instrument); 2 – Command of instrument demonstrates potential for musical growth; 3 – Command of instrument has achieved a point where musical maturity is possible; 4 – Command of instrument is proficient; 5 – Command of instrument demonstrates potential for professional success. 3. 1 – Presentation demonstrates a lack of sensitivity to musical expression; 2 –Presentation demonstrates a potential for musical growth; 3 – Ability to present a musical performance has achieved a point where musical maturity is possible; 4 – Presentation demonstrates that the ability to perform musically is proficient; 5 – Ability to perform musically demonstrates potential for professional success.	5-point rubric (1–5)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Russell (2010a) Original work (thesis): Russell (2010b)	Guitar performance rating scale (GPRS)	1. interpretation/musical effect 2. technique 3. rhythm/tempo 4. tone 5. intonation	1.1. Melodic expression 1.2. No contrasts in performance 1.3. The interpretation was musical 1.4. Spiritless playing 1.5. Performance not expressive 1.6. Performance reflected sensitivity 1.7. Melodic phrasing 2.1. Tone is strong 2.2. Tone is full 2.3. Thin tone quality 2.4. Tone is rich 2.5. Sound is clear and resonant 2.6. Tone quality is beautiful 2.7. There was a lack of tonal color 3.1. String crossing is controlled and smooth 3.2. Played fluently 3.3. Poor synchronization of pick and frethand fingers 3.4. Lack of clarity in picked passages 3.5. Flubbed 3.6. Attacks were clean 4.1. The tempo was steady 4.2. Correct rhythms 4.3. Off-beats played properly 4.4. Hurried repeated notes 4.5. Lack of a steady pulse 4.7. Tempo not controlled 4.8. The tempo was in good taste 5.1. Played out of tune 5.2. Intonation is good 5.3. Intonation is inconsistent 5.4. Ignored key signature	5-point scale (5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Wrigley and Emmerson (2013) Other PERS retrieved from author's doctoral thesis Wrigley (2005)	Performance examination rating scale (PERS)	Piano: 1. Technical mastery and control 2. Sound quality 3. Convincing musical understanding Strings: 1. Technique 2. Musical understanding and performance Brass: 1. Technical preparation 2. Sound production 3. Musical interpretation Woodwind: 1. Technical control 2. Sound production 3. Musicality and interpretation Voice: 1. Technique 2. Interpretation 3. Musicality 4. Communication	Piano: 1.1. notes: accurate and secure 1.2. physically: comfortable and at ease 1.3. tempo: choice well judged and steady tempo control 1.4. rhythm: accurate and secure or stable control 1.5. articulation: clear 1.6. confident: assertive, flair 1.7. memory: accurate, secure and reliable 2.1. tone, color or dynamics: variety or range and shading or depth 2.2. phrase: sufficient phrasing or shape 2.3. pedal: clear, accurate and refined 2.4. energy: high drive, forward movement, vitality or verve 2.5. flowing: highly fluent or fluid 2.6. texture: clear 2.6. projection: good 3.1. mood or emotion: well conveyed 3.2. ideas, structure, style and character: deeply understood 3.3. musically: very convincing Strings: 1.1. body: comfortable, at ease or relaxed body, technique, lh, rh playing 1.2. bow: high level of control and clear articulation 1.3. tone: full tone, sound quality or color 1.4. intonation: accurate, secure and/or reliable 1.5. vibrato: appropriate speed, flexible width and expressive 1.6. memory: secure and reliable 2.1. tempo: choice well judged and steady tempo control 2.2. rhythm: accurate and secure or stable control 2.3. phrase: well sustained, sensitive and imaginative phrase, line or shape 2.4. dynamics: high dynamic range/variety or contrast 2.5. mood/ feeling range: high degree of range or contrast of expression 2.6. vitality: high energy, drive, buoyancy or vitality 2.7. free and/or flowing: highly fluent or fluid 2.8. style and character: deep awareness and understanding 2.9. ideas: imaginative musical ideas conveyed with conviction 2.10. ensemble: high degree of balance and collaborative awareness 2.11. confident performance Brass: 1.1. notes: accurate and secure 1.2. rhythm: accurate 1.3. intonation: accurate 1.4. dynamics: contrast 1.5. tempo register/range: upper, lower 1.6. stamina/endurance 1.7. memory: accurate 2.1. tone/sound: clear 2.2. airflow/breathing: efficient	7-point scale (generally inadequate throughout; limited throughout; inconsistent throughout; moderately consistent throughout; mostly consistent throughout; consistent command throughout; complete mastery throughout)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
			2.3. articulation: clear 2.4. projection: good 3.1. musical/expressive: lyrical, drama, excitement etc. 3.2. style/interpretation 3.3. phrase/shape 3.4. confident 3.5. ensemble: balance, interaction and knowledge woodwind: 1.1. notes: accurate and secure 1.2. rhythm: accurate and secure 1.3. articulation: clear 1.4. memory: secure 2.1. tone/color: clear, even, register, vibrato 2.2. breath/air: efficient 2.3. reed intonation: accurate, control 3.1. musical/expressive: mood, lyrical, drama, spirit, energy, etc. 3.2. style/character/interpretation: sensitivity 3.3. phrase/shape: musical, legato 3.4. dynamics: contrast 3.5. tempo: steady, secure 3.6. projection 3.7. confidence 3.8. ensemble: balance, interaction and knowledge voice: 1.1. articulation: clarity, freedom 1.2. registration: low, high, balanced, tessitura 1.3. intonation: accuracy 1.4. tone/color: chiaro scuro, vibrancy, clarity 1.5. air/breath: appoggio, energy 1.6. tension: body alignment, ease 1.7. freedom 2.1. text: accuracy, clarity 2.2. interpretation: expressive, insightful, tone color 2.3. characterization: stage presentation, convincing 2.4. insight: meaningful, imaginative 3.1. style: insightful, musical integrity 3.2. phrase: direction, shape 3.3. dynamics: contrast, choice 3.4. rhythm and tempo: accuracy, choice 4.1. communication: expressive, honest, committed, engaging 4.2. poise/confidence	

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Russell (2015)	Aural musical performance quality (AMPQ)	1. tone 2. intonation 3. articulation 4. rhythmic accuracy 5. tempo 6. dynamics 7. timbre 8. interpretation 9. technique 10. musical expression 11. overall quality perception	1.1. Tone is strong 1.2. Tone is full 1.3. Thin tone quality 1.4. Sound is clear 2.1. Played out of tune 2.2. Performer was able to adjust pitch 2.3. Intonation is inconsistent 2.4. Intonation is good 3.1. Correct rhythms 3.2. Off-beats played properly 3.3. Rhythm was distorted 3.4. Insecure rhythm 4.1. Poor synchronization 4.2. Attacks and releases were clean 4.3. Impeccable articulation 4.4. Articulation is overly percussive 5.1. Tempo is steady 5.2. Tempo not controlled 5.3. The tempo was in good taste 5.4. Lack of a steady pulse 6.1. Dynamics are played 6.2. Dynamics used to help phrasing 6.3. Good dynamic contrast 6.4. Appropriate dynamics 7.1. Timbre was harsh or strident 7.2. Demonstrated a singing quality 7.3. Lacked resonance 7.4. Timbre appropriate for style 8.1. The interpretation was musical 8.2. Lack of style in performance 8.3. Effective musical communication 8.4. Melodic phrasing 9.1. Made numerous errors in technique 9.2. Insecure technique 9.3. Precision is lacking 9.4. Played fluently 10.1. Performance not expressive 10.2. Performance reflected sensitivity 10.3. Melodic expression 10.4. Spiritless playing 11.1. Overall quality lacking 11.2. Excellent performance overall 11.3. Poor performance quality 11.4. Quality of performance is good	4-point scale (4 = Strongly Agree, 3 = Agree, 2 = Disagree, 1 = Strongly Disagree)

(Continued)

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Costa and Barbosa (2015)	Scale of evaluation of the musical execution (SEME)	1. Materials 1.1. Sensorial (capacity of exploring contact with the trumpet) 1.2. Manipulative (technical manipulation and control) 2. Expression 2.1. Personal (capacity of playing expressively and with musical taste) 2.2. Vernacular (expressive sense according to the established conventions of the musical language) 3. Shape 3.1. Speculative (capacity of controlling expressive details and highlight the piece's structure) 3.2. Idiomatic (capacity of playing according to technical and aesthetic options according to the musical epoque and style) 4. Value 4.1. Symbolic (refinement of the previous parameters in combination with personal interpretation of the piece) 4.2. Systematic (technical mastery, communication, emotion, and autonomy)	1.1.1. Posture (body/embouchure) 1.1.2. Breathing control 1.1.3. Sound emission 1.2.1. Atack 1.2.2. Articulation 1.2.3. Register/tessitura 1.2.4. Tuning 1.2.5. Sound quality 2.1.1. Respect for the musical text 2.1.2. *Tempo* choice 2.1.3. Rhythmic stability 2.1.4. Use of different dynamic levels 2.2.1. Rhythmical organization of phrases 2.2.2. Melodic organization of phrases 2.2.3. Fluency of musical discourse 2.2.4. Expressivity of musical discourse 3.1.1. Security of musical discourse 3.1.2. Dynamic control and variety 3.1.3. Understanding of musical structure 3.2.1. Notion of musical style 3.2.2. Identification with epoque-related aesthetic options 4.1.1. Refinement of expressive and structural details 4.1.2. Compromise between interpretation and musical style/shape 4.2.1. Excellent technical mastery 4.2.2. Capacity of communicating and conveying emotion 4.2.3. Capacity of self-regulation	4-point scale (insufficient, sufficient, good, excellent).

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Wesolowski et al. (2017)	Music Performance Rubric for Secondary-Level Instrumental Solos (MPR-2 L-INSTSOLO)	1. technique 2. tone 3. articulation 4. intonation 5. visual 6. air support 7. melody 8. expressive devices	1.1. Finger/slide dexterity 1.2. Coordination between tongue and fingers/slide 2.1. Tone quality in varying registers 2.2. Tone while executing expressive gestures 3.1. Consistency of articulation 4.1. Intonation accuracy 5.1. Body posture 5.2. Instrument angle 5.3. Head position 5.4. Arm position 5.5. Wrist position 5.6. Hand position 5.7. Embouchure/flexibility 5.8. Cheeks 5.9. Jaw movement 6.1. Breath intake 6.2. Sufficiency of air 6.3. Air support in various registers of the instrument 7.1. Note accuracy 7.2. Communication of musical phrases 7.3. Connection of phrases 7.4. Inflection at cadence points 8.1. Stylistically related dynamics 8.2. Contrast in dynamics 8.3. Subdivision of the rhythm 8.4. Appropriateness of tempo 8.5. Steadiness of pulse 8.6. Expressive pulse and tempo fluctuation	2 to 4-point qualitative rubric, depending on the category To access descriptors of each category, see Appendix A at http://bcrme.press.illinois.edu/media/215/

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TABLE 2 (Continued)

Author (year)	Assessment system	Categories	Items	Rating method
Álvarez-Díaz et al. (2021)	Álvarez-Díaz Scale	1. Technical Level 2. Quality of interpretation 3. Stylistic coherence 4. Difficulty of the repertoire 5. Stage presence The norms in competition set weightings to the five criteria as follows: Technical level 30%, Performance quality 30%, Stylistic coherence 10%, Difficulty of chosen pieces 20%, Stage presence 10%	Select one level per category: Level 1 (1–2 points): Limited control in the production and continuity of sound and of the intonation. Limited control of mechanical skills. Limited control of the pulse and sense of rhythm. Level 2 (3–4 points): Appropriate control in the production and continuity of sound and of the intonation. Appropriate control of mechanical skills. Appropriate control of the pulse and sense of rhythm. Level 3 (5–6 points): Excellent control in the production and continuity of sound and of the intonation. Excellent control of mechanical skills. Excellent control of the pulse and sense of rhythm. 2.1. Level 1 (1–2 points): The coherence of tempi in the piece and its parts is irregular. The control of phrasing and ornamentation is irregular. Limited control of nuances, sound levels and dynamics. 2.2. Level 2 (3–4 points): The coherence of tempi in the piece and its parts is appropriate. The control of phrasing and ornamentation is appropriate. Appropriate control of nuances, sound levels and dynamics. 2.3. Level 3 (5–6 points): The coherence of tempi in the piece and its parts is excellent. Excellent control of phrasing and ornamentation. Excellent control of nuances, sound levels and dynamics. 3.1. Level 1 (1–2 points): Limited control of the characteristics which identify the artistic trend of a musical period, or genre, or a composer style in the pieces performed and the relationship between its parts. 3.2. Level 2 (3–4 points): Appropriate control of the characteristics which identify the artistic trend of the musical period, or genre, or the composer style in the pieces performed and the relationship between its parts. 3.3. Level 3 (5–6 points): Excellent control of the characteristics which identify the artistic trend of the musical period, or genre, or the composer style in the pieces performed and the relationship between its parts. 4.1. Level 1 (1–2 points): The level of virtuosity proposed is low and/or significant parts of the pieces are excluded. 4.2. Level 2 (3–4 points): The level of virtuosity proposed is adequate and significant parts of the pieces are not excluded. 4.3. Level 3 (5–6 points): The level of virtuosity proposed is extremely high and significant parts of the pieces are not excluded. 5.1. Level 1 (1–2 points): Little naturalness of gesture, poor memorization and/or independence from the score. Little care about staging or self-control throughout the performance. 5.2. Level 2 (3–4 points): Appropriate naturalness of gesture, good memorization and/or independence from the score. Appropriate care of staging and self-control throughout the performance. 5.3. Level 3 (5–6 points): Excellent naturalness of gesture, flawless memorization and/or independence from the score. Excellent care of staging and self-control throughout the performance.	6-point qualitative rubric (final score ranging from 5–30 points)

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more information). On the other hand, Davidson and Coimbra (2001) arrived at three main *a posteriori* categories (body communication, technical accuracy, artistry) based on evaluators' ratings and qualitative comments and open-ended responses.

The second-level items ranged from 10 (Stanley et al., 2002) to 44 items (Russell, 2015) across studies, with each of the previous categories commonly being expanded onto multiple items. Three systems did not present items as two comprised a direct rating per category (Fiske, 1975; Stanley et al., 2002) and the other, although mentioning that each category was defined by three items to keep evaluations short, did not provide descriptions in the corresponding article (Bergee, 2003). Items are reported in detail in Table 2.

The rating scales retrieved can be organized into three types: rating scales ($n = 19$), rubrics ($n = 4$), checklists ($n = 2$), and combined checklist and rubric ($n = 1$). Unlike traditional rating scales, rubrics provide detailed information for each score level.

In terms of the number of levels within these scales, the distribution is as follows: 14 systems used 5-point scales (qualitative, $n = 10$; qualitative rubric, $n = 2$; quantitative, $n = 1$; A – E system, $n = 1$), four used 4-point scales (qualitative, $n = 2$; qualitative rubric, $n = 1$; position only, $n = 1$), one adopted a 2 to 4-point qualitative rubric depending on the category; two used 6-point scales (qualitative, $n = 1$; qualitative rubric, $n = 1$), one used a 7-point qualitative scale, one used a 10-point quantitative scale, and one did not provide information. Two studies combined qualitative rating scales with single overall quantitative scores in 10-point and 13-letter scales. Additionally, the WFPS resulted in scores under a 12-point scale. This diverse range of rating scales highlights the variability in assessment approaches and underscores the need for standardization to ensure consistent and reliable evaluations across different studies.

3.4 Critical analysis of performance assessment methods

Our review primarily focuses on the methods of performance assessment methods. In this sense, for all studies, the primary outcome of all publications comprised the development, validation, and/or implementation of a music performance assessment. Nonetheless, we present below some of the most relevant complementary findings across studies. Table 3 synthesizes the objectives and findings for each study.

Five studies (and seven assessment systems) (Abeles, 1973; Bergee, 1993, 2003; Jones, 1986; Nichols, 1991, as cited in Bergee, 2003; Russell, 2010a; Zdzinski and Barnes, 2002) used facet-factorial approaches, defined as conceptualizing the behavior as multidimensional and selecting scale items through factor analysis, validating the method as an effective technique for the construction of rating scales. These studies collected a pool of initial items (range: 90–99) generated by experts, to which factorial techniques were applied to produce a final version of the measurement instrument that included items with high factor loadings (range: 27–32). Zdzinski and Barnes (2002) found that the factor grouping slightly differed from those in Abeles (1973) and Bergee (1993), most likely due to instrument-specific technical requirements. For example, for strings, tone and articulation were grouped in the same factor (Zdzinski and Barnes, 2002); for brass, tone and intonation were grouped and technique was accommodated in another factor (Bergee, 1993); and for woodwinds, separate factors were established for tone, articulation, and intonation (Abeles, 1973). The SPRS was the only system that included vibrato items in a separate factor. Similarly, the Jones Scale (Jones, 1986) yielded a different factor structure with Interpretation/Musical Effect as common and other factors consisting of Tone/Musicianship, Technique, Suitability/Ensemble, and Diction. The piano scale developed by Bergee (2003) consisted of only three factors (Interpretation/Musical Effect, Rhythm/Tempo, and Technique).

Wrigley and Emmerson (2013) developed PERS models for five instrument families (piano, voice, strings, brass, woodwind) distilling acceptable levels of reliability (internal reliability alphas ranging from 0.81 to 0.98) and construct validity. Their results also confirmed the importance of using instrument-specific scales, as, although the authors found consistency between instrument departments at the general factor of evaluation, they also found considerable variation between dimension constructs, which can be attributable to instrumental idiosyncrasies. Moreover, this was the only work identified in which the same author team developed evaluation systems for five instrumental families. Wesolowski et al. (2017) recently applied the Multifaceted Rasch Partial Credit Measurement Model to create a 30-item solo wind performance assessment rubric. In summary, Rasch techniques enable construct-irrelevant factors, such as individual characteristics of persons, raters, or items, to not interfere between observed data and predictions of the model, accounting for multiple issues related to individual variability observed in facet-factorial approaches. The scale displayed overall good psychometric qualities (reliability, precision, and validity).

Regarding assessment systems transversal to multiple instruments, Mills (1987) found that a bipolar scale effectively explained a high proportion of variance in overall ratings. Ciorba and Smith (2009) developed a multidimensional assessment rubric, applicable across instruments and university years, that revealed moderate to high levels of agreement among judges and was influential in measuring students' achievement, as proved by the positive correlation between performance achievement and participants' year in university (freshman, sophomore, junior, and senior). Recently, Álvarez-Díaz et al. (2021) also validated a unidimensional assessment rubric applicable across instruments.

Russell (2015) introduced novel findings regarding the weight of each performance dimension, demonstrating a positive causal relationship between technique and musical expression. Technique showed direct effects on the ratings of overall quality and musical expression, while musical expression demonstrated direct effects on overall quality only, suggesting that deficiencies in technique will not only influence assessments of it but also of musical expression and the overall perception of performance quality.

In a literature review, Zdzinski (1991) discussed that despite the widespread application of the Watkins-Farnum Performance Scale (1954) in music performance research up to date, studies have shown moderate and low validity coefficients (e.g., 0.63, 0.40, 0.12) when comparing the WFPS with other scales. Moreover, the WFPS is based on calculating a score derived from bar-by-bar performance errors (e.g., rhythm, pitch), which poses multiple drawbacks: (a) the final score does not allow for differentiation of errors as they are summed; (b) only one point (corresponding to one error) can be deducted by measure regardless of the number of errors occurring; and (c) the score does not

TABLE 3 Objectives and synthesized findings of included studies.

Author (year)	Objectives	Findings
Abeles (1973)	To examine a technique for the development of performance rating scales to measure achievement.	The three major results of the study were: (1) a 30-item rating scale based on a six-factor structure of clarinet music performance; (2) high inter-judge reliability estimates for both the total score (> 0.9) and the scale scores (> 0.6); and (3) criterion-related validity coefficients >0.8. Such results suggest that the facet-factorial approach can be an effective technique for the construction of rating scales to measure complex behavior such as music performance.
Fiske (1975)	To examine differences in trumpet performance assessment between brass and non-brass judges, and wind and nonwind judges.	The results showed no significant differences between brass and non-brass judges. Technique was found to be rated significantly different when wind judges were compared with nonwind judges, and it was also the most distinct trait when the groups of judges were combined into a single judge group and the five rated traits were intercorrelated.
Mills (1987)	To analyze the assessment of solo musical performance in the Western Classical tradition and to offer a model which can be used to better measure solo music performance.	The results showed that a high proportion of the variance in the overall marks can be accounted for by linear and quadratic equations in the bipolar "constructs," meaning that the overall marks can be explained in terms of characteristics which can be understood by nonspecialists, and which are not related to instrument-specific technique. The proportion of variance in rank accounted for was hardly less among nonspecialists than among music specialists; overall marks given by nonspecialists seem as "rational" as those given by specialists.
Zdzinski (1991)	To review studies dealing with solo instrumental music performance measurement and their implications for future research in performance measurement.	The Watkins-Farnum Performance Scale (1954) has been widely used in music education research as a measure of performance achievement despite its seemingly validity problems. Other studies have attempted to improve musical performance evaluation by replacing ratings based on overall impressions with more systematic rating scales and by using evaluative criteria that sample performance areas. Reliability and validity data for these studies seem promising (Abeles, 1973; Bergee, 1987), suggesting that common judging criteria help to improve musical performance evaluation. Another promising area regards the advances in acoustic and computer-assisted measurement, suggesting that several performance parameters can be judged with great accuracy and increased reliability.
Bergee (1993)	To explore the efficacy of peer and self-evaluation of applied brass jury performances considering faculty evaluation as standard of comparison. Second, to assess the effects of videotape vs. live performance and internal vs. external adjudicators on evaluation.	Inter-judge reliability for faculty and peer evaluation panels generally was high, with total score correlations ranging from 0.83 to 0.89 ($p < 0.01$). Correlations among faculty and peer-group evaluations also were high, with total score r ranging from 0.86 to 0.91 ($p < 0.01$). Data indicated consistent agreement on factors describing musical effectiveness, tone quality/intonation, and technique. Rhythm-tempo, however, revealed less consistency of agreement. Consonant with prior investigations, self-evaluation correlated poorly with faculty and peer evaluation. The effects of videotaped performances were minimal and prior knowledge of performers did not seem to affect evaluations.
Winter (1993)	To examine the effects of training and experience on qualified musicians' and music educators' judgments.	The results suggested that the training a music examiner receives prior to the performance assessment session may be more important in producing consistent and accurate reports than the amount of previous examining experience. The criteria used by the music examiner should be clearly presented with appropriate dimensions for the musical instrument on which the student performs.
Saunders and Holahan (1997)	To determine the suitability of the use of criteria-specific rating scales in the selection of high school students for participation in an honors ensemble.	The rating scales yielded substantial variability and moderately high-to-high alpha reliabilities. Different judges collectively demonstrated a consistency of performance evaluation results. The data presented provided indirect evidence that criteria-specific rating scales have superior diagnostic validity than Likert-type rating scales and traditional open-ended rating forms. Stepwise multiple regression indicated that student total scores could be predicted from scores of five major dimensions: tone, technique/articulation, rhythmic accuracy, interpretation, and sight-reading-interpretation (Multiple $R = 0.96$).
Davidson and Coimbra (2001)	To examine issues related to assessing biases and development of assessment criteria by studying the case-study of the evaluation processes undertaken by a panel assessors of mid-term recitals at the Guildhall School of Music.	The major categories assessors relied on for their evaluation were: body communication, technique, and presentation of musical content (i.e., emotional expression, personality of the interpreter). The assessors showed a high degree of correlation in their assessment grades and the way in which they discussed individuals, indicating that they shared similar ideas. Nonetheless, the criteria for the assessments were implicit rather than explicit: in one hand, results suggested that there was a shared code of assessment criteria between assessors; on the other, the lack of articulated criteria means that no individual assessor is certain of what beliefs (personal or others') drove decisions.

(Continued)

TABLE 3 (Continued)

Author (year)	Objectives	Findings
Stanley et al. (2002)	To investigate examiner perceptions of the effects of introducing criteria into music performance assessment procedures at a tertiary conservatorium of music.	In discussing their music performance assessment strategies examiners described holistic and criteria-specific approaches. Some examiners felt using criteria helped them focus on important assessment issues and that criteria were useful for articulating desirable performance characteristics in feedback to students. Other examiners believed criteria-based assessment represented a narrow view which tended to interfere with their holistic assessments of music performance. Discussions generated a new assessment system to be implemented in this pedagogical context.
Zdzinski and Barnes (2002)	To develop a valid and reliable assessment measure for stringed instrument performance.	The factor analysis of an initial pool comprising 90 assessment items resulted in the detection of five principal factors (interpretation/musical effect, articulation/tone, intonation, rhythm/tempo, and vibrato) and the selection of 28 items for the subscales of the SPRS. Reliability varied from 0.873 to 0.936 for each judging panel. Two studies were conducted to establish criterion related validity, with correlations ranging from 0.605 to 0.766 between the SPRS and two other rating scales.
Bergee (2003)	To examine the inter-judge reliability of faculty evaluation of end-of-semester applied music performances considering the variables variability in size of adjudication groups, mode of evaluation, and adjudication experience.	Full-panel inter-judge reliability was consistently good regardless of panel size. All total score reliability coefficients were statistically significant, as were all coefficients for the global letter-grade assessment. All subscale reliabilities for all groups except Percussion (which, with an $n = 2$, had a stringent significance criterion) were statistically significant, except for the Suitability subscale in Voice. For larger panels ($n =$ of 4 and 5), rating scale total score reliability was consistently but not greatly higher than reliability for the letter-grade assessment. There was no decrease of average reliability as group size incrementally decreased. Permutations of two and three evaluators, however, tended on average to exhibit more variability, greater range, and less uniformity than did groups of four and five. No differences in reliability were noted among levels of experience or between teaching assistants and faculty members. Use of a minimum of five adjudicators for performance evaluation in this context was recommended.
Thompson and Williamon (2003)	To develop a research tool by examining some of the assumptions and implications inherent in any formal system of musical performance assessment, and to illustrate some of these by reporting data from an empirical study.	Correlations between evaluators were moderate and some evidence of bias according to the evaluators' own instrumental experience was found. The use of a larger n of evaluators is recommended to fade away individual differences. Strong positive correlations were found between items on the assessment scheme, indicating an extremely limited range of discrimination between categories. This can be attributed to semantic problems which can be solved by providing more precise guidelines, defining each category in detail.
Barry (2009)	To explore some of the key topics related to music performance evaluation including significant political and social issues, pitfalls and concerns.	While both formal and informal evaluations are inherent and essential aspects of music learning and performance, the particulars of how to carry out evaluation as well as how the results of evaluation should be used remain controversial. Apart from presenting the example performance evaluation tools, the author also provides instructions on how to develop such instruments.
Ciorba and Smith (2009)	To investigate the effectiveness of a multidimensional assessment rubric administered to all students performing instrumental and vocal juries at a private Midwestern university during one semester.	Inter-judge reliability coefficients indicated a moderate-to-high level of agreement among judges. Internal reliabilities were consistent within each performing area. Results also revealed that performance achievement was positively related to participants' year in school, which indicates that a multidimensional assessment rubric can effectively measure students' achievement in solo music performance. High correlations among scale dimensions were found. Although the unique contribution of each score to the composite may be limited, the comparison of scores in different dimensions presents a profile of student achievement that can lead to plans for future instruction to address areas of weakness, supporting the benefits of criteria-based systems in comparison to overall ratings.
Russell (2010a)	To identify the underlying aural factors of guitar performance by developing a guitar performance rating scale using facet-factorial techniques.	The results of a factor analysis applied to an initial pool of 99 item statements yielded a five-factor structure comprising interpretation, tone, technique, rhythm/tempo, and intonation. These factors accounted for approximately 71% of the total variance. The selection of the 32 items chosen to represent the factors of the Guitar Performance Rating Scale (GPRS) was based on factor loadings. Alpha reliability for the GPRS was estimated at 0.962 for the 32-item scale.

(Continued)

TABLE 3 (Continued)

Author (year)	Objectives	Findings
Wrigley and Emmerson (2013)	To investigate ways to improve the quality of music performance evaluation in tertiary music education.	Findings suggested that, although several construct and general dimension commonalities were found among the items across all scales, the presence of significant instrument-specific differences indicated that the use of generic rating scales may not provide sufficient content validity. This study demonstrated that disciplinary objectivity in music performance assessment could be empirically defined and measured within an ecologically valid framework at a tertiary-level Australian music institution using a rigorous combination of qualitative and quantitative methodologies. Each of the PERS models (piano, voice, strings, brass, woodwind) provided acceptable levels of reliability and construct validity. High internal reliabilities were found with each of the PERS factors, with alphas ranging from 0.81 to 0.98.
Russell (2015)	To test a hypothesized model of solo music performance assessment, considering the influence of technique and musical expression on perceptions of overall quality.	The analysis of the performance data in relation to the proposed model demonstrates a significant and positive causal relationship between technique and musical expression. Results indicated the ability to predict increases in the perception of overall quality both directly and indirectly through technique and musical expression. Technique demonstrated direct effects on overall quality and expression, while expression demonstrated direct effects on overall quality only. Results suggest that deficiencies in technique will not only influence assessments of technique, but also musical expression and overall perception of performance quality.
Costa and Barbosa (2015)	To contrast the assessments done by trumpet's teachers, based on Scale of Evaluation of the Musical Execution, with the free assessments carried out by the same group of teachers.	By comparing the two forms of evaluation, we verify the inconsistency of the assessments and judgments in respect to the performance of the students. Although results showed high inter-judge variability in both evaluation models, variability increased in evaluations without pre-defined criteria. Additionally, our results show that Trumpet's teachers´ evaluation of the students´ instrumental performance is mostly focused on two dimensions: materials and expression, which are stages at the most basic levels of the Spiral Theory.
Wesolowski et al. (2017)	To describe the development of a valid and reliable rubric to assess secondary-level solo instrumental music performance based on principles of invariant measurement.	The result was the development of the Music Performance Rubric for Secondary-Level Instrumental Solos (MPR-2L-INSTSOLO), a 30-item rubric consisting of rating scale categories ranging from two to four performance criteria. The scale displayed overall good psychometric qualities (reliability, precision, and validity). This is the first music performance assessment measure developed using item response theory techniques and, more specifically, Rasch measurement techniques.
Álvarez-Díaz et al. (2021)	To design and validate an analytical evaluation rubric allowing for the most objective evaluation possible of a musical solo performance in a regulated official competition.	The essential unidimensionality of the rubric was confirmed. The results of the PCA indicated that the five criteria can be summarized in a single factor accounting for 80% of the variance. No differential effects between raters were found, nor were significant differences seen in each rater's internal consistency.

include parameters such as musicality, phrasing, or intonation. The author also highlighted that systematic and criteria-based assessment systems such as the ones by Abeles (1973) or Bergee (1993), yielded promising results in terms of reliability and validity. Saunders and Holahan (1997) and Barry (2009) also emphasize that, although more challenging to build, criteria-specific rating scales have superior diagnostic validity than Likert-type rating scales and traditional open-ended rating forms. In line with these findings, Costa and Barbosa (2015) discovered that variability within trumpet judges increased in evaluations without pre-defined criteria, although it was generally high in both free and criteria-based evaluation models. In fact, multiple studies reported high correlations between performance assessment categories (Álvarez-Díaz et al., 2021; Ciorba and Smith, 2009; Fiske, 1975; Thompson and Williamon, 2003), underscoring that, although the unique contribution of each score to the composite may be limited, the comparison of scores in different dimensions presents a profile of student achievement that can be transposed into valuable feedback related to specific performative skills and lead to plans for future instruction to address areas of weakness.

From a complementary perspective, Davidson and Coimbra (2001) found that, although assessors demonstrated high degrees of correlation in grades, their criteria were implicit rather than explicit. Assessors seemed to share a code of assessment criteria but lacked articulation and delimitation, suggesting that they were uncertain of what their own or others' beliefs drove decisions. In the interview study by Stanley et al. (2002), examiners at a tertiary music conservatorium presented mixed opinions regarding criteria-based assessments. While some felt using criteria facilitated the focus on essential assessment issues and was helpful in articulating desired performance characteristics in feedback to students, others believed criteria-based assessment represented a narrow view that tended to interfere with their holistic assessments of music performance. Discussions with examiners led to the adaptation of the conservatorium's assessment system, considering their preference for fewer criteria so that more time could be dedicated to writing detailed comments (Stanley et al., 2002).

Regarding mediator factors in performance assessment, studies reported no differences between brass and non-brass judges (Fiske, 1975), nor between music specialists and nonspecialists (Mills, 1987). Nevertheless, in Mills (1987), the constructs used did not require possessing musical knowledge (e.g., the performance was hesitant/fluent). Fiske (1975) also found that technique was rated differently between wind and nonwind judges (Fiske, 1975), and Thompson and Williamon (2003) reported evidence of bias according to examiners' instrumental expertise. Bergee (1993) found high inter-judge reliability for faculty and peer evaluation panels, demonstrating consistent agreement on all factors but rhythm-tempo; self-evaluation,

however, correlated poorly with faculty and peer evaluation. No differences were found between levels of evaluative experience or between teaching assistants and faculty members (Bergee, 2003). In fact, Winter (1993) found that the prior training received by music adjudicators was more significant in producing consistent and accurate assessments than the previous experience in such a role. Finally, Bergee (2003) found that inter-judge reliability was consistently good regardless of panel size, although permutations of two and three evaluators tended to exhibit more variability, greater range, and less uniformity than did groups of four and five. Hence, the author recommended using at least five adjudicators for performance evaluation. Furthermore, the same study found no effects of videotaped (versus live) performances or prior knowledge of performers.

4 Discussion

4.1 Main findings

This systematic review summarized solo music performance assessment methods reported in published scientific research for over 50 years. Significant heterogeneity was observed between the included studies regarding the assessment systems used to evaluate performances, allowing for the retrieval and analysis of 26 different systems reported across 20 publications. We found 11 generalized, six family-, and nine instrument-specific scales, among the identified systems. Some studies advocate for adopting family- and instrument-specific scales that consider the idiosyncrasies related to instrumental and vocal technique. For example, in assessing vocal performance, diction and language facility are relevant skills (Jones, 1986), just as breathing, air support, and tongue are for winds (Bergee, 1993; Wesolowski et al., 2017) or vibrato for strings (Zdzinski and Barnes, 2002). The argument for instrumental scales is further supported by findings such as rating differences between wind and nonwind judges in the technical dimension (Fiske, 1975), evidence of bias according to examiners' instrumental expertise (Thompson and Williamon, 2003), substantial variability between instrument departments on the level of dimension constructs (Wrigley and Emmerson, 2013), and factor grouping of assessment items varying between instrumental families [e.g., the String Performance Rating Scale by Zdzinski and Barnes, 2002 yielded a different factorial organization than the Clarinet Performance Rating Scale by Abeles, 1973]. On the contrary, generalized scales seem to facilitate the standardization of assessment practices across instrumental and vocal departments and foster the development of a common criteria vocabulary among examiners, a previously identified deficiency (Davidson and Coimbra, 2001). After carefully considering examiners' opinions, requesting fewer criteria and more space for subjective comments, one tertiary music conservatorium replaced a family-directed assessment system with a set of common assessment criteria (Stanley et al., 2002). Generalized systems have been successful in contexts where direct comparisons are desired, for instance, in measuring students' achievement throughout university years (Ciorba and Smith, 2009), in multi-instrument competitions (Álvarez-Díaz et al., 2021), or in music performance assessment by non-experts (Mills, 1987). We conclude that, as posed by Barry (2009), there is no "one-size-fits-all approach to music evaluation" and that, depending on the context, function of the assessment, and institutional culture, both generalized and instrument-oriented methods can be effectively implemented.

Regarding the main assessment categories, most assessment systems adopted a structure comprising one technical category, one interpretative/expressive category, and multiple musical feature categories (e.g., pitch, rhythm, intonation). Additionally, eight systems reserved one category for stage presence, and even fewer encompassed categories for aesthetics and epoque adequacy, and body behavior. Although this structure seems reasonable, one may reflect on how technique relates to both musical effect execution and interpretation. Musical execution and communication are only attainable if the performer possesses substantial skill levels in their instrument, supporting the priority to developing a precise technique in music education settings (Gellrich and Parncutt, 1998; McPherson, 2022). For example, clarinet players' finger movements in pressing and releasing keys, together with breathing, determine the timing of tone onsets (also known as tempo or rhythmic accuracy in the categories of assessment systems) (Palmer et al., 2009). Similarly, violin players need to master upper body movements to express melodic continuity through timing (*rubato*), a common marker of personal interpretation (Huberth et al., 2020). Russell (2015) findings further support this notion, showing that technique directly impacts the ratings of overall quality and musical expression, while musical expression solely impacts the overall quality. Hence, technical deficiencies affect not only on technique ratings but also on the perception of musical expression and the overall performance quality. In accordance, Álvarez-Díaz et al. (2021) attributed the higher assessment weights (30% each) to the technical level and performance quality, followed by the difficulty of chosen pieces (20%), stylistic coherence, and stage presence (10% each). This categorical intertwinement has also been noted through inter-category correlations in several studies (Álvarez-Díaz et al., 2021; Ciorba and Smith, 2009; Fiske, 1975; Thompson and Williamon, 2003). Considering these findings, we believe it is worth reflecting on the weight given to the technical category in relation to others and to what extent it could be pertinent to aggregate skills related to musical features, such as pitch, intonation, or articulation, in this sector.

By analyzing the rating scales implemented, we identified that most assessment systems used 5-point Likert qualitative scales, which reflect the evaluators' level of agreement with a set of assessment elements. However, we noted that, gradually, more recent studies started replacing these with rubrics, which provide detailed descriptions for each level of the achievement scale. Such descriptions constitute beneficial feedback for the evaluated individuals, as they present a clearly defined set of descriptors related to learning expectations, providing both a measure of the present performance and information to improve future performances (Ciorba and Smith, 2009). Moreover, rubric descriptors also facilitate the examiners' role by delimiting the expected outcomes for each level, again promoting the much-needed common understanding of assessment criteria (Wesolowski, 2012). In terms of the number of levels within scales, consensus among authors appeared challenging to reach. Most kept to traditional 5-point Likert scales (e.g., Bergee, 2003; Saunders and Holahan, 1997), while some selected even numbered scales (e.g., 4-point) to eliminate neutral categories by forcing positively or negatively positioned responses (Mills, 1987; Wesolowski et al., 2017),

and others adopted 1–10 quantitative scales due to their direct relation with the 100-point scale frequently used in music educational contexts (Thompson and Williamon, 2003). Research has shown that scales with more than 10 points result in decreased reliability, although they provide respondents with increased precision levels (Preston and Colman, 2000), and that 5-point scales can produce inconsistent answer scores (Toepoel and Funke, 2018). Curiously, seven-point scales seem to be the best compromise (Krosnick and Fabrigar, 1997; Maitland, 2009), and they were only adopted in the PERS (Wrigley and Emmerson, 2013). Nevertheless, it is crucial to highlight that, in developing rubrics, implementing a high number of levels can be challenging, as it becomes more difficult to define differences between expected outcome descriptors.

One surprising finding regards the almost imperceivable differences in assessment criteria between diverging types of populations. Most of the studies focused on either high schoolers or university students, representing distinct performance levels. Hence, we expected that, at the item level, descriptions would be adapted to the expected skill competence for each learning stage. However, the descriptions were general to the extent to which most items were applicable to multiple populations. For example, when presented with the following item: command of instrument is (select one option) below minimum expectations/demonstrates potential for musical growth/has achieved a point where musical maturity is possible/is proficient/demonstrates potential for professional success (Ciorba and Smith, 2009), judges are unable to infer what is, indeed, the expected command of instrument for the student at hand. For example, for a beginner saxophone player, producing sound without squeaking would be a good demonstration of the command of the instrument, while for a superior-level student, it could be the ability to play harmonics while maintaining intonation and timbre quality. Barry (Barry, 2009) introduces a fine example of a rubric adapted for a preparatory piano exam in which descriptors are objective and level-appropriate (e.g., not yet – student misses standard fingering more than once; almost – student misses standard fingerings once; … exceeds standard – student develops more efficient fingering practice). Without a doubt, music performance assessment, unlike more objective disciplines, is particularly defying due to the involvement of expressive decisions and response divergence (Wesolowski, 2012). Moreover, it has been discussed that music educators, in particular, face challenges in systematically documenting and quantifying the essential concepts and skills they want their students to acquire and demonstrate at different levels of performance achievement (Payne et al., 2019; Wesolowski, 2015). Therefore, we postulate that the level of accuracy the assessment systems lacked in determining the specific goals for each learning stage may be a reflection of the path music education has yet to pursue to reform outdated practices and adopt more effective, efficient, and clearly defined methods for measuring student growth, aligning with other general education policies.

4.2 Limitations

Two main limitations were identified in this work. First, we included only reviews and original research published in peer-reviewed journals. Citation searches revealed that numerous studies on music performance assessment exist in grey literature, such as doctoral dissertations and institutional pedagogical guidelines. However, many assessment systems initially presented in these were later converted into articles by the same authors or implemented by others. Therefore, we focused this review on published, peer-reviewed works to ensure validity and scientific rigor, even though it may have implicated discarding additional publications. Second, our review's scope limits our ability to draw conclusions about the efficacy of the assessment systems reported. We focused on their construction, characterization, and validation rather than analyzing replication studies. While the assessment systems analyzed generally reported good reliability and consistency in their original studies, subsequent research might have identified weaknesses. For instance, Zdzinski (1991) noted in his literature review that multiple *post hoc* studies using the Watkins-Farnum Performance Scale (1954) had already revealed moderate and low validity coefficients compared to other scales. Future research should map the use of various assessment systems post-implementation, providing insights into their frequency of use and into additional validity results.

5 Conclusion

In conclusion, this review documents the major progress in music performance assessment simultaneously underscores the imperative for continued research to address persistent gaps and improve existing methodologies. We investigated music performance assessment systems found in scientific literature, analyzing their corresponding evaluation categories and descriptive criteria, rating methodology, and target audience. A total of 51 full-text publications were assessed for eligibility, which were reduced to 20 articles that met the inclusion criteria.

The literature review identified 26 assessment systems for detailed analysis. Most studies evaluated high school and university students, with evaluators primarily being music teachers and faculty members. About one-third of the studies assessed a heterogeneous group of instrumental and vocal performances, while the others focused on specific instruments/voice or instrumental families. Consequently, most assessment systems were designed for use across various instruments, though some were family- or instrument-specific. Many systems followed a structural logic including one technical category, one interpretative/expressive category, and multiple musical feature categories (e.g., pitch, rhythm, intonation), further expanded into descriptive items. Five-point Likert qualitative scales were most common, though recent studies showed a trend towards rubrics for detailed feedback, facilitating both examiners comprehension and student progress. Interestingly, no differences were found in assessment criteria for students at different learning stages. Research efforts should be directed toward developing and validating assessment criteria specific to different proficiency stages. Customizing assessment tools to meet the needs of beginners, intermediate, and advanced students is crucial. It allows educators, researchers, and curriculum developers to offer more relevant and constructive feedback, a contribution that is crucial for fostering individual growth and progress in music performance. Also, this strategy ensures that assessment methods are suitably challenging and developmentally appropriate for each level of a student's educational journey.

By delimiting and characterizing the existing assessment systems, this study represents a novel contribution for educators and policymakers looking to enhance curriculum design and instructional practices in music education, as well as for researchers aiming to design science-based, objective performance assessment studies. With continued efforts in these areas, we can look forward to a future where music performance assessments are more reliable, equitable, and truly support and enhance the musical journey of every student.

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/s.

Author contributions

NM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. PD: Conceptualization, Validation, Writing – review & editing. LV: Conceptualization, Validation, Writing – review & editing. PO-S: Validation, Writing – review & editing. SS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, 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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Exploring the well-being of professional female musicians: a self-determination theory perspective

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Background: This study investigated the well-being of 16 professional female musicians through the lens of Self-Determination Theory, focusing on the satisfaction of their psychological needs for autonomy, competence, and relatedness, as well as the unique challenges they encounter in their careers.

Methods: Semi-structured interviews were undertaken and analyzed using thematic analysis.

Results and discussion: Three broad themes and 10 sub-themes emerged from the interviews. The findings demonstrate that the well-being of female musicians is closely tied to the satisfaction of their psychological needs for autonomy, competence, and relatedness. Conversely, when these needs are frustrated, their well-being is negatively impacted. Other themes that emerged from the interviews are intrinsic motivation and the gender specific challenges within the music industry.

Conclusion: The study highlights the need for supportive environments to enhance the well-being of female musicians (and performers as a whole), addressing both their psychological needs and the specific gender-related challenges they face.

KEYWORDS

professional musicians, women, well-being, self-determination theory, qualitative interviews

1 Introduction

For over 20 years, the World Health Organization (2024) has identified psychological well-being as a pivotal health concern in contemporary society. Despite this recognition, well-being in performance domains, particularly music, has only recently garnered research attention (Ascenso et al., 2018; Bonneville-Roussy and Vallerand, 2020). Well-being generally refers to an individual's overall mental, emotional, and social health, encompassing aspects such as life satisfaction, happiness, and the ability to manage stress and challenges (Seligman, 2018). The work of Ascenso et al. (2017, 2018, 2022) has been crucial in understanding how well-being is experienced in professional musicians. Their work has examined musicians' psychological well-being through the PERMA model, which delineates five core elements of human flourishing: Positive Emotions, Engagement, Relationships, Meaning, and Accomplishment (Seligman, 2011).

Contrary to common perceptions of musicians' lifestyles, Ascenso et al. (2017) observed that engaging in music is often viewed as challenging to well-being, noting that "Music activity has typically been considered a threat to holistic well-being" (p. 66). Their research, which

involved in-depth interviews with professional musicians, revealed that some individuals struggle to separate their personal identity from their musical identity, leading to emotional and professional instability. However, the authors also found that many musicians demonstrate resilience: their ability to cope with and recover from the challenges they face in their careers. Professional musicians also experience flow, excitement, and positive emotions that enhance their overall well-being (Ascenso et al., 2017). Moreover, musicians often work in high-stress environments, where the pressure to constantly perform at a high level can lead to anxiety and a hindered sense of well-being (Bonneville-Roussy and Vallerand, 2020). In sum, well-being in musicians is multifaceted, involving the balance between managing the stressors of a high-pressure profession and nurturing the positive psychological satisfaction that comes with musical engagement. Furthermore, women in music face additional challenges, including longer leaves of absence, irregular schedules, and financial instability, which may hinder their well-being (Hruska and Bonneville-Roussy, 2022). Notably, in most countries worldwide, women continue to pursue gender equality in professional musical environments (Smith and Hendricks, 2022; Valenzuela et al., 2020).

Self-Determination Theory (SDT; Deci and Ryan, 1985) is a robust framework for examining motivation as a pathway to well-being, particularly in high-performance domains such as music. By focusing on the satisfaction of the psychological needs for autonomy, competence, and relatedness, SDT provides insights into how these factors contribute to overall well-being (Ryan and Deci, 2017). The present study aims to explore the well-being of female professional musicians through the lens of needs satisfaction and SDT. To explore these complex dynamics in professional female musicians, we employed a qualitative method, specifically thematic analysis of interviews, which are well-suited to capturing the depth and nuance of participants' lived experiences (Braun and Clarke, 2006). Previous studies, such as Ascenso et al. (2017) have successfully used a similar methodology to uncover the multifaceted nature of musicians' well-being. This approach enables us to align participants' narratives with SDT's theoretical constructs, offering a comprehensive understanding of the interplay between motivation, well-being, and gender-specific challenges in the music industry.

1.1 Self-determination theory and psychological needs

Understanding the mechanisms that underpin well-being in musicians is essential, particularly concerning how motivation can be sustained throughout their careers. The goal of nearly every classical music student is to become a professional performer. However, only a small percentage achieve this goal, with even fewer women reaching this level (Alberge, 2024). Those who achieve top-level success have invested thousands of hours in focused practice (e.g., Ericsson et al., 1993). Achieving such an elite musical status requires considerable motivation (Hatfield, 2024). One theory of human motivation frequently used to study musicians is SDT (Deci and Ryan, 1985; Ryan and Deci, 2017). SDT, as a theory of human motivation, focuses not only on the amount of motivation but mostly on the quality of that motivation. At its core, SDT distinguishes between intrinsic (driven by the sheer enjoyment and interest of doing an activity) and extrinsic forms of motivation (driven by internal or external outcomes, such as rewards or punishments), with intrinsic motivation fostering the highest quality of motivation. This theory has had profound implications in various fields, including music, where understanding the motivational dynamics can significantly influence career success among professional musicians (Evans, 2015; Evans and Ryan, 2022). For instance, Evans and Bonneville-Roussy (2016) and Bonneville-Roussy and Evans (2024) found that higher levels of autonomous motivation (in which intrinsic motivation is included) predicted greater practice frequency and higher levels of psychological well-being in student musicians. Most SDT research in music has focused on these types of motivation and how they relate to musicians' achievement, persistence and well-being, especially in music students (Bonneville-Roussy et al., 2020; Evans, 2015; Evans and Bonneville-Roussy, 2016). This aspect may also be crucial for professional musicians, particularly in ensuring that their motivation is sustainable in the short term and throughout their musical lifespan (Evans, 2015) (Deci and Ryan, 1985; Ryan, 2023; Ryan and Deci, 2000, 2017).

SDT also posits that humans have three fundamental psychological needs—autonomy, relatedness, and competence (Deci and Ryan, 1985; Ryan, 2023; Ryan and Deci, 2017). The fulfillment of these needs fosters intrinsic motivation, growth, and well-being (Ryan and Deci, 2017). These needs align with key concepts of well-being, such as fostering positive emotions, engagement, and relationships (Seligman, 2011). While these three psychological needs are well understood in music students (Evans, 2015), their roles in the lives of professional musicians remain largely unexplored. SDT links the spectrum of extrinsic to intrinsic motivation with psychological needs by suggesting that the more the needs are satisfied within a given activity, the more intrinsically motivated a person is likely to be in that activity and the more they are likely to derive well-being from it (Cerasoli et al., 2016; Ryan, 2023; Ryan and Deci, 2017; Slemp et al., 2024). For elite performers, such as athletes, musicians, and experts in the workplace, satisfying these needs is critical to achieving peak performance and well-being. Nevertheless, most research on psychological needs satisfaction has been done with students or young athletes (Cerasoli et al., 2016).

1.2 Autonomy, competence, and relatedness in music

Autonomy refers to the need to feel in control of one's actions and decisions. In the context of elite performance, autonomy is crucial for fostering intrinsic motivation. Studies have shown that when elite performers feel they have a choice in their decisions, they are more likely to feel intrinsically motivated and experience enjoyment, leading to enhanced performance (Bonneville-Roussy et al., 2020; Lonsdale et al., 2009; Lundqvist and Raglin, 2015). Moreover, autonomy-supportive environments that provide options and encourage input have been linked to higher satisfaction levels (Adie et al., 2012; Bonneville-Roussy et al., 2013, 2020).

Competence involves feeling effective and capable of achieving desired outcomes. For elite performers, continuous improvement and mastery are vital (Cerasoli et al., 2016). The sense of competence is reinforced through clear feedback and achievable challenge levels. In high-stakes environments, feedback that emphasizes skill development rather than outcomes helps sustain motivation in the long run. Research highlights that athletes who perceive their environments as supportive of skill development report higher levels of sustained engagement and performance (Cerasoli et al., 2016; Verner-Filion and Vallerand, 2018).

Relatedness is the need to feel connected to others. Fulfilling the need for relatedness can be particularly challenging for elite performers, including orchestral musicians. While orchestral musicians work in ensemble settings, the competitive and high-performance nature of their roles can still lead to a sense of isolation. Research has shown that a robust support system can significantly impact performers' psychological well-being, particularly in long-cycle domains like orchestral music and competitive sports (Evans, 2015; Larson et al., 2019; Reis et al., 2000). For example, research by Williamon and Antonini Philippe (2020) has found that musicians and athletes both benefit significantly from a strong social support system to mitigate stress and enhance performance. Satisfying the basic psychological needs outlined by SDT is crucial for elite performers across various domains. Ensuring that these needs are met promotes higher performance levels and well-being.

Prior studies have underscored the critical role of fulfilling psychological needs in music. Freer and Evans (2019) have demonstrated that the satisfaction of the needs for autonomy, competence and relatedness directly influences the decision to continue in music. Research has shown that autonomy support is linked with musicians' achievement, persistence and well-being (Bonneville-Roussy et al., 2013, 2020; Krause et al., 2019). Further supporting these findings, research has identified a positive relationship between fulfilling these needs and musicians' persistence, higher levels of internal motivation, practice, and challenge-seeking. In contrast, frustration of these needs had the opposite effect, with less effective stress management skills and less ongoing commitment to a music career (Ascenso et al., 2017, 2018, 2022; McCready and Reid, 2007). Alessandri et al. (2020) have found that perceptions of competence among musicians are closely linked to their well-being. In professional musicians, creating a sense of belonging and feeling that they are part of a musical community is especially important. Although these studies mainly cater to music education contexts, they highlight outcomes relevant to the professional music setting. These findings collectively suggest that the satisfaction of the three basic psychological needs plays a pivotal role in the musical lives and well-being of musicians.

1.3 The challenges of being a woman in music performance

Women in the professional music industry face numerous challenges rooted in historical biases and contemporary societal norms (Smith and Hendricks, 2022). Research has shown that highly qualified music listeners are unable to distinguish between male and female performers when presented with auditory information alone (without visual information; Davidson and Edgar, 2003; Sergeant and Himonides, 2014). In spite of this, women remain disproportionately underrepresented in the classical music industry despite often having equal or greater representation in music education (Goldin and Rouse, 1997; Smith and Hendricks, 2022). Sergeant and Himonides (2023) have found that under 40% of musicians are women in the top 40 orchestras internationally. Men predominantly hold higher-level positions like conductors, soloists, principal musicians, and artistic directors (Scharff, 2018; Sergeant and Himonides, 2014, 2019). Women, on the other hand, are disproportionately more likely to become music teachers. While hiring practices have improved over recent years, discrepancies in gender pay persist (Smith and Hendricks, 2022). These structural challenges likely have significant psychological impacts on female musicians, yet their effects on well-being remain underexplored. While existing research has largely focused on issues such as representation and pay equity, it has often neglected the lived experiences of women in these professional contexts.

The primary challenge women face in Western classical music may no longer be overt sexism. Instead, a variety of factors may hinder the careers of female musicians. In a qualitative study that investigated the challenges of professional female musicians in Australia, Green and Mitchell (2023) have found that women face issues such as bias in the audition process, isolation, lack of support, stereotyping within male-dominated cultures, and a scarcity of female role models within orchestras. In addition, the greater caregiving responsibilities women typically assume may deter them from pursuing top-tier roles in the field (Hruska and Bonneville-Roussy, 2022). Moreover, women often encounter challenges related to work-life balance, particularly concerning ongoing family responsibilities. The need for touring and irregular hours can be particularly unforgiving for women seeking to balance family life (Cohen and Ginsborg, 2021). Many female musicians postpone or opt out of motherhood, fearing that taking parental leave might jeopardize their careers. Moreover, secure positions in music are scarce, with most being temporary contracts. This precarity is exacerbated for women returning from extended parental leave, who face the significant risk of being overlooked for rehire. Although women face these challenges, there is a lack of evidence of their impact on their daily lives and whether they affect their well-being.

1.3.1 Needs satisfaction, well-being, and performance of female musicians

The intersection of gender and well-being in music performance has drawn increasing attention, particularly in understanding how female musicians experience stress, mental health, and career satisfaction. Research specific to female musicians indicates that they face unique challenges impacting their psychological health. For instance, studies have shown that female classical musicians experience poorer overall psychological health (Antonini Philippe et al., 2019). Similarly, Ascenso et al. (2018) found that female musicians report lower levels of positive emotions and overall well-being, especially at the beginning of their careers. Negative facets of well-being, such as depression, stress, and anxiety, are also reported mainly by women (Bonneville-Roussy et al., 2017; Loveday et al., 2023; Musgrave, 2023).

In broader research on needs satisfaction, findings have shown that autonomy tends to be lower in women, while relatedness and personal growth are higher, highlighting differing values that may shape career experiences (Matud et al., 2019). Additionally, job stress appears to affect women's well-being significantly, with potential cumulative impacts over time, though social relationships at work can buffer the adverse effects of stress on their well-being, offering valuable sources of support and resilience (Mensah, 2021). Despite these insights, existing studies on the lived experiences of female musicians often focus on negative outcomes, such as stress or burnout, while neglecting the positive aspects of well-being, such as motivation, fulfillment, and personal growth. This imbalance highlights the need for a more comprehensive approach to studying female musicians' well-being. By framing the research around SDT, this study aims to fill

this gap by capturing both the challenges and sources of well-being in the professional lives of female musicians.

1.4 Research questions

The present study aims to answer these two research questions through the lens of SDT:

1 What factors positively and negatively relate to the well-being of female professional musicians?
2 What specific challenges do women face in the music industry?

A qualitative interview study was used to explore these questions. This method allowed for a detailed and nuanced understanding of the participants' lived experiences, providing rich, contextual data that quantitative methods might not capture (Braun and Clarke, 2006).

2 Methods

2.1 Participants and procedure

As part of a larger research project involving two quantitative research surveys and an interview on the links between motivation, performance and well-being in high-achieving domains, such as sports, high-skilled careers and music, over 200 high-achieving individuals were recruited to take part in the quantitative section of the project, of which 16 female musicians agreed to participate in the qualitative interviews. The participants were recruited by word-of-mouth and snowballing in professional classical orchestras in Canada. Therefore, they were all professional, active classical musicians. The participants had a mean age of 40.44 years (25–58 years, SD = 10.84). Participants had, on average, 31.31 years of experience with their instrument. Their musical instruments included woodwind, brass, strings and keyboard. Descriptive statistics for each of the participants are found in Table 1.

Two postgraduate students in music psychology interviewed the participants. The interviews lasted on average 37.25 min, and were recorded using the interviewers' phones, then password-protected, anonymized, and transferred to a university-protected cloud account.

To minimize bias, the interviewers were trained to ask questions, prompts, and follow-up questions consistently across all study participants. One interviewer was a classical musician herself. Therefore, to minimize interviewers' bias, we ensured that the researcher did not interview participants who had a working or close relationship with her.

Ethical approval was granted by the authors' institution (2022-4224). All participants signed a consent form and were sent the interview questions beforehand.

2.1.1 Interview questions

The interviews were targeted toward a specific activity, depending on the participant's primary area of expertise (music, sports or work). Subsequently, the questions all referred to this activity (in the present study, music performance). At the beginning of the interview, participants were asked to name their area of expertise (in this case, music performance, but they had the opportunity to elaborate, for instance, by providing their musical instruments) and to refer to it when answering the questions. Since the interview was not targeted only toward musicians, the research team chose not to alter the questions to minimize bias. Participants were asked the following four questions in order:

1 How do you feel when you are doing your activity?
2 Does this activity give you a sense of well-being?

TABLE 1 Descriptive statistics of each of the female participants included in the study.

Participant	Instrument family	Age	Playing years - professional	Playing years - in general	Level of education
Part. 1	Strings	58	40	53	Master's
Part. 2	Strings	41	17	36	Master's
Part. 3	Strings	58	35	55	Bachelor's
Part. 4	Strings	57	28	–	Master's
Part. 5	Keyboard	32	5	12	Doctorate
Part. 6	Woodwinds	45	23	40	Master's
Part. 7	Strings	25	10	20	Bachelor's
Part. 8	Strings	39	21	35	Doctorate
Part. 9	Strings	42	25	33	Master's
Part. 10	Woodwinds	34	13	23	Master's
Part. 11	Woodwinds	33	7	23	Master's
Part. 12	Brass	34	10	17	Master's
Part. 13	Woodwinds	33	16	26	Master's
Part. 14	Strings	35	16	30	Doctorate
Part. 15	Keyboard	53	30	45	Doctorate
Part. 16	Woodwinds	28	10	25	Master's

3 Does this activity have a negative impact on your well-being?
4 In general, does this activity have a positive or negative impact on other aspects of your life (social, leisure, work, family)?

2.2 Data analysis

The study employed an inductive-deductive thematic analysis following a structured methodological approach (Braun and Clarke, 2006; Fereday and Muir-Cochrane, 2006). Firstly, recorded interviews were transcribed verbatim by two interviewers and a research assistant. This technique was selected for its methodical organization of qualitative data. The study initially used deductive thematic analysis by drawing on the established theoretical frameworks of SDT and well-being. These existing frameworks drove the research questions and preliminary data coding. Themes such as autonomy, competence, and relatedness were derived from this theory to answer the research questions about the well-being of female professional musicians. The analytic framework also incorporated women's experiences to explore how the professional female musicians in our sample discussed gendered issues such as caregiving responsibilities and work-life balance. The questions were not gendered *per se*, allowing the codes to naturally emerge without being prompted.

We followed a procedure for coding themes applied to SDT based on Raabe and Readdy (2016). First, after familiarizing themselves with the transcripts, all authors (serving as coders) independently highlighted relevant sections and assigned initial descriptive codes aligned with existing SDT literature. Next, each author independently grouped related data into 28 lower-order themes. The authors reviewed these preliminary themes independently, offering perspectives and making adjustments as necessary. Through an iterative process involving feedback from all authors, consensus was reached on the themes and codes that best represented participant experiences. In the first meeting, the 28 themes were consolidated into 19 based on their importance and how well they captured key participant ideas. In a second meeting, the 19 themes were either merged due to similarity, kept unchanged, or eliminated if they were mentioned by fewer than 30% of the sample. Saturation was achieved when no new themes emerged, resulting in a final set of 10 unique and significant themes. Subsequently, all authors independently confirmed that the themes accurately reflected the participants' experiences. Finally, the authors selected participant quotes that best illustrated each theme and their experiences.

Then, the themes were refined inductively according to the participants' narratives and experiences (Fereday and Muir-Cochrane, 2006). The inductive approach became prominent when refining the broad themes. As participants' narratives were analyzed, new insights and themes emerged directly from the data rather than being strictly aligned with the predefined theory. This iterative process involved reviewing the participants' experiences, allowing new codes and themes to emerge, which were not necessarily predicted by the theory.

In sum, this research used a rigorous inductive-deductive approach. Transcripts were coded for themes and sub-themes based on the participants' narratives. These codes were organized to reflect both the prevalence (number of participants) and the depth of discussion surrounding each theme. While Table 2 provides a summary of the frequency of participants who mentioned each theme, the narrative analysis presents the contextual richness of the data.

3 Results and discussion

As shown in Table 2, the analysis of interviews with the 16 professional female musicians uncovered three key themes and 10 sub-themes related to their well-being. The three key themes were: (1) Basic psychological needs for autonomy, competence and relatedness; (2) Sustained intrinsic motivation; and (3) Challenges of being a woman in music performance.

Table 2 presents a summary of the key themes and sub-themes, the number of participants who contributed to each sub-theme, and the overall positive or negative effects each of these subthemes had on the participants' level of well-being.

3.1 Psychological needs for autonomy, competence, and relatedness

Psychological needs were identified as one of the overarching themes. As highlighted in the first section of Table 2, psychological needs encompassed six sub-themes: autonomy satisfaction and thwarting, competence autonomy satisfaction and thwarting, and relatedness autonomy satisfaction and thwarting.

3.1.1 Need for autonomy

As can be seen in section 3.1.1 of Table 2, 69% of musicians mentioned the need for autonomy, such as a constantly renewed choice of staying in music and a greater opportunity to make choices as career advances, and a sense of control over their choices as essential to their well-being. Over 60% also mentioned some need

TABLE 2 Themes and subthemes drawn from the thematic analysis.

Overarching themes	Sub-themes	% (N)	Effect on well-being
3.1. Psychological needs	3.1.1. Autonomy	–	
	3.1.1.1. Satisfaction	68.75 (11)	Positive
	3.1.1.2. Thwarting	62.50 (10)	Negative
	3.1.2. Competence	–	
	3.1.2.1. Satisfaction	50.00 (8)	Positive
	3.1.2.2. Thwarting	68.75 (11)	Negative
	3.1.3. Relatedness	–	
	3.1.3.1. Satisfaction	75.00 (12)	Positive
	3.1.3.2. Thwarting	50.00 (8)	Negative
3.2. Intrinsic motivation	3.2.1. Love of music	68.75 (11)	Positive
	3.2.2. Sense of transcendence	31.25 (5)	Positive
3.3. Challenges of being a female musician	3.3.1. Work-life balance	81.25 (13)	Negative
	3.3.2. Resilience	68.75 (11)	Positive

N = 16; % represents the percentages of participants in the sample who mentioned each theme, with the N in parentheses. The number beside each theme and sub-theme relates to the corresponding theme in the results section.

thwarting situations, such as being dependent on contracts and callbacks, as a threat to their well-being.

3.1.1.1 Autonomy satisfaction

The interviewees agreed that the facets of autonomy in their careers, such as a sense of choice and control over one's own career, were crucial for their well-being. Most participants mentioned that they were musicians by choice, and if they were allowed to change careers, they would stay in music.

> There are many people who have influenced me, and I think they make it so that… I think it's a choice I constantly make, to keep doing what I do. I think it has a lot to do with colleagues, people I also see and admire. I think there is always a way to reinforce that choice by seeing the people around me. (Part. 11).

Some participants even perceived this choice of field as a calling, a vocation:

> It chose me, one way, because I played instruments from the time I was four. We think "Oh maybe I should do something else. Is this worth it? Is this gonna work? Am I gonna make a living?" There's a lot of doubt. But […] my inner self was telling me I had to do it. Because I did not have anybody telling me what to do anymore. (Part. 15).

The interviewees' experiences underscore the critical role that autonomy plays in their professional lives, emphasizing the freedom to make independent career choices as a significant factor in their overall satisfaction. Autonomy as a core psychological need is particularly relevant in this context (Evans, 2015; Ryan and Deci, 2017). For musicians, the ability to choose their career paths freely contributes to their sense of purpose. Participants' continuous choice to stay in music, driven by the influence and admiration of colleagues, aligns with findings in music psychology that suggest autonomy-supportive environments foster greater well-being among musicians (Bonneville-Roussy et al., 2020). Similarly, music being a calling reflects the concept of eudaimonic well-being (Ryff and Keyes, 1995), where personal growth and pursuing one's true potential are central to one's professional life (MacDonald et al., 2017). This continued sense of choice reinforces the musicians' commitment to their field despite career uncertainties.

3.1.1.2 Autonomy thwarting

The results showed that the lack of autonomy in the musicians' careers negatively impacted their well-being. Many participants mentioned that being dependent on contracts and callbacks made them feel insecure and constrained in their professional lives.

> So I do not know if, well, it must be like that for pretty much everyone in freelancing, but you know when your phone or your email, when you do not get as many job offers, whether you like it or not, you know it makes you question yourself a lot and then, well, psychologically it messes with your head. (Part. 6).

One participant felt discouraged as she experienced job insecurity despite all the efforts and achievements she had made throughout her career.

> I think we put in more hours, you know, the hours I practice or rehearse, or the courses I take, we put in an enormous amount of hours, and yet… I do not consider that I have a profession or a position that allows me to make a living, you know. So yes, I manage really well, because I'm freelancing and I work a bit everywhere, but having a job that guarantees a certain security, I have not achieved that yet. […] I find it discouraging. (Part. 9).

Musicians also observed that the inability to refuse work or take career breaks led to substantial stress and frustration.

> Well, I need to learn to say no. And that's what I'm doing, I'm learning to say no. I'm taking fewer and fewer contracts. […] If I say no, they will not like me anymore, they will not call me anymore. (Part. 3).

Some musicians pointed out that auditions demanded considerable effort but provided minimal control over the outcomes, resulting in feelings of helplessness and discontent.

> And it's not the kind of field where, even if you succeed 1,000 times, it all rests on an audition. So you tell yourself, I cannot even be sure that, you know, by doing super rigorous training or studying more, by maintaining good contacts, you know, that's not even what really determines if you'll get the job. (Part. 14).

The findings indicated that a lack of autonomy significantly impacted the well-being of musicians. The feeling of a lack of control reflects broader issues at work, where job insecurity can lead to significant psychological stress (Vander Elst et al., 2014). This aligns with findings from studies on freelance musicians, which highlight the precarious nature of their work and its impact on mental health (Gross et al., 2018; Musgrave and Gross, 2020). The feeling of discouragement and lack of professional stability is common in the music industry, where the balance between effort and reward often appears skewed (Gross et al., 2018; Loveday et al., 2023). A study conducted with musicians who had utilized mental health services revealed that more than three-quarters of them reported high or overwhelming financial stress and perceived lack of choice in accepting contracts, which was also associated with higher levels of self-reported depression and anxiety (Berg et al., 2022). The inability to secure a stable position despite extensive practice and training exacerbates frustration. Despite the personal cost, this pressure to accept all available work is a well-documented issue in freelance professions, where job scarcity and competition are high (Bennett, 2016). Furthermore, some musicians pointed out that auditions demanded considerable effort but provided minimal control over the outcomes, resulting in feelings of helplessness. This lack of control over career advancement is a critical issue, contributing to the overall stress and dissatisfaction experienced by some musicians.

3.1.2 Need for competence

Section 3.1.2 of Table 2 shows that while 50% of musicians reported competence satisfaction, 69% of them stated elements of competence thwarting. Musicians conveyed that their need for competence was fulfilled daily through experiences of mastery, learning, and improvement of their musical skills. This satisfaction was associated with enhanced feelings of well-being. Conversely,

insufficient preparation or time to fully master a repertoire or a new skill was cited as a source of stress and feelings of inadequacy (Vellacott and Ballantyne, 2022).

3.1.2.1 Competence satisfaction

Many musicians indicated that music was their primary area of competence and found it stimulating to engage in continuous learning and challenges.

> You know what I mean, I move forward with my backpack, and my backpack keeps filling up. But it's like Hermione's bag in Harry Potter. It has no bottom, you know. I can just keep adding things and learning, developing new knowledge, developing new skills, always learning more. (Part. 13).

They also mentioned experiencing greater enjoyment of performances when mastery was achieved through dedicated practice.

> When you feel like you have really reached… like… you have found something special, you have also reached a good level of preparation. Then, sometimes it feels like everything is going well, I do not know, you get on stage, you feel good […].Those concerts are really fun. (Part. 9).

The perspective that music is the primary competence area for many musicians indicates that continuous learning and skill development are crucial for musicians' professional growth and personal satisfaction (Manturzewska, 1990). Musicians mentioned the deep satisfaction of achieving a high level of skill (Vellacott and Ballantyne, 2022). Araújo and Hein (2019) have found that more time spent practicing daily is linked to experiencing flow, indicating that flow might enhance one's commitment to daily practice. This phenomenon is supported by flow and peak performance theories, which suggest that high levels of skill and preparation lead to highly rewarding and enjoyable experiences (Seligman and Csikszentmihalyi, 2000). The satisfaction derived from achieving mastery contributes to a positive feedback loop, reinforcing the musicians' commitment to continuous practice and improvement (Bonneville-Roussy and Bouffard, 2015).

3.1.2.2 Competence thwarting

Musicians also reported that insufficient practice time led to stress and being caught up in the music's technical aspects, hindering their sense of enjoyment.

> Because sometimes I feel like I have not practiced enough, I'm stressed, uh, I'm not mentally available… to what's around me. Uh… yes, it creates stress for me. Sometimes, it causes insomnia for me, sometimes. (Part. 2).

This is consistent with existing research, which suggests that inadequate preparation can lead to heightened stress and decreased performance quality (Kenny and Ackermann, 2016; Vellacott and Ballantyne, 2022).

3.1.3 Need for relatedness

In this study, the need for relatedness emerged as a major theme among female musicians, with 75% of them reporting elements of relatedness satisfaction in their answers and 50% of relatedness frustration (section 3.1.3 of Table 2). They all noted that most of their friends were fellow musicians and that the music industry felt like a family. However, it was a significant source of stress when relationships were conflictual.

3.1.3.1 Relatedness satisfaction

Some musicians have mentioned that music, especially when played in orchestras or ensembles, has the power to bring people together.

> I'm attached to people, I'm attached to the beauty of how they coexist. I find an orchestra really amazing. I have a fascination for all the cohesion that can exist, and how people come together and do their best, collectively, to give the best result. It's like… It does not happen often in society. (Part. 12).

Another theme highlighted by the participants was that relationships with colleagues offered mutual support and long-term friendships, which were sources of happiness and fulfillment.

> I find that it allows for the development of beautiful relationships. […] So I have a lot of friends that I've met, and I think that, it's a really nice environment. […] And I found it interesting because, I think that, we have friendships that we have kept for a long time. And you know, I'm always happy to see, you know, like sometimes I have a gig and it's like, "oh," you know, "you are here." And you know, it's fun to see each other like that. (Part. 14).

Finally, the musicians identified the importance of sharing music with family, friends, and the general public as a source of well-being for both themselves and others.

> Regarding family, part. 5 said:
> It can have a positive impact because, you know, it also brings people together. You know, that having events and concerts, like my family is super happy to come and hear me, and it creates events where we gather afterward, we go eat together.
> Part. 1 added in relation to friends:
> It's super nice to give that to friends, to be able to offer music, it's something we do […] But in my personal life, offering concerts to friends, going to their living rooms, it's something we really enjoy doing, which is very, which is very rewarding. There is a certain power in music, to use it to bring joy and have good times.

One musician mentioned the enjoyment she gets from passing on her knowledge to younger musicians as a mentor.

> I feel like I have enough expertise and enough knowledge that I just love to share it with younger musicians, as a mentor or as a coach. And I want to share my pleasure. I want to share my pleasure with everyone. And help people, especially help students to find that also I can go into, because I feel very competent. (Part. 15).

Many musicians mentioned that playing music fosters a sense of togetherness among musicians, relatives, and people outside of the music industry. This shared effort reflects findings that participating

in ensembles strengthens social connections and a sense of belonging among people (Creech et al., 2013). Musicians also highlighted the joy of developing enduring friendships through music and the pleasure of reuniting with colleagues during performances. This observation aligns with research suggesting that strong interpersonal relationships in professional settings greatly enhance well-being and job satisfaction (Kansky, 2017), as well as the role of music in strengthening social bonds and enhancing communal joy (Creech et al., 2013).

3.1.3.2 Relatedness thwarting

Almost all musicians mentioned that the music industry could also threaten their need for relatedness, leading to decreased well-being. Since the community of musicians is close-knit, they could not avoid toxic relationships.

> On a social level, the circle definitely becomes the people we work with because we have all studied together and worked together. […]. And there's like… it's super hermetic. […] Interviewer: And is that positive or negative? Participant: Both. I think it's positive: it creates tight bonds. But the flip side is that everyone knows each other and what we do is so intimate that it can be both positive and negative. It depends on who. (Part. 16).

For instance, one musician mentioned that she had a strained relationship with a colleague in her orchestra, with whom she had to interact several times a week. This strained relationship led to increased stress and decreased satisfaction during rehearsals.

> Regarding being the section lead in an orchestra, one participant said:
> Let us say the last concert, I was the one in front, so it was kind of me who had to handle… everyone's emotions. […] Of course, when I was in that situation last time, well… I cannot say it contributed to my happiness (laughs). It's… it's more stressful, it's less enjoyable. […] It's always little comments like that, which makes relationships harder and it's also stressful. (Part. 7).

One musician mentioned that the lack of preparation from colleagues before a performance could be unsettling, affecting her well-being as a result.

> For me, if I'm sitting with someone… who has not practiced well, who does not know what they are doing or what… it's really distracting to be sitting with someone who is not well-prepared. (Part. 9).

One participant mentioned that being part of an ensemble could lead to feelings of anonymity and a lack of recognition.

> For example, again, as a violinist, we are part of a violin section. So, it's very anonymous. It can be challenging sometimes, I mean, I would not be there. […] I practiced 30 h to be able to play that, but I would not be there and no one would notice. (Part. 1).

The need for meaningful connections with others is thwarted when musicians feel that they have unhealthy relationships with their colleagues, or that these connections are meaningless. In our study, musicians described how their social circle is predominantly composed of colleagues they have studied and worked with, creating strong bonds and potential for negative interactions due to the intimate and hermetic nature of the community. Depending on the individuals involved, this duality can lead to positive and negative experiences (Ascenso et al., 2022). Musicians also described the challenge of feeling unnoticed despite significant effort and preparation. The sense of anonymity within a larger group can diminish a musician's sense of worth and satisfaction (Kenny et al., 2014).

3.2 Intrinsic motivation

Intrinsic motivation refers to engaging in an activity for the inherent satisfaction and pleasure derived from the activity, rather than for external rewards or pressures (Evans, 2015, 2023). All musicians mentioned forms of intrinsic motivation in their interviews, highlighting that being intrinsically motivated was a major source of well-being. Two sub-themes were prevalent with regards to intrinsic motivation: the inner love for music, reported by 69% of the sample, and a transcendental experience (31%, see section 3.2 of Table 2).

3.2.1 Love of music

Almost all musicians expressed a deep love for their craft. Specifically, many mentioned that practice was inherently enjoyable and often led to feel-good moments.

> When we practice, we cannot think about anything else. So it's a, it's like a moment… a very… very good moment in a day. There's not much during the day that will bother us. […] We're in a pretty, pretty calm zone. (Part. 4).

Others said they used practice as a form of self-regulation to improve their psychological well-being.

> And well, music in itself, I think, is something therapeutic in life, so, uh, when I'm stressed, or when I'm sad, or whatever, well, often I take out my [instrument] and, uh… it makes me feel better. (Laughs). (Part. 7).

One musician mentioned that music was so enjoyable that it felt more like a hobby than a career to her.

> I really feel like it's more of a hobby, something I would do, and I do not feel like it's a chore. (Part. 7).

One musician referred to a sense of flow or of 'being in the zone' while playing.

> It soothes the soul at times. And even, you know, there are moments, like when we talk about flow, there are moments where everything feels right technically, and with your instrumental comfort. […] It's in those moments that you really feel like saying, 'it's all worth it for moments like this. (Part. 14).

According to SDT, intrinsic motivation arises when engaging in an activity for its inherent interest or pleasure (Deci and Ryan, 1985; Ryan and Deci, 2017). Musicians often exhibit intrinsic motivation

through their love for music and the enjoyment they derive from playing their instruments. This intrinsic motivation leads to increased practice time (MacIntyre et al., 2018), higher quality practice sessions, and a greater preference for challenging tasks (Evans and Bonneville-Roussy, 2016). Additionally, intrinsic motivation helps musicians build resilience against the challenges of pursuing a musical career, and increase musicians' sense of flow (Habe et al., 2019; Schnare et al., 2012).

3.2.2 Sense of transcendence

Musicians referred to recurring experiences where they felt a profound sense of elevation and transformation while engaging with music. These moments go beyond the ordinary, often evoking intense emotions and a profound sense of well-being.

> Sometimes I play pieces, and I'm like, "Wow, God exists," you know. The piece is so fantastic, you think, "Wow, this is not human, it's not a human who wrote this, it comes directly from divine inspiration," you know. (Part. 3).

One musician described that her love of music was almost transcendental:

> There are emotions that I feel sometimes when I'm playing music that I do not ever feel at other times. Like emotions that I did not know existed. I can feel them when I'm playing music. So it's like a healing process also. (Part. 15).

Music evokes emotions and sensations that are rarely found elsewhere. This aligns with existing literature, highlighting music's ability to evoke peak experiences and facilitate a sense of connection to something greater than oneself (Gabrielsson, 2011). When individuals fully immerse themselves in music, they can experience an expanded sense of self (Bernard, 2009). Musicians often perceive music as something greater than themselves, allowing them to delve deeper into their emotions (Hruska and Bonneville-Roussy, 2022; Scharff, 2018; Sergeant and Himonides, 2014). This deep emotional connection contributes to their enjoyment and pleasure when playing their instruments, serving as a source of intrinsic motivation.

3.3 Challenges of being a female musician

Although we did not specifically inquire about the challenges faced by female musicians, most women in the study highlighted them. The primary sub-theme identified was the difficulty maintaining a work-life balance, stated by 81% of the sample (section 3.3.1 of Table 2), negatively impacting their well-being. Interestingly, another sub-theme that emerged was that, for some women, these challenges fostered personal growth and resilience, ultimately enhancing their well-being over time (reported by 69%, section 3.3.2 of Table 2).

3.3.1 Work-life balance

The necessity of maintaining a work-life balance was a major concern among our participants. Juggling atypical schedules and working while others were off created family and social life issues.

> Sometimes I find it difficult to be a very, very, very high-level musician and have a balanced life with family, with children, especially for women. […] It's really a lifestyle where you have to make decisions based on what you want and what you need for your life balance. And sometimes it works, sometimes it does not. So it has a significant impact on our personal life. On our family life. On our colleagues. (Part. 16).

Many women questioned motherhood and family life as a result of their career choice, with several mentioning they had delayed having children because the demands of being an early-career musician were incompatible with the constraints of a young family.

> And you know, even just making life decisions. Like important decisions. For instance, whether we can have children. (Part. 14).

> There are so many things to consider. In the sense that I also want to be a mom at some point. So it will not be my peak time for [instrument]. And it's a project that will happen soon, I hope. So let us say we give it a year for my peak [laughs]. (Part. 10).

Additionally, many women mentioned having to choose between spending more time with their children and life partners or playing more music.

> So sometimes it… bothers me a bit to say, "Well, listen, my dear, I have to go practice, and… that's life." I would spend time with [family], but you know, I do not really have a choice. (Part. 8).

> Sometimes my daughter says "You're out too much at night." For concerts. […] She feels abandoned. I mean, not abandoned, but you know, like she feels like I'm sometimes out too much. At certain periods of the years even my son sometimes in very busy periods of concerts, he'll be like, "Mommy you are not here." So there's a drawback of being a performing musician for family life. (Part. 15).

Some musicians said that having such an atypical schedule made it challenging to maintain a social network outside of music.

> And of course, the fact that our schedules are atypical, we work when others have free time. Like, friendships, for example, I have many friends who are teachers. So it's not always easy to be able to see each other because I work evenings and weekends. They work during the day, on weekdays. (Part. 13).

Our participants faced significant challenges in balancing work and life, particularly when deciding whether to have children. Female musicians, in particular, must manage family responsibilities alongside their careers (McDowall et al., 2019). As primary caregivers, women have the additional burden of organizing childcare, which is especially challenging due to the unconventional hours musicians work, such as weekends and evenings when schools and daycares are typically closed. This scheduling conflict results in less time spent with their children than desired. Additionally, maternity leave and childcare responsibilities are frequently viewed negatively, disadvantaging women (Curtis, 2013). Musicians also struggle to spend time with their partners and friends. These findings align with the literature indicating that work-life balance

is one of the most significant challenges musicians face (Bartleet et al., 2020). The competition between professional demands and family life negatively impacts musicians' well-being (Musgrave, 2023).

3.3.2 Resilience

Resilience is a critical attribute for professional musicians, enabling them to navigate their careers' various demands and pressures. The stress and challenges associated with musical performance are well-documented in the literature, and these elements are seen not only as obstacles but also as opportunities for personal growth and development. Resilience in this context involves the ability to manage performance anxiety, physical strain, and the high expectations placed upon musicians (Kegelaers et al., 2021).

In this study, some participants said that being a professional musician comes with challenges that allow them to grow as a person.

> Well, of course, it's stressful. […] But it makes you work on yourself. I think it's not negative, and wanting to do this job means you have to learn to juggle that aspect, the performance stress and the physical strain too. […] But after that, you learn to work so that it's as painless as possible. And easier. (Part. 16).

For example, a musician explained that she had to become more self-compassionate to deal with the high expectations of a career in music.

> Maintaining the technical level, to always be at the top of your form, it's complicated. It's complicated. I have a young child… and there are many factors. I have students to manage, I have a lot of things going on. So it definitely requires… a lot of self-compassion. (Part. 8).

Other participants said that the atypical working hours led them to develop organizational skills and strategies that allowed them to make the most of their practice time.

> You know, unlike others who are not in this situation, for example, who have more free time in the evenings and weekends, I know that I have this in the afternoon, I need to learn… 'this' sheet music, you know. I have to do my work with the utmost concentration. So I try to put technologies aside, so I will not be disturbed […] (Part. 2).

Musicians also said that music practice enabled them to develop and maintain their cognitive and physical abilities.

> I find an extraordinary benefit for the development of my brain, the shaping of my brain. Uh, maintaining, maintaining gains, both in terms of reflexes, mental quickness, and good mood. (Part. 4).

Despite the numerous challenges our participants faced, playing music enabled them to grow and strengthened their ability to overcome difficulties. They built resilience by fostering self-compassion, developing organizational and time management skills, and maintaining their focus(Kansky, 2017). One participant noted the cognitive benefits of playing music, which has been shown to positively impact various cognitive functions, including memory (Bruhn, 2002). These resilience factors positively influence musicians' well-being, as resilience is negatively associated with mental health issues such as anxiety and depression (Kegelaers et al., 2021).

4 Conclusion

This study provides novel insights into the well-being of professional female musicians through the lens of SDT. While previous research has predominantly focused on structural barriers and negative outcomes, this study takes a more holistic approach, integrating both positive and negative aspects of well-being in the lived experiences of female musicians. Our findings highlight the critical role of psychological needs satisfaction in shaping their well-being. Importantly, this study is among the first to qualitatively explore how the unique challenges faced by women in music and psychological needs satisfaction converge, offering a richer understanding of how female musicians experience them. By addressing this gap, we contribute to a more nuanced understanding of well-being in the music industry and propose actionable insights for creating more supportive environments for women in high-performance domains.

The findings emphasized the critical importance of satisfying psychological needs for autonomy, competence, and relatedness, as well as intrinsic motivation, in enhancing the well-being of these musicians. In general, our results have highlighted that female musicians report more positive than negative effects of being a musician on their well-being. In terms of the PERMA model of well-being, our results revealed that musicians' musical environment provided them with positive emotions, meaningful relationships and engagement with others and music (Ascenso et al., 2017, 2018; Bonneville-Roussy and Vallerand, 2020). This led to a sense of life purpose and deep satisfaction with their craft. However, some aspects of the music industry also posed challenges to their well-being. In particular, women in music seem to still experience greater work-life balance issues. Our study goes beyond confirming SDT's relevance to musicians' well-being by offering new insights into how female musicians navigate gender challenges that affect their psychological needs and well-being. These findings highlight the importance of addressing gender-specific barriers to promote well-being in high-performance fields like music.

Participants highlighted that their sense of autonomy was critical to their well-being because it enabled them to feel in control of their career paths. However, the lack of autonomy created stress and insecurity. Regarding competence, musicians stated that their everyday experiences of mastery, learning, and skill advancement were critical to their well-being. The deep satisfaction of obtaining high proficiency levels via dedicated practice was linked with increased well-being. Conversely, insufficient practice time caused stress, reducing musicians' enjoyment and perception of competence. Nearly all participants stated that their need for relatedness was met in music, which fostered a sense of family and mutual support. However, the close-knit structure of the music community presented difficulties, as conflicts within these connections were significant sources of stress.

Furthermore, the often isolating character of high-performance environments led to feelings of anonymity, reducing musicians' sense of fulfillment. The musicians' well-being was also influenced by intrinsic motivation, or engaging in an activity for its inherent satisfaction. A prominent element of the current study was a great love of music. The participants described moments of transcendence when performing music, with a feeling that music was greater than themselves, which offered profound emotional and psychological satisfaction.

The gender-specific challenges faced by professional female musicians emerged as a significant, though not explicitly inquired about, aspect of this study. Many participants highlighted issues

related to work-life balance, caregiving responsibilities, and professional instability—challenges that disproportionately affect women in high-performance fields like music. These findings align with existing literature, which underscores that female musicians often face greater difficulties in maintaining career momentum due to irregular work schedules, the need for extended leaves, and societal expectations around caregiving roles (Hruska and Bonneville-Roussy, 2022; McDowall et al., 2019). Without sufficient institutional or structural support, these challenges can undermine not only the professional advancement of female musicians but also their psychological well-being (Ascenso et al., 2017). Despite these problems, some participants reported that their experiences boosted their personal growth and resilience, allowing them to better manage the pressures of their careers. Although the study did not include a specific gender-focused question, the natural emergence of these themes underscores the importance of addressing gender in discussions of well-being and career satisfaction within the music industry (Scharff, 2018; Smith and Hendricks, 2022).

4.1 Limitations

This study provides valuable insights into the well-being of professional female musicians, but several limitations should be noted. The small sample size of 16 participants from Canadian classical orchestras may limit the generalizability of the findings. Future research should involve larger and more diverse samples. Additional data collection methods, such as direct observations or longitudinal studies, could help validate the results of this study. Additionally, the study did not explore external factors like institutional policies, cultural differences, or socioeconomic status. Finally, the cross-sectional design captures experiences at a single point in time, limiting insights into causality or changes over time. Longitudinal studies could offer more robust insights into how well-being and psychological needs evolve throughout musicians' careers.

4.2 Implications and future research

In sum, professional musicians, particularly women in this field and other performance domains, would benefit from environments that satisfy the basic psychological needs for autonomy, competence, and relatedness. Although the industry has made significant progress in addressing systemic well-being issues, these psychological needs are still not fully met. Since satisfying these needs is a crucial predictor of intrinsic motivation and well-being, greater awareness of these issues is necessary. Ensuring that environments within the music industry support the psychological needs of autonomy, competence, and relatedness can significantly enhance musicians' well-being and professional satisfaction. Additionally, female musicians face gender-specific challenges and often bear the primary responsibility for childcare, further constraining their well-being. Addressing these unique challenges female musicians face, such as work-life balance and the need for career stability, is crucial. Future research should address these concerns.

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 Comité d'éthique de la recherche avec les êtres humains, UQAM, no. 2022-4224. 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

LP: Conceptualization, Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing, Data curation, Project administration. LL-G: Formal analysis, Methodology, Writing – original draft, Writing – review & editing, Resources. FK: Formal analysis, Writing – original draft, Writing – review & editing, Data curation, Validation. MF: Formal analysis, Writing – original draft, Writing – review & editing, Methodology. AB-R: Formal analysis, Methodology, Writing – original draft, Writing – review & editing, Conceptualization, Funding acquisition, Supervision.

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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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Interpretive autonomy at the heart of classical musicians' learning and well-being: the role of professional education

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A classical musician's role is to convey their interpretations of pre-composed pieces to audiences; however, classical musicians have been criticized for conforming to normative interpretations, demonstrating a lack of autonomy in interpretation. While a lack of interpretive autonomy may harm musicians themselves by leading to maladaptive learning behaviors and lowered well-being, this has not been thoroughly examined. Additionally, interpretive autonomy may be hindered by professional training that emphasizes reproducing normative interpretations, but the extent of this remains unclear. Therefore, we conducted case study research on eight elite piano and violin students to explore how interpretive autonomy is promoted or hindered by learning experiences, and how it influences their learning behaviors and well-being. In addition, we investigated how inhibited interpretive autonomy can be promoted by education, and how earlier learning experiences in interpretation have long-term effects in college and post-college. Using a model of *Werktreue* internalization, we found that interpretive autonomy was promoted through need-supportive learning experiences, where students felt competent, autonomous, and related in interpretation; on the other hand, it was inhibited by need-thwarting learning experiences, where students felt incompetent, forced, and rejected in interpretation. We also found that interpretive autonomy is central to self-regulated learning behaviors and well-being. Furthermore, early need-thwarting experiences created psychological barriers to conveying intended interpretations during college and post-college, even when their needs were not directly threatened. In contrast, early need-supportive experiences enabled musicians to express original interpretations, even when they faced restrictive norms in the classical music field. Therefore, the study shows that while need-thwarting experiences, such as authoritarian teaching, parental overcontrol, and competitions were often implemented with good intentions to advance students' career success, such professional education may harm their long-term artistic growth. The study also provides hope, as interpretive autonomy could be promoted by education even after being inhibited. We conclude the article with examples of learning experiences that provide students with a sense of competence, autonomy, and relatedness in musical interpretation, offering insights into how we may transform professional education for the optimal development of students and the classical music field.

KEYWORDS

music education, interpretation, interpretive autonomy, self-regulated learning, self-determination theory, well-being, autonomy

1 Introduction

> "Striving for perfection—to avoid wrong notes, wrong timbres, wrong chord progressions, wrong interpretations—often means striving to fulfill someone else's ideal of how music should or should not sound. In this sense, anxiety about making mistakes becomes yet another mechanism for social enforcement of conformity" (Hill, 2018, p. 109).

A classical musician's role is to convey interpretations of pre-composed pieces to audiences. Since there is no "single ideal" interpretation, musicians can cultivate their creativity and intellect in deciding what and how to communicate them, manipulating tempo, dynamics, and timbre (Palmer, 1997, p. 119; Héroux, 2016, 2018; Payne, 2016). This creative freedom results in varied performances of the same piece both within and across musicians, enriching audiences' experiences. However, it has been argued that classical musicians have conformed to normative interpretations rather than pursuing originality, lacking autonomy in interpretation (e.g., Szigeti, 1979; Taruskin, 1995; Adorno, 2006; Leech-Wilkinson, 2020a).

To understand the complex discourse surrounding interpretive autonomy, one needs to address the *Werktreue* ideology—to be true to work—which has been regulating classical musicians' approaches to interpretation. Around 1800, music began to be seen as artistic works by composers, and performers' duty became to interpret works faithfully to the composer's intentions (Goehr, 1992). In the nineteenth century, performers gradually withdrew from improvisation, as it deviated from scores, which were considered the best representation of composers' intentions (Goehr, 1992). Early twentieth-century recordings reveal that performers still made a wide variety of interpretive choices, such as flexible tempo changes, rhythm distortions, dislocation of melody and accompaniment, added ornamentation, and use of portamento (Philip, 1992; Day, 2000). This was, however, gradually replaced by literal interpretations of notation, as greater emphasis was placed on "precision" and "clarity" (Philip, 1992, p. 233). In reviews of recordings in *Gramophone*, critics increasingly used the terms "mannerism" and "mannered" from 1951 to accuse performers of being "narcissistic" when their individuality was noticeable, acting as "the norm police" (Leech-Wilkinson, 2020b, p. 107). By the end of the twentieth century, musicologists claimed that performers refrained from conveying original interpretations to conform to the expectations within the professional community, and performances became static (e.g., Small, 1986; Taruskin, 1995; Adorno, 2006).

While a lack of interpretive autonomy may result in monotonous performances, it may also negatively affect musicians themselves. Despite their dedication, conservatory students often show various maladaptive learning behaviors which may stem from a lack of interpretive autonomy. Students who did not consider developing interpretation as part of instrumental learning followed teachers' instructions passively (Reid, 2001) and practiced ineffectively without setting musical goals (McPherson et al., 2019). In addition, musicians who focused on technical accuracy and others' evaluation gave unsatisfactory performances (Clark et al., 2014). In contrast, those who aimed at conveying personal interpretations displayed more effective learning behaviors, such as selectively incorporating teachers' advice (Reid, 2001) and constructively engaging in goal setting and self-reflection in practice (Van Zijl and Sloboda, 2011; Wise et al., 2017; McPherson et al., 2019). Performers who concentrated on musical characters also entered a flow state during the performance (Clark et al., 2014).

While researchers have investigated effective learning processes by applying Zimmerman's (2002) self-regulated learning (SRL)[1] (see Varela et al., 2016; Dos Santos Silva and Marinho, 2025 for reviews), what differentiates effective self-regulated learners from naïve learners remains unknown. Since maladaptive learning behaviors in lessons, practice, and performance risk students' mental and physical well-being (Perkins et al., 2017), it is urgent to identify what contributes to effective self-regulated learning. In addition, how interpretive autonomy is promoted or hindered in education remains unclear. In the absence of understanding, autonomous learning behaviors (Gaunt, 2008) and musicality or expressivity (Kingsbury, 1988; Laukka, 2004) are often attributed to students' innate talent by teachers.

The scarcity of empirical studies on interpretive autonomy is partly due to the difficulty of defining interpretive autonomy, as definitions of what constitutes a faithful interpretation vary among musicians. Some musicians hold a subjective view where a performer develops interpretations based on subjective feelings and ideas, whereas others hold a formalist view, aiming to let the score "speak for itself" and remove oneself as a "servant" of the composer (Silverman, 2007, p. 102). While the latter may regard musicians as "subordinate" to composers (Silverman, 2007, p. 108), it does not necessarily indicate a lack of autonomy, making the issue complicated.

To address these gaps theoretically, Fujimoto and Uesaka (2024) proposed a model of *Werktreue* internalization (Figure 1). By applying self-determination theory (SDT) (Deci and Ryan, 2000; Ryan and Deci, 2000, 2017) to how musicians internalize the *Werktreue* ideology, the model defines interpretive autonomy, explains how musicians' interpretive autonomy is promoted or inhibited, and shows how it affects learning behaviors and well-being.

We briefly summarize the model of *Werktreue* internalization (Fujimoto and Uesaka, 2024). When musicians' basic psychological needs for autonomy, competence, and relatedness are supported in interpretation—meaning they perceive themselves as capable, free to make musical choices, and able to connect with others in faithful interpretation—they internalize the *Werktreue* ideology autonomously. Musicians develop interpretations based on intellectual curiosity, individual sensibilities, and values, and the ideology is integrated with the true self. This is the autonomous *Werktreue* internalization which indicates promoted interpretive autonomy. Musicians with the autonomous *Werktreue* internalization employ self-oriented interpretive approaches, which require active interpretive decision-making (Table 1). These approaches are then related to self-regulated learning behaviors which in turn enhance well-being and musical identity.

1 Self-regulated learning is a cyclical process consisting of three phases: forethought, performance, and self-reflection. In the forethought phase, self-regulated learners set specific goals and plans while motivating themselves for the task. During the performance phase, they employ various learning strategies while monitoring their effectiveness. Finally, in the self-reflection phase, they self-evaluate their learning performance and attribute errors appropriately. Learners then motivate themselves to engage in the next cycle, setting new goals and plans (Zimmerman, 2002).

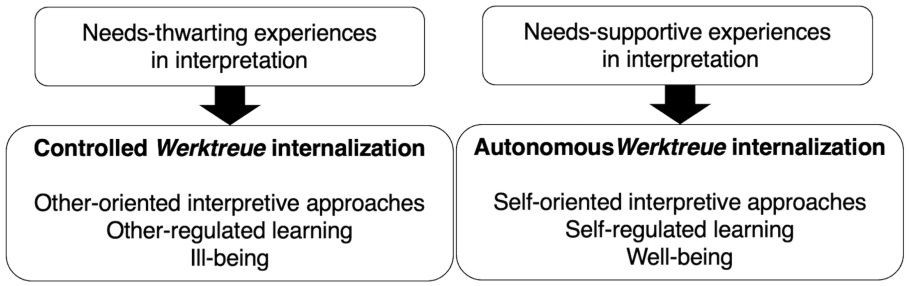

FIGURE 1
The model of *Werktreue* internalization. Adopted from Fujimoto and Uesaka (2024).

TABLE 1 Other- and self-oriented interpretive approaches.

Other-oriented interpretive approaches			Self-oriented interpretive approaches		
Approaches	Description	Examples of learning behavior	Approaches	Description	Examples of learning behavior
Impersonal	Performers restrain from imposing personal views	Failing to personally connect with music	Personal	Performers bring their personality and subjectivity into interpretations	Considering musical learning as personal development
Explicit notation	Performers follow explicit notations on a score	Failing to relate notations to musical meaning	Implicit intention	Performers neglect or change notations on a score, valuing implicit expression	Understanding musical meanings behind notations
Teacher-centered	Performers expect teachers to pass on interpretations to students	Accepting teacher's interpretations passively	Student-centered	Performers expect students to develop their own interpretation	Evaluating teachers' interpretation critically
Reproductive	Performers reproduce interpretations as they were rehearsed in performance	Being inflexible on stage	Improvisatory	Performers spontaneously bring new interpretations into performance	Being flexible on stage
Unconscious	Performers unconsciously develop interpretations	Lacking awareness of expressivity	Conscious	Performers consciously develop interpretations	Intentionally exploring expressivity
Separated	Performers disregard interpretations when they work on techniques	Working on segments technically without having musical aims	Integrated	Performers continually consider interpretations	Grasping an overview initially and working on techniques to express intended interpretations

Adopted from Fujimoto and Uesaka (2024).

On the other hand, when musicians' basic psychological needs for autonomy, competence, and relatedness are thwarted in interpretation—meaning they perceive themselves as incapable, forced, and rejected by others in interpreting faithfully—musicians internalize the ideology in a controlled manner. They develop interpretations to gain external rewards, such as fame and money, or to avoid punishments, such as criticism; as a result, the ideology becomes alienated from the self. This is the controlled *Werktreue* internalization which indicates hindered interpretive autonomy. Musicians with the controlled *Werktreue* internalization employ only other-oriented interpretive approaches that are related to other-regulated learning behaviors (Table 1). These in turn lead to ill-being and disintegrated musical identity.

The model of *Werktreue* internalization also identifies learning experiences that hinder interpretive autonomy. Lessons where teachers reject students' musical ideas (Persson, 1996; Silverman, 2008) or teach a specific interpretation as "correct" regardless of students' individuality (Rostvall and West, 2003; Burwell, 2021) may thwart the needs for autonomy and competence. Similarly, examinations, auditions, and competitions in which students' performances are evaluated or rejected based on pre-existing norms (McCormick, 2015) may thwart the needs for autonomy, competence, and relatedness. Conservatory students expressed anxiety about conveying original interpretations in these settings, since deviation from norms can result in being labeled a disrespectful musician by gatekeepers; yet because the norms are often ambiguous, they have to

play guessing games (McCormick, 2015; Hunter and Broad, 2017; Holmgren, 2022).

Some instrumentalists, such as pianists and violinists, may be at greater risk of having their interpretive autonomy hindered from an early age especially when they aspire to become soloists. Wagner (2015) observed that children in soloist violin classes typically began playing the violin before the age of 6. Teachers then expected students to conform to "(1) technical norms, meaning technical mastery of violin; (2) attitudinal norms; behavior during the lesson and in the student's musical interpretation and within the soloist world" (p. 103). Parents were also greatly involved, coaching their children to meet teachers' expectations at home. Some students participated in competitions even before their teenage years with teachers' and parents' guidance to build a successful career.

Such early education focused on "imitation and repetition" is cautioned to undermine the long-term development of interpretive autonomy, as a "certain learned interpretation and performing style becomes their norm and sets aesthetic limits to their creative skills" (Doğantan-Dack, 2017, p. 132). Similarly, Leech-Wilkinson (2020a, chapt. 7.2) problematized how "conformist values" are ingrained in musicians' psyches from childhood, as the teachers/parents/child form a team to achieve "the approved ways of being musical." However, empirical research is limited.

Therefore, we conducted case study research (Yin, 2018) on elite piano and violin students to investigate how interpretive autonomy is promoted or hindered in learning experiences, and how interpretive autonomy plays a role in learning behaviors and well-being. This addresses existing knowledge gaps and validates the plausibility of the model of *Werktreue* internalization (Fujimoto and Uesaka, 2024). Additionally, we examined the chronological development of interpretive autonomy, focusing on whether interpretive autonomy could be promoted even after being hindered, and how early experiences in interpretation affect students in the long term. These are summarized below:

(1) How do need-thwarting and need-supportive learning experiences affect students' interpretive approaches, learning behaviors, and well-being?
(2) How can interpretive autonomy be promoted even after it has been hindered?
(3) How do pre-college learning experiences affect students during and after college?

2 Materials and methods

Case study research is suited for investigating "a contemporary phenomenon (the "case") in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident" (Yin, 2018, p. 15). Researchers bring *a priori* theoretical propositions to guide research design and data collection, which are supported, rejected, or modified during analysis to develop a theory that provides plausible explanations for the phenomena. The resulting theory is then considered applicable to other cases, allowing "analytic generalizations" (p. 38). In this study, we applied the model of *Werktreue* internalization (Fujimoto and Uesaka, 2024) as a theoretical framework. We also chose a multiple-case study design to identify robust findings replicated across cases.

2.1 Participants

Through purposive sampling, eight musicians were recruited (Table 2). All the participants were expert pianists or violinists. Seven participants had attained a Bachelor of Music at prestigious conservatories, including The Juilliard School, The Curtis Institute of Music, The Royal College of Music, The Paris Conservatory, and Seoul National University. One participant was not studying at a conservatory yet has frequently won national competitions. Participants were in their twenties ($M = 24.88$, SD = 2.17), and six of them were studying in performance programs at the time of the interviews. The nationality included three Japanese, two Chinese, one Korean, one American, and one British, and two of them were female. For privacy, we concealed the nationality and sex and translated all the quotes into American English.

2.2 Data collection

Before the interviews, all the participants provided informed consent. The interviews were conducted on Zoom or in person in either English or Japanese and lasted from 92 to 403 min ($M = 203$ min). Three participants had multiple sessions, and each session was recorded with their permission. The first author asked questions regarding:

TABLE 2 Summary of participant profiles.

ID	Age	Instrument	Degree	Venue	Total time (min) (time for each session)
A	24	Piano	M.M.	Zoom	175 (112, 63)
B	23	Violin	B.M.	Zoom	92
C	27	Piano	D.M.A.	Zoom	125
D	25	Violin	M.M.	Zoom	229
E	21	Piano	B.A.	In-person	309 (128, 97, 84)
F	27	Violin	A.D.	Zoom	114
G	25	Violin	B.M.	In-person, Zoom	403 (237, 166)
H	27	Piano	M.M.	Zoom	177

B.M., Bachelor of Music; B.A., Bachelor of Arts; M.M., Master of Music; D.M.A., Doctor of Musical Arts; A.D., Artist Diploma.

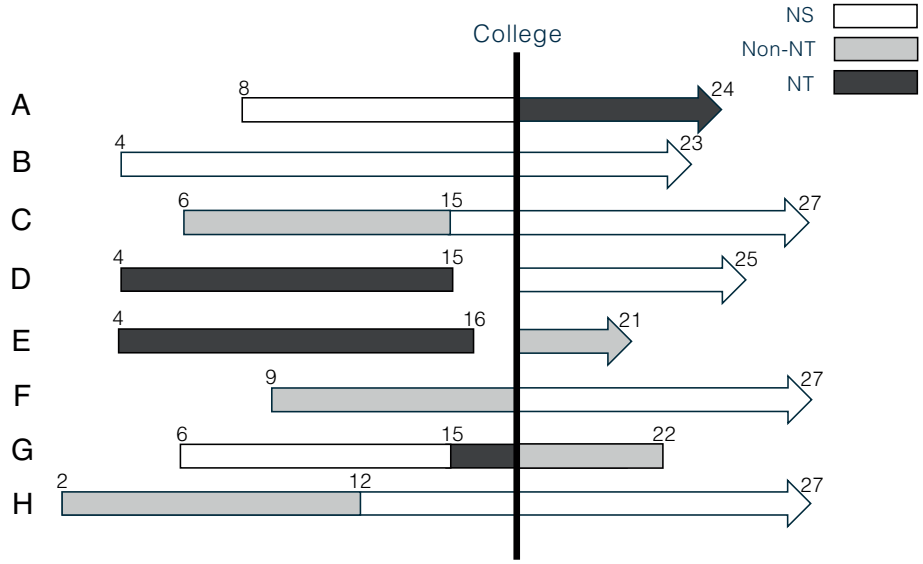

FIGURE 2
Learning experiences of the participants. The black line indicates need-thwarting experiences, the gray line indicates non-need-thwarting experiences, and the white line represents need-supportive experiences. The number indicates the age, and the black line is drawn vertically to indicate college entrance. For D and E, the lines are interrupted when they stopped taking lessons. For G, the line stopped at 22 when G left a music career.

(1) Learning experiences in lessons, practice, and performance (e.g., How did/do your teachers teach? What was/is the practice environment like? How did/do you perceive performance settings?)
(2) Interpretive autonomy (e.g., How did/do you approach interpretation? How did/do you see current performance practices and styles? How did/do you perceive a classical musician's role in interpretation and define the *Werktreue* ideology?)
(3) Learning behaviors and well-being in lessons, practice, and performance (e.g., How did/do you engage in lessons and feel about it? How did/do you practice and feel about it? How did/do you perform and feel about it?)

The participants freely elaborated on each question and brought other topics as they wished. After the eighth participant, diverse accounts were collected, thus data were considered adequate. Recordings were fully transcribed and used for analysis. Participants received an Amazon Gift Card equivalent to 20 dollars for their participation, and the study was approved by the Research Ethics Committee at the University of Tokyo.

2.3 Analysis

The first author transcribed the interviews while rendering personal data anonymous. Coding was done deductively using the model of *Werktreue* internalization as a framework. First, overarching categories were created: need-supportive/need-thwarting learning experiences, self-oriented/other-oriented interpretive approaches, self-regulated/other-regulated learning behaviors, and well-being/ill-being. All categories except interpretive approaches were further divided into three learning contexts: lessons, practice, and performance. Next, initial codes were generated under each category. For need-supportive and need-thwarting learning experiences, coding was done based on each participant's perceived fulfillment of the basic psychological needs. When statements were unclear, the first author interpreted latent meanings. After initial codes were created, similar codes were grouped, and themes were formed. While this was not our main interest, it helped to grasp common features in learning experiences, interpretive approaches, learning behaviors, and well-being across the participants (see Supplementary Material). Then generated codes were used to organize each case to find patterns within each participant. Finally, individual cases were compared to discover common patterns across the participants.

The first researcher studied violin professionally, and this helped her to elicit and analyze detailed accounts from the participants. She also listened to the participants' performances to deepen her understanding. Meanwhile, recognizing that her prior beliefs may affect the interview process, she asked open-ended and non-leading questions.

3 Results

All the participants were highly educated elite classical musicians, trained to be faithful to the composer's intention; yet they had diverse learning experiences in interpretation (Figure 2). D, E, and G had need-thwarting experiences before college and then had non-need-thwarting[2] or need-supportive experiences in college. Contrastingly, B, C, F, and H only had need-supportive or non-need-thwarting experiences throughout their education. Finally, A went through

2 The term "non-need-thwarting learning experiences" refers to experiences that were perceived as need-thwarting by other participants yet were not perceived as such by the participant.

need-supportive experiences before college and then had need-thwarting experiences in college.

We identified four patterns that aligned with self-determination theory (Deci and Ryan, 2000; Ryan and Deci, 2000, 2017) and enriched the model of *Werktreue* internalization. While we will use limited cases to introduce each pattern, four patterns were replicated in all the cases.

3.1 The cause and the effects of interpretive autonomy

In this section, we will address the first research question: how do need-thwarting and need-supportive learning experiences affect students' interpretive approaches, learning behaviors, and well-being? In short, we found that the model of *Werktreue* internalization was supported by all the cases; need-supportive learning experiences led to self-oriented interpretive approaches, self-regulated learning behaviors, and well-being, whereas need-thwarting learning experiences led to other-oriented interpretive approaches, other-regulated learning behaviors, and ill-being.

3.1.1 The cause and the effects of promoted interpretive autonomy

When participants had need-supportive or non-need-thwarting learning experiences in interpretation, they adopted self-oriented interpretive approaches; they personalized interpretation, valued implicit meanings of the scores, regarded teachers as facilitators, explored interpretive ideas spontaneously, consciously developed interpretation, and regarded technique as a means for expression (Table 1). These approaches empowered participants to initiate self-regulated learning, using interpretations as "guiding tools [F]" to set musical goals and self-evaluate their own performance. They critically incorporated advice from teachers, "experimented [B]" with a wide variety of interpretive possibilities in practice, and actively engaged in performance with mastery goals to convey original interpretations to audiences. This enhanced their well-being and musical identity.

We also confirmed that self-oriented interpretive approaches are clearer indicators of interpretive autonomy than musicians' accounts of the *Werktreue* ideology, since self-oriented interpretive approaches were adopted regardless of views ranging from the subjective to the formalist (Silverman, 2007). C expressed, "You know, they [composers] are dead. … And I just want to be able to do whatever I feel when I play music," and, as we will illustrate bellow, C adopted self-oriented interpretive approaches. On the other hand, B had the formalist view: "My mentality is that you are a bridge between the audience and the composer. … You're invisible on stage." B then employed both self-oriented and other-oriented interpretive approaches: "I do a lot of spontaneous things without realizing. So, why not just focus on the things that I can put in place." This confirms that the use of self-oriented interpretive approaches indicates interpretive autonomy (Fujimoto and Uesaka, 2024).

3.1.1.1 Need-supportive learning experiences

C's case illustrates how interpretive autonomy is promoted and how it leads to self-regulated learning behaviors and well-being.

C mostly had need-supportive learning experiences throughout their education. Starting piano at 6, C was taught by college students at a music academy. C's parents, "not typical Asian parents," never forced C to practice. After learning through "nothing professional" training, C was accepted into a prestigious music middle school at 12. In school, C studied with a teacher who was "too technical and philosophical," but C did not feel limited, since C was "too young to have [C's] own interpretation."[3] In high school, C had an "eye-opening" masterclass in which the teacher explicitly addressed expression and interpretation:

> "I felt like [the previous teacher] never actually taught me how to express through music—how to be expressive, how to be an artist, and how I need to approach music in general. … When I got a master class from him [the next teacher], it was so fresh. Because everything was about stories, colors, imagination—all that interpretational stuff."

After the masterclass, C switched to that teacher and studied with him throughout high school. The teacher encouraged C to develop original interpretations through open-ended questions and metaphors:

> "He always asks, 'Why do you think Brahms or Chopin wrote this way?' … So, he would say, 'Oh, maybe this is a conversation between a couple like a man and a woman.' … So, he just taught me how to interpret music, I think. And how to read music—not just notes, but as a story, as a color, or as effects."

The teacher also trained techniques so that C could express interpretive ideas convincingly:

> "If there's like a super lyrical passage, and then if I'm just playing it, he would say, 'Oh, you should do this and that physically, so that way, you could make the phrase longer, more lyrical, and more poetic.'"

C described the teacher as "my musical godfather," who had "the most influence on [C] as a musician": "We had a lot of time together outside of school as well. … He taught me how to drive. He taught me how to drink. … So, basically, he taught me life."

In graduate school, C actively chose another need-supportive teacher with whom C "literally clicked and just fell in love" during a trial lesson. The teacher accepted C's original interpretive ideas, even when those ideas might be criticized by expert audiences:

> "I mean, he loves the way I play. But also, because I have a pretty strong sense of musicality, he knows that some people would say, 'That's just not right' or 'That's just too much.' … And then my teacher says, 'Oh wow, I've never thought of that passage that way.'"

3.1.1.2 Self-oriented interpretive approaches, self-regulated learning behaviors, and well-being

C took the personal and the student-centered approaches from the beginning of the study:

> "I never wanted to just obey my teacher. … I think every lesson should be something like teachers would share their interpretations or how they feel about that music. Then they could suggest many possibilities for interpreting certain passages. And

3 This is an example of non-need-thwarting learning experience.

> students can take it if they like it. If they don't like it, they shouldn't take it. They don't play for their teachers just to copy them, you know?"

C also adopted the improvisatory approach, allowing spontaneity in performance to give "the charm of live performance": "I wouldn't try to do like, 'Oh, I practiced this way, so I need to do exactly this way.' … But that's how music is. It should be different [every time]."

C also valued implicit intentions in a score:

> "I know that some people would say, 'That's too much' because it's not written on the score. … [Composers] just wrote notes and some sort of tempo markings and little descriptions, but it was never thorough. So, a pianist's responsibility is to interpret that and then deliver it to an audience."

Lastly, C took an integrated approach, grasping overall musical characters from sight-reading and using it as a guide when C practiced techniques: "When you see the score, you should be able to just picture what the music is trying to say. … If you don't have an interpretation, what are you going to practice?"

Adopting self-oriented interpretive approaches, C initiated self-regulated learning effectively. When C found a need-supportive teacher who helped C to develop personal interpretation, C changed the teacher while the old teacher "did not like [C] leaving him." In practice, C actively listened to unconventional interpretations as a source of inspiration: "They're not confined by a traditional way of approaching classical music. So, there's definitely a lot of freshness." In performance, C never experienced serious performance anxiety despite being in a "very competitive" school. In addition, since C was satisfied with their own performance, C's self-esteem was not affected by professors' evaluations in exams:

> "The thing is, even when I was not the best student there, I thought my playing was fine. And I never understood why I always got like 30 to 40 range out of 60 or 50 students. And then when I was ranked in the top three, also—I mean that's good—but like, 'What's the difference?' (laugh) … I was the same pianist."

C pursued a music career, placing the development of original interpretation at the heart of the musicianship:

> "Through my D.M.A. or the master's [program], I'm realizing who I am as a musician. … So, my music is always about interpretation—how to make this music fresh and new or even more attractive and charming. You know, what kind of story this music has, or what kind of story I want to tell people."

3.1.2 The cause and the effects of hindered interpretive autonomy

In contrast, when basic psychological needs were thwarted in interpretation, participants employed—or were forced to employ—only other-oriented interpretive approaches; they formed interpretations that were disconnected from their personality, followed notations on scores rigidly, accepted teachers' interpretive ideas passively, reproduced prepared interpretations on stage, were not conscious of interpretation, and practiced techniques in isolation from expression (Table 1). Taking other-oriented interpretive approaches, participants demonstrated other-regulated learning behaviors in lessons, practice, and performance; they were passive in lessons, their exploration in practice was limited, and they felt detached during the performance. This lowered their well-being; strong music performance anxiety, burnout, intake of alcohol or prescribed drugs, and physical injuries were reported. Perceiving that expressive freedom is limited in the classical music field, they became doubtful of pursuing music careers despite their high expertise and strong passion for music.

3.1.2.1 Need-thwarting learning experiences

From the age of 15 to 17, G's interpretive autonomy was severely hindered in an elite music boarding school where "everything was about perfection."

Before then G had need-supportive experiences. G started learning the violin at 6 with warm support from parents. G took lessons with two violin teachers and "enjoyed" being exposed to different ideas: "Because I just thought 'Oh, here are new ideas. … I can choose which one I want.'" At 8, one of the teachers introduced G to vibrato, a technique that "really attracted [G] to the violin in the first place": "Practicing vibrato for about three hours … because I was so mesmerized by the sound that was created on the violin. … I just kept experimenting with this new technique of vibrato." G also had frequent performance opportunities in non-music schools. When G performed with a college orchestra, G felt "an excited sensation" before the performance and enjoyed performing and seeing their delighted parents afterward. At 13, one of the teachers introduced recordings from the twentieth century, leading G to discover a musical role model, Jascha Heifetz: "I wanted to do everything like him. … He was absolutely my idol."

Aspiring to become a musician, G auditioned and was accepted to a prestigious music boarding school at 15. Then G was assigned to a teacher, well-known for "giving students an amazing technique setup." From the first lesson, "everything was reset." Despite having played advanced repertoires, G was instructed to play scales and etudes for months "to reset the shape of [their] left hand" and "relearn how [G] lift and drop [their] fingers":

> "I had to completely change my bow hold because I was playing like this with my index finger pronated forward in the style of Heifetz as I admired so much. … She wouldn't have any of it. … Vibrato was another topic that had to be completely overloaded."

G had one-hour lessons four times a week, two of which were taught by ex-students of the teacher who were "really careful… not [to] contradict what the teacher said, especially in terms of technique." G had no say in choosing repertoire, and the order of pieces was predetermined as each piece served "a technical purpose." After months of etudes and scales, the first pieces G learned were Handel's Sonatas because "they are not too demanding, and they allow you to practice a lot of technique as well." G's interpretation was "micromanaged" as the teacher gave detailed technical instructions, but G was never "given a reason why." G was told that it was "better," "the way that everyone plays today," and "the right way to play." Furthermore, the teacher was "so unpredictable" during the lesson:

> "I didn't know how she would react to what I was trying to do in the lesson. … She would just explode and start to raise her voice

> and get angry at me. To me, everything that I was doing was just trying to prevent that from happening."

Practice was also need-thwarting, as G was instructed to follow the teacher's instructions rigidly in case anything interfered with their technical development. Practice rooms were poorly sound-proofed, and G could "always hear other people, and there was that constant subconscious comparison going on all the time."

One of the performance opportunities was studio class in which the teacher's students performed one by one. Pieces became a benchmark to assess a student's technical development, and students sounded inevitably "the same" with the same posture, fingerings, and bowings. In addition to an "extremely comparative" environment enhanced by the monotony of students, the teacher promoted criticism between students:

> "I remember one person said that, after a student played through scales and etudes, they really liked their tone or something. And I just remember that [the teacher] just immediately disagreed with the student and said, 'No.' 'No, I thought the tone was bad. It wasn't good at all. Do you have ears?' … So, everything was about negatives."

Other performance opportunities were school concerts in which performances were, again, criticized by the teacher and judged by peers:

> "[G's peers] would only come backstage if they felt you gave a 'good' performance. … That level of judgment—*unspoken judgment* and comparative education where you are always being compared to or benchmarked against other students—is just not helpful. … I mean, it certainly made me feel isolated and ostracized from my fellow students [emphasis added]."

At 17, G experienced a "traumatic" performance that "left a lot of scars for years." At that time, G started to "negotiate" over musical ideas in lessons. G then "gambled" to take a masterclass with another teacher in a summer course after obtaining permission from the teacher. In the masterclass, G enjoyed being exposed to new ideas and trying them in the "safe place." However, when G returned to the school, the main teacher had an "allergic reaction" to the other teacher's technical and interpretive suggestions that G had to "relearn everything again". After two weeks, G gave "the worst performance":

> "I had successive breakdowns on stage. I had memory slips, my legs were shaking, I wasn't breathing properly, and my hands felt completely frozen and tense. Because I was so confused mentally. … I think I was confused because I had so many ideas that I wanted to express which were put down by my teacher."

After the performance, G was hurt by reactions from the teacher, peers, and their parent:

> "Clearly, I was having serious mental problems on stage, and I did not receive the level of support that I should have received from my colleagues and from my teacher. And even my mom had no idea how to react to it. … She couldn't understand why it happened, and she just thought that I had a problem. … Because you put so much trust into the school, so much trust into the teacher that you end up following and going along with what the school says and what the teachers say. … This was very difficult."

3.1.2.2 Other-oriented interpretive approaches, other-regulated learning behaviors, and ill-being

G never believed that "there is only one right way of doing things," since G had been exposed to different musical ideas in childhood. However, G chose to take the teacher-centered approach, passively accepting the teacher's interpretation "to keep my teacher happy and restful." By reproducing the teacher's interpretation, G also took the impersonal approach, where interpretation was detached from their own personality. G "felt emotionally numb" during performances:

> "Because I just felt that I was going out on stage to demonstrate what I learned in the lesson and what I was building in terms of my technique. … And on many occasions, either the students or parents would remark that they felt very touched by my performances. But actually, I was always quite surprised that they said that because I didn't really feel that much inside."

G also employed the explicit notation approach: "My teacher had set all the bowings and all the fingerings for me. I couldn't choose any of those, and even the dynamics were pre-marked. I had to play it exactly that way." Regardless of the composer, the teacher insisted scores published by a company in a country, where the teacher was originally from. In addition, G took the reproductive approach, reproducing what was practiced on stage because "if you did something by mistake that was not what you prepared in the lesson, then that would be picked up [by the teacher]." Finally, G took the separated approach, as G was forced to go through a "disciplined systematic methodology" that trained technique in "extreme isolation."

These other-oriented interpretive approaches prevented G from initiating goal-setting and self-evaluation. By taking the teacher-centered approach, G passively accepted the teacher's instructions in lessons. In practice, G only practiced what was said by the teacher, and exploration was limited:

> "Objective, plain practice. It was just to execute. … The moment that I felt that I wanted to express something in the old way with my own way of doing vibrato and with my own expression, the voice in my head said, 'No, you can't do that … because the teacher is not going to be happy.'"

In performance, G evaluated the quality of performance based on technical fluency and others' evaluations: "So, if you didn't have a good performance, or what they felt was a 'good' performance, and you didn't execute well enough, you [were] sort of left to feel ashamed about it".

After the traumatic performance at 17, G had "serious self-doubt and anxiety," and G started to drink alcohol as "self-medication": "Just to calm nervous because I was shaking so much." G also lost their motivation to study abroad, thus G continued studying with the same teacher in college.

Although G escaped from a need-thwarting environment in college, which we will explore in the section 3. 4. 2., G decided to

pursue a non-music career despite their strong passion, hard work, and high achievements:

> "I eventually realized that my personality and what I wanted from music was not going to be found in the soloist's path or career. … I disliked competitions, politics, and the level of subjectiveness [in music]. … And the thought of putting the rest of my life in the hands of other people who were choosing whether or not my music-making was worthy of management representation or competition prizes just was not for me. I wanted to be in charge of *my* future [emphasis added]."

Having gone through "pretty bumpy journey," G wished that things were "better explained." However, G showed great respect and appreciation for the teacher:

> "I would never be able to play the violin today in the way that I can play if it wasn't for my teacher. … That was what she felt was best for her students. … [At 15 years old] I knew that my technique was not up to the standard that was required to be a professional violinist. I was therefore willing to sacrifice my autonomy when it came to my interpretations."

3.2 Promoted interpretive autonomy after being hindered

This section addresses the second research question: we found that interpretive autonomy can be nurtured even after it has been hindered.

As already shown in the case of C, participants naturally employed some self-oriented interpretive approaches from childhood, such as the personal and the student-centered approaches; even when they were unaware of the *Werkreue* ideology, they believed that music is personal and teachers are facilitators of their music-learning. G, D, and E, who had need-thwarting experiences in their teens also began to adopt self-oriented interpretive approaches once they moved away from a need-thwarting environment, resulting in improved learning behaviors and well-being. This aligns with SDT's assumption that human beings are "active, growth-oriented organisms" (Deci and Ryan, 2000, p. 229).

While need-thwarting teachers were powerful in inhibiting interpretive autonomy, teachers were also influential in promoting interpretive autonomy. When instrumental teachers were need-supportive, all the participants started to adopt self-oriented interpretive approaches which improved learning behaviors and well-being regardless of their prior experiences. This indicates that interpretive autonomy can be nurtured even after it has been hindered, and instrumental teachers play a crucial role in it. This also aligns with SDT which posits that internalization types shift "depending on both prior experiences and current situational factors" (Ryan and Deci, 2000, p. 73).

3.2.1 Hindered interpretive autonomy in childhood

In the next case, a participant's needs were thwarted in childhood and then satisfied by a need-supportive teacher during college. The participant demonstrated significant improvement in learning behaviors and well-being.

D began learning the violin at 4 under the guidance of their mother who was deeply invested in their professional training. The mother took videos and notes in every lesson and assisted D's practice by reinforcing the teachers' instructions. D recalled, "I practiced about three hours around that time [at the age of 5]. But I was fighting with my mom maybe for one hour and a half. … When I was practicing a scale, she would sit by the piano and keep playing a note until I could play it in tune." D switched teachers as D's mother found better violin teachers. One teacher taught interpretation by talking about emotion, but it confused D. From the age of 10, D started to participate in competitions which increased their frustration:

> "Before the lesson, I was like, 'I don't want to go to lesson today,' and after the lesson, 'I didn't understand what the teacher said,' and like, 'I wanna stop playing.' … And 'I didn't win in competitions.'"

In junior high school, D studied with a teacher, so highly sought after that other students would travel by plane to take lessons. The teacher taught how to play "inoffensive" performances that were "better technically, better for competition, but not emotionally profound":

> "[The teacher] just says, 'OK, this needs to be more like this. … Fix this. Do this like this.' That's how he teaches. And very, very rarely or not even once, you would hear something emotional coming out of his mouth to influence the music. … So, it's very, very methodical and very emotionally detached."

At 13, D took the impersonal approach, the unconscious, and the teacher-centered approaches:

> "I always played with some kind of musical phrasings intuitively. … But I was emotionally detached. … When I was studying with the teacher, I really hated playing the violin, and I don't think any emotion truly came from my heart when I was playing."

This made D passive in lessons: "I had no opinion. I just stood in the lesson room and did whatever I was told. … I was like, 'I will do it if you tell me what to do.'" D never practiced voluntarily. In performance, D often compared their own performances to those of older students, which lowered D's self-esteem: "I thought 'I can't play like them. I'm a failure.'" Being "burned out," D stopped playing the violin for about four years.

3.2.2 Promoted interpretive autonomy in college

D then entered a college which housed a conservatory. D's mother asked to have a trial lesson with a violin faculty at the conservatory, and this became a turning point:

> "During the lesson, I told him, 'I don't like this competitive music world where you are always compared to others.' … Then he said, 'The point of music is not competition. … The most important thing in music is that you keep pursuing your own performance.' I was really moved by his words. I thought, 'For that then, I can work hard—not to win, but to strive for more beautiful performances.'"

D auditioned for a conservatory to study with the teacher. In lessons, the teacher warmly accepted D's musical ideas and valued their long-term development:

> "When I introduced my musical ideas, he never rejected them. … Also, when I was concerned about my life, he was very supportive. So, I felt that he cared not only about my violin studies but also my personal development. … He didn't pressure me to enter competitions. Instead, he focused on helping me connect my emotions with the music while training my techniques."

This led D to take self-oriented interpretive approaches: "I realized that I have to have a good reason for what I do." Then D started to demonstrate effective learning behaviors. In the lessons, D "asked a lot of questions": "I often said, 'I want to make this kind of sound, but I can't,' and 'I want to express this, but I don't know how.'" D practiced five to six hours every day:

> "So, after studying with him for a while, I began to reflect more on my emotions in practice. … For the first time, I discovered the joy of pursuing emotional meanings in music."

In performance, D initially struggled with anxiety, being preoccupied with negative thoughts. However, toward the end of college, D focused more on conveying personal meanings:

> "At conservatory, I started to become aware of how, if I don't perform 'well,' I am getting judged by my colleagues … It influences who asks you to play together or what opportunities you get. A conductor might be watching, and he might not put you in the first chair, if he hears you play badly in public, right? … And then what if other faculties happen to be there because they have the power to give you performance opportunities, and you might not get them, right? … So, the fear of getting judged and the consequences of that holds. … That was a very fundamental fear. … [By the end of college] a little bit that started to shift toward 'Can I be convincing? Can I connect with the audience? Can I show who I am through my music?'"

After college, D auditioned a prestigious conservatory for a graduate program to study with another teacher who helped D achieve a personal goal "to use [their] body more naturally" to connect with music. After graduation, D pursued a music career, recognizing that music provides the most meaningful experiences for D.

3.3 Interpretive autonomy as resilience against need-thwarting environments

While this was not part of our research questions, we found that interpretive autonomy enhanced musicians' resilience in need-thwarting environments. When participants with self-oriented interpretive approaches perceived that their needs were being thwarted by authoritarian teaching, they tried to change the teacher or school. When changing the environment was not possible, they engaged in alternative activities to fulfill their needs, such as freely exploring interpretive possibilities in practice or listening to unconventional interpretations. While this resilience was evident both in childhood and college, as we will illustrate, children were more susceptible to need-thwarting environments.

In contrast, while other-oriented interpretive approaches were often employed to adapt to a need-thwarting environment, these approaches made their learning more dependent on others, increasing their vulnerability to such environments. In addition, to improve the situation, participants reinforced other-regulated learning behaviors, such as following a teacher's instructions rigidly, which thwarted their needs further as illustrated in G's case above.

This indicates that interpretive autonomy, promoted by need-supportive experiences, enhances need-satisfaction further, whereas a lack of interpretive autonomy, forestalled by need-thwarting experiences, thwarts the needs further. SDT supports this, as while "autonomous regulation involves greater need satisfaction" (Deci and Ryan, 2000, p. 243), controlled regulation that "serve[s] to protect them from the threat and preserve as much satisfaction as seems possible in the non-supportive situations … has the unfortunate consequence of continuing to thwart need satisfaction, even in situations where satisfaction might be available" (p. 249).

3.3.1 Resilience in college

We will present two cases of participants who demonstrated strong resilience against need-thwarting environments in college and childhood. While A, having gone through need-supportive experiences beforehand, demonstrated a strong resilience in college, E's resilience is threatened due to enduring need-thwarting environments from childhood.

A mostly had need-supportive learning experiences until college. A began learning the piano at 4 "casually" with their father who never pressured A to practice. A also studied with need-supportive teachers who often praised A's interpretation that it "tell[s] a story." A enjoyed performing in public, whether in competitions or studio classes.

In college, however, A studied with a need-thwarting professor who constantly criticized A's interpretations for being too personal for six years:

> "She always keeps telling me, 'Your playing is always yourself too much. … You just play what you feel.' … When I was playing Scriabin's Sonata, she said 'What you are playing is [A]'s Sonata. Not Scriabin's Sonata.' … She sometimes comments like, 'Your playing is in general like a primitive person.'"

Furthermore, the teacher did not demonstrate on the piano but would "sing very ugly, imitating what [A] played," so A was confused and frustrated.

Being always "yelled at," A got nervous before the lessons. One day before a graduation recital, the teacher told A that their playing worsened compared to five years ago, making A self-doubt, "Whether I really play like that or not."

However, A showed strong resilience against the teacher, as A believed that interpretation is personal and students should develop their own interpretations:

> "It's easier to think that way actually … [to play] to make her happy otherwise she will kill [you]. It's very easy to think that way, but I don't think like that. Because no matter how well you play, she would still kill you. (laugh) … I think her attitude is right. You have to study the score very carefully because that's

> the only reference the composer left. But how do you know your impression of this music is right, and my impression is not right?"

A participated in competitions without consulting with the teacher, saying, "because if I asked, I know she will say, 'No.'" While the teacher told A to find a pre-composed cadenza by others, A composed their own cadenza. During performances, A forget about the teacher and focus on the music, adopting an improvisatory approach: "Because what [the teacher] says is always very detailed. If I think of too many details, I can't really play. … You will never catch up with music."

A pursued a music career with a clear artistic goal, and A recalled a recent performance of performing a favorite piece from childhood:

> "After I finished, [the audience] all came to ask me, 'What's the title of that piece again? Can you say that again?' … Actually, it makes me very happy. Since that's actually one of my dreams to spread all [A's national] music to people all over the world. … Today, I think I just let them understand better what [A's national] music sounds like."

3.3.2 Resilience in childhood

In the case shown above, the participant had need-supportive experiences before college. In the next case, however, E mostly had need-thwarting environments from the beginning of the study. While E initiated SRL with self-oriented interpretive approaches, E gradually suffered from need-thwarting learning experiences.

Having started piano lessons at 4, E participated in competitions every year from the age of 5. The first teacher greatly cared about results in competitions, and E's parent took videos and notes during lessons and supervised practice at home. Before competitions, parents—both of them could play the piano—assisted E's practice, sometimes all day.

While these learning experiences could be perceived as need-thwarting, E appreciated the teacher for teaching "the enjoyment of music." E also thanked the father even though E "cried badly" when E negotiated musical ideas with him:

> "Because my father didn't give up, I had to accept his ideas. … So, when I accepted it and tried his musical idea, I thought, 'It's actually good!' Then I didn't feel like my musical ideas were put down. …. And I felt like I improved a bit. … I was probably around 8 years old."

E was resilient because E was always interested in learning composers' intentions and felt that they helped E to understand music better. When E discovered a favorite composer Chopin at 8, E composed pieces in the style of Chopin. E enjoyed reading composers' biographies, finding the composers relatable.

Taking the personal approach, E engaged in various musical activities that satisfied their needs in interpretation. In practice, E enjoyed sight-reading a variety of pieces other than assigned pieces and listening to favorite interpretations. In junior high school, E played the viola in an ensemble club and accompanied a choir. In high school, E organized and performed two recitals with friends in a local town.

However, E gradually struggled with need-thwarting environments which pressured E to adopt other-oriented interpretive approaches. While E won the first prize several times in competitions, the preparation eventually became overwhelming for their parents. At 9, they switched to a teacher who disliked competitions. The teacher constantly rejected E's ideas and did not allow E to choose pieces or musical ideas that would be beneficial in competitions. E, nevertheless, respected the teacher's values and adopted the teacher-centered approach:

> "When I tried to make the music more interesting, the teacher rejected my ideas. He was quite the opposite of my first teacher, and when I played with obvious expressions, he said, 'It's unnatural.' … In every lesson, I did my best to understand what he wanted, though."

At 13, E was eliminated in a competition:

> "It was shocking because I listened to other performances, and I didn't like them. … Yes, I did make some mistakes, but I was confident that my music was better."

Because the previous teacher's student advanced to the next round despite her "uninteresting" performance, E returned to the first teacher and won a prize a year later.

In high school, E gave an improvisatory performance that was "full of musical ideas but no control," which "just exploded" in a competition. E was eliminated from the round and advised to play more stably by a conservatory professor. In the final year of high school, E decided to apply to an academic university that has no music performance department: "I wanted to keep the feeling from my childhood that music is wonderful. I thought, 'If I go to a conservatory, I will lose myself because I have to compete with others.'"

3.4 The long-term effects of early learning experiences

The last section addresses the third research question: how do pre-college learning experiences affect students during and after college? Analysis revealed that earlier learning experiences had lingering effects on students when they began to develop their interpretations actively during and after college. Participants who had need-supportive learning experiences earlier could focus on conveying original interpretation in performance even when they felt restricted by interpretive norms within the classical music field. In contrast, those whose needs were thwarted earlier experienced anxiety and a sense of detachment in performance when they tried to convey their interpretation.

3.4.1 The effects of early need-supportive learning experiences

Participants with earlier need-supportive learning experiences demonstrated strong resilience against need-thwarting environments. This is already introduced in A's case, who resisted the teacher's criticisms, but it was also apparent when the need-thwarting figure was more conceptual.

In college, six out of eight participants recognized the classical music field as need-thwarting; they were aware of perfectionistic standards in interpretation, limited interpretive choices, and intense competition among peers to present "better" interpretations. The six participants also recognized and criticized normative interpretations, describing them as "lazy [F]," "boring [C, D, G]," "plain [C]," "tiring [G]," "dangerous trend [A]," and "unnatural [E]." Their authenticity was also questioned:

> "Very accurate with the music, technical perfection, and not very improvisatory. That's like the standard, right? … Mozart, I think it should be a lot more free than how a lot of people play it. Because he himself was very improvisatory. … A lot of contemporary pianists don't [improvise]. Because they are afraid to, and they don't know how to [D]."

They also noted that audiences "hate [C]" musicians who present atypical interpretations and even world-renowned musicians did not necessarily convey unique interpretations.

Despite such a situation, earlier need-supportive experiences let students focus on conveying their original interpretations, regarding it as a crucial role of classical musicians. C recognized restrictive norms in competitions and the field in general, noting that there is "definitely a very favoured interpretation":

> "Like very virtuosic and dramatic, but nothing too out there. Nothing too crazy. … And then if you can fit yourself into those criteria, you are considered a good player. And if you do like excessively rubatoes, or if you do dynamics too intensively, people will say, 'Oh, that's just not right.'"

Then C modified the *Werktreue* ideology in a way that freed C from interpretive norms:

> "I try to refuse already pre-existing connotations of composers that 'Bach should be this way' … because we really don't know who they were in real life. … So, I think there are limitless possibilities. … So, I try to bring a fresh, new perspective of each composer or each piece."

Similarly, having studied with teachers who were "all about, even if you don't get a good result [in competitions], you should stay true to yourself," F stated that without developing personal interpretation, "it loses the meaning of playing written music completely." F also modified the *Werktreue* ideology effectively, allowing themselves to be driven by the goal of making an impact on audiences through the music:

> "You revive the feeling that the piece, or the impact that the piece created at the time for the listeners back then. … When Beethoven's 9th Sonata was performed, it was artistic terrorism to the listeners at the time. And then for this sonata to create the same impact for modern audiences, it needs to be much more extreme for people to feel like 'This is terrorism. This is not music.' … The composer's intentions are important, but they are important, not because you want to play exactly how it was played back then."

F also recognized restrictive interpretive norms but managed to convey intended interpretations. Before a competition, F was told by a teacher, "I really like how you played this, but I know people on the jury are going to have problems with it." F then felt, "If I go into a competition with too much of my own thoughts or what I think of the music, I would get washed out." F initially tried to make interpretive decisions "less aggressive" and "less unheard of," not being "my true self because it was a toned-down version of it." However, it was "really difficult" to assimilate into a preferred interpretation, so F changed the strategy "to choose repertoire that [F's] idea sort of lines up with what general people think." This led F to be more comfortable: "So, going in [the competition], I didn't really think about 'Oh, I have to play this way or that way.'" In recital, F is focused on sharing their "vision of what the music sounds like" and has done creative projects to "mak[e] this a real experience … instead of putting classical music on a high horse, and we think of ourselves as highly educated elite."

The remaining two students who had only need-supportive experiences did not perceive the classical music industry as need-thwarting, unlike the other six participants. This may be due to their positive experiences with normative performances during their teenage years. H was often moved by "beautiful" performances in lessons and concerts: "I was so touched by their performances. They made me think, 'This is what music is.'" H did not recognize interpretive norms because H "listen[s] to others' performances to get inspiration, not to evaluate if they are playing 'correctly.'" H has been actively engaged with solo and chamber concerts to "deliver love through music to people as much as possible." B recognized that "in very famous pieces people just do the same kinds of things," yet B stated that "individuality is overrated" in the field, reflecting their formalist view that performers should "remove [themselves] from the playing." B recalled that B's teacher was "always thinking about the composer first, and that's what ma[de] his playing so special."

Interestingly, accepting the formalist view was not so straightforward for B; B wanted to be "unique" and "special" but adopted the formalist view during college years due to a sense of "failure":

> "I didn't understand that you have to remove yourself from the playing. … If you play in concerts, you get the sense of what the audience *actually* thinks based on what they're saying. … You shouldn't force trying to be unique. … If you force it, it's bad because people can tell. … I think my biggest pet peeve is people that try to show off. So basically, I'm the biggest pet peeve myself from two years ago [emphasis added]."

B frequently emphasized that B's view is yet "always changing": "I'm OK not sounding up to my full potential right now as long as I'm trying things. … I think once I find my voice, I'm going to also establish a taste in music a little bit firmer."

3.4.2 The effects of early need-thwarting learning experiences

In contrast, early need-thwarting learning experiences had negative long-term effects; participants whose interpretive autonomy was hindered earlier struggled to convey their original interpretations in performance. They often experienced strong music performance anxiety beforehand, felt disconnected from the music during the performance, and were dissatisfied afterward, even when their needs were no longer thwarted directly. This was particularly evident in

performance settings where interpretive norms were shared among audience members, such as school concerts, auditions, and competitions.

After two years of need-thwarting learning experiences, G escaped from the aversive learning environment in college. The same teacher gave no more need-thwarting lessons, treating G as an "adult." G was at a higher level than most students, and G won a prize at an international competition. Naturally, G took self-oriented interpretive approaches: "I wasn't thinking in terms of what would my teacher like. … I just wanted to achieve quality in my playing with as much individuality as I could manage. … I would just come to the lesson with my interpretation."

However, even then G suffered from anxiety when G tried to convey personal interpretation in performance. G recalled the competition:

> "It's not that I deliberately played in a way that I thought [judges] would like, but I just remember feeling very self-conscious about whether what I was doing was correct or what I was doing was in good taste or acceptable. I found it quite hard to be myself."

Before lessons and performances, G continued to drink alcohol as "self-medication," which was eventually replaced by prescribed beta-blockers. This is because the abovementioned performance at 17 gave "PTSD" that "every occasion that [G] stood up and played the violin in front of someone, it was a trial or a battle." Despite G's technical ability was "only getting better," G's mentality was "seriously getting behind," making G decide to pursue a non-music career. Even when G started studying a new field, G suffered from a perfectionistic "insidious mentality" and was "learning to shake all of that off."

Similarly, while D's learning behaviors improved drastically during college, D recalled struggling with performance anxiety in graduate school. D once had a mental breakdown before studio class because "emotionally [D] wasn't able to connect with [their] music":

> "I had been struggling with that for like a month. … I was already about to burst into tears by the time I started because I was like, 'I know I'm not emotionally there, and I don't know how to reconnect with my playing emotionally.' … And it didn't go well. And then I ended up crying after. Then [the teacher] was like, 'Oh my gosh,' and everyone was so nice though. But that kind of specific struggles that I was having with music would sometimes be a source of nerves."

Lastly, even though E naturally exhibited strong interpretive autonomy from childhood, E expressed discomfort in conveying interpretations in lessons and competitions:

> "I feel like I'm trying too hard. … In competitions, I suddenly made mistakes on stage, and I was always concerned with that. But I didn't know what to do with it."

E was also aware that their interpretation conflicted with their father's ideas:

> "When I was in elementary school, I couldn't really explain the differences since my ideas were not crystallized as much as his ideas, but I certainly felt that they were different. … My father wants to hear music that convinces him. He believes that if I play in a way that satisfies him, I will achieve good results—and he's probably right. But neither of us can forgive ourselves for not playing the way we truly want to. And I don't want any trouble from this."

While recognizing the restrictions on interpretation in competitions, E continued participating in competitions: "Since I am not at conservatory, I think winning competitions makes it more socially acceptable for me to continue playing the piano. It might open up career and performance opportunities too." E continued:

> "I just want to find a way out. … When I was in high school, I thought if I became a professional, I would be stressed out. … But now, I'd accept it if I could continue living with music. It's definitely better if I could focus only on music in my life, right?"

3.5 Summary

Four patterns were found that supported and enriched the model of *Werktreue* internalization (Fujimoto and Uesaka, 2024). First, need-supportive learning experiences in interpretation led the participants to adopt self-oriented interpretive approaches regardless of their varied stances on what constitutes an authentic interpretation. With self-oriented interpretive approaches, participants initiated self-regulated learning, maintained well-being, and pursued music careers with integrated identity as classical musicians. In contrast, need-thwarting experiences in interpretation forced participants to take only-oriented interpretive approaches regardless of their ability to develop interpretation. They then showed dependent learning behaviors, lowered well-being, and doubt about pursuing a music career.

Second, all the participants showed a natural inclination toward interpretive autonomy; even when their interpretive autonomy was hindered, once they moved away from a need-thwarting environment, they started to take self-oriented interpretive approaches. Instrumental teachers were especially influential in supporting such orientation toward growth. This indicates that interpretive autonomy can be promoted even after it has been inhibited, and instrumental teachers were powerful in supporting the participants' needs in interpretation.

Third, while this was not part of research questions, interpretive autonomy buffered the negative effects of need-thwarting learning environment. Participants adopting self-oriented interpretive approaches could successfully manage the aversive environments, whereas participants with other-oriented interpretive approaches were more vulnerable to the environment. Additionally, the participants were more susceptible to the need-thwarting environment in childhood even when they showed a strong inclination toward interpretive autonomy as a child.

Lastly, learning experiences in interpretation before college had long-term effects on musicians in college and post-college. Participants with earlier need-supportive learning experiences could perform their original interpretations satisfactorily even when they perceived restrictive norms within the classical music field. In contrast, participants with need-thwarting learning experiences struggled psychologically when they tried to perform

their personal interpretations. This difficulty persisted even when their needs were not directly threatened by the environment and was particularly evident in evaluative performance settings, such as competitions.

4 Discussion

These findings show that (1) interpretive autonomy supports students' self-regulated learning and well-being in both the short- and long-term, and (2) it is essential to support students' interpretive autonomy from the first stage of learning.

4.1 How does interpretive autonomy support students' learning behaviors and well-being?

While the importance of interpretive autonomy has been implied for instrumental learning (e.g., Reid, 2001; Clark et al., 2014; McPherson et al., 2019), this is the first empirical study that revealed a close relationship between interpretive autonomy, SRL, and well-being. Interpretive autonomy was essential in promoting SRL and well-being; to develop and convey original interpretation, students effectively adopted teachers' advice, engaged in explorative practice, and were fully focused on conveying intended interpretation in performance. This led to enhanced self-efficacy and integrated identity as classical musicians. SRL also promoted interpretive autonomy; for example, adopting a teacher's advice selectively satisfied the need for autonomy in interpretation, showing a mutual relationship.

Interpretive autonomy especially helped the participants to initiate SRL in performance. Even in high-stake performance settings, students whose interpretive autonomy was supported from an early stage could set a mastery goal to convey intended interpretations and be the "true self [F]" during the performance. This experience itself satisfied them even when they received negative evaluations or made technical mistakes, motivating them to engage in the next performance.

In contrast, participants whose interpretive autonomy was hindered before college struggled to initiate SRL in performance. Before performances, they were pressured to reproduce interpretations, externally imposed by teachers, scores, norms, or ultimately themselves. During performances, they felt "detached [D]" from their own playing, and they took others' negative feedback personally or could not appreciate positive feedback because they were dissatisfied with their own performance. These participants reported maladaptive states that are often associated with music performance anxiety (MPA), such as perceived performance impairment (Fehm and Schmidt, 2006; Murphy et al., 2025), playing-related physical injuries (Kenny and Ackermann, 2015; Amorim and Jorge, 2016), perfectionistic concern over mistakes (Liston et al., 2003; Yoshie and Shigemasu, 2007; Kobori et al., 2011; Dobos et al., 2019), the use of alcohol and drugs (Kenny et al., 2014; Hernández et al., 2018; Burin et al., 2019; Lupiáñez et al., 2022), and intentions to leave a music career (Hernández et al., 2018; Wang and Yang, 2024; Casanova et al., 2025).

The current and past studies suggest that promoting interpretive autonomy helps musicians self-regulate themselves in performance. Chen (2023) claimed that offering courses on musical interpretation led more students to report experiencing flow in performance. Others have shown that the improvisatory approach is effective in releasing anxiety. Learning and performing improvisation reduced music performance anxiety among young piano students (Allen, 2013), and professional musicians reported feeling less self-critical when adopting the interpretive approach than when they reproduced a prepared interpretation (Hill, 2017; Dolan et al., 2018). This leads us to the next discussion point—how can we nurture students' interpretive autonomy?

4.2 How can we nurture music students' interpretive autonomy?

4.2.1 Factors behind need-thwarting learning experiences

Let us reflect on need-thwarting learning experiences first; why do they exist in the first place? Notably, six participants recognized the classical music field as need-thwarting; they felt interpretive autonomy was threatened by social pressure to conform to normative interpretations. Some participants were constantly over-challenged, forced, and rejected in musical interpretation from childhood to conform to those norms, which harmed their professional development and well-being. This paradox of the classical music industry and professional training, which is supposed to celebrate and nurture independent artists, is also observed in Wagner (2015). She found that students must conform to teachers' expectations from the first stage, and "too much personality" is seen as "an obstacle to education" (p. 107). However, students were also expected to demonstrate artistic personality on stage as soloists, and many obedient students struggled to transform themselves into a "true artistic personality" in adulthood (p. 208).

Teachers were especially powerful in hindering interpretive autonomy, as they could control students' behaviors in practice and performances. Need-thwarting teachers' behaviors aligned with cautioned strategies in prior studies, such as an exclusive focus on technique (Rostvall and West, 2003; Young et al., 2003; Karlsson and Juslin, 2008; Gaunt, 2010; Holmgren, 2022), enforcement of certain interpretive ideas while rejecting students' ideas (Persson, 1996; Silverman, 2008), and little demonstration (Rostvall and West, 2003; Burwell, 2021). They also added others, such as monotonous students' playing styles and competition in a studio.

Importantly, need-thwarting experiences were often provided with good intentions to advance students' careers. Some teachers criticized students' interpretive ideas as violating the composer's intentions, but they seemed more concerned with students' short-term achievements which depended on other experts' evaluations. Persson (1996) observed that an authoritarian teacher felt responsible for teaching the duty of "commitment to others' expectations" and assessed students' performances based on "the consensus" of good performances among other professors (pp. 41, 43). In competitions, atypical interpretations or prioritization of emotional investment over technical perfection result in elimination, but competitions offer a "unique opportunity to 'build a career'" (McCormick, 2015; Wagner, 2015, p. 70). Finally, parents who assisted their children excessively wished to provide the best professional training. They selected teachers based on reputation—even though it did not guarantee that students' interpretive autonomy would be supported—hoping for the career success of their child. Participants who felt incompetent,

limited, and rejected in learning interpretation showed appreciation for their teachers and parents, understanding that the educators did what they felt "best [G]" for the participants.

Yet the more educators impose interpretive norms to prepare students for career success, the earlier and more intensely students' interpretive autonomy may be suppressed. The more students are psychologically controlled, the more that they may pursue conformity out of anxiety or even stop performing professionally, reinforcing interpretive norms within the field and perpetuating the cycle.

4.2.2 Providing need-supportive learning experiences

The study also provides hope, as interpretive autonomy could be promoted by need-supportive learning experiences.[4]

Teachers were, again, powerful in nurturing students' interpretive autonomy. Having a teacher who always accepted their interpretations encouraged students to convey personal interpretations even in a challenging environment. Need-supportive teaching strategies aligned with those presented in Nerland's (2007) study. A wind instrument teacher provided historical recordings and books, encouraged students to have original ideas, promoted peer collaboration, and allowed students to take lessons with others. This was to make the discourse of authenticity and instrumental traditions open and transparent so that students could "renew" them in a personal way (p. 410). Other effective strategies aligned with previous studies, such as open-ended questions (Meissner, 2017, 2021; Meissner and Timmers, 2019, 2020; Meissner et al., 2021), illustrative metaphors[5] (Lindström et al., 2003; Schippers, 2006; Woody, 2006), and self-selected repertoires (Renwick and McPherson, 2002). Warm personality and encouragement were also appreciated, and most participants referred to their teachers as parental figures, such as "mom [A]" and "godfather [C]."

Since participants shared difficulties in finding or changing teachers, an issue that is not uncommon (Gaunt, 2011; Wagner, 2015), we now turn to experiences outside of lessons. Learning a wide variety of music—such as contemporary, cross-genre, free-style improvisation, or theatrical acting—in a classroom was also perceived as need-supportive, as it lets students explore expressive possibilities beyond norms within the field (Varvarigou, 2017; Hill, 2018). Additionally, performances at non-traditional venues, such as senior centers, were perceived as need-supportive "because there [was] no pressure from the audience [A]," in line with Paolantonio et al. (2022). Working with living composers was also beneficial because students could engage in open discussions on interpretation, fostering "creative collaboration" (Clarke et al., 2005, p. 44). Lastly, listening to a wide variety of recordings helped students explore interpretive ideas (Volioti and Williamon, 2021). Many participants appreciated Patricia Kopatchinskaja whose interpretations often sparked controversies among audiences (Leech-Wilkinson, 2020b). She "explained everything so clearly in her own way [F]," was "creative [C]," and made "us rethink what truth is if there's any such thing in music [D]." G recalled that G would have "rejected all of that and been quite repulsed by it almost" when G was in college, then G continued:

> "But actually, I think that she's tapping into something very important for young people to see … [that] it's okay to take risks on stage. … Stop thinking about perfectionism and impressing other people. And let us really try and go back to being master interpreters and creative artists rather than being slaves to the competition machine."

We can also consider how need-thwarting learning environments could become more supportive. Parents may leave a space for their children for free self-exploration while providing necessary resources and support. Since studios are often isolated, conservatories may offer opportunities for instrumental teachers to self-reflect and collaborate with other teachers (Burwell et al., 2019). Institutions can also prepare courses for students to explore various genres of music-making, conduct workshops in a local community, and engage in multidisciplinary collaboration (Hill, 2018). Finally, competitions may have distinctive aims and juries rather than them being "almost always the same [F]," since competitions can "also be artsy … [having] their own identity [F]." They may also help winners with their careers so that they are not "completely forgotten [G]." Parents, conservatories, and competitions would contribute to students' development significantly when they support their interpretive autonomy.

4.3 Limitation

While this study is grounded on valuable data from elite music students, there are limitations due to the qualitative method. Data relied on participants' self-reports including those regarding interpretive autonomy and norms. Future studies may analyze other forms of data to investigate holistically. While case study research permits analytic generalizations, more empirical studies are needed to validate the plausibility of the model of *Werktreue* internalization. Additionally, no participants had need-thwarting learning experiences throughout their education, thus its effects remain unknown. Lastly, all the participants were in their 20s, and how the observed long-term effects may stay or diminish is unknown.

5 Conclusion

Having autonomy in interpretation—freely exploring and deciding what message to convey to audiences through performance—was a driving force for classical musicians to strive for excellence. Since interpretation is an essential part of music-making where musicians bring their own "voice," interpretive autonomy allowed musicians to be their "true selves" even when they perceived the classical music field as over-challenging, controlling, and rejecting. In contrast, musicians with hindered interpretive autonomy perceived classical music performance as a harsh "battle [G]," where they compete against one another to reproduce an expected performance as flawlessly as possible. Musicians' perceptions of the professional world were greatly shaped by early learning experiences; "casual [A, C, F]" exploration

4 The long-term effects were observed only at college and post-college level; E, D, G continue to engage in performing, teaching, and deepening their knowledge with their passion, which may mitigate fear and anxiety further, leading them to fully embrace the joy of music-making.

5 Note that when metaphors are difficult to understand, they can be frustrating as illustrated in D's case.

laid a strong foundation for interpretive autonomy, while the enforcement of normative interpretations suppressed their voices.

Autonomous interpreters would not only exhibit strong resilience when the classical music field poses challenges but could also contribute to transforming the field into a more supportive environment. When musicians creatively bring personal interpretations, they enhance interpretive diversity, fostering a healthier artistic ecosystem. To support musicians' optimal professional development and the evolution of the classical music field, parents, teachers, gatekeepers, performers, and researchers play a crucial role in reconsidering professional training from an early stage.

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 at the University of Tokyo. 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 potentially identifiable images or data included in this article.

Author contributions

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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.

Generative AI statement

The authors declare that Gen AI was used in the creation of this manuscript. The first author used the free version of ChatGPT and Claude AI to detect any grammatical errors, given her first language is not English. She carefully reviewed each suggestion before adopting it.

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Supplementary material

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Past social support influences pre-performance self-confidence and performance quality among student musicians

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Music performance anxiety (MPA) is a serious and prevalent problem among student musicians. Although previous studies have indicated the importance of social support from parents and teachers in the management of MPA, it remains unknown whether past social support influences pre-performance mental states and performance quality among student musicians. To address this, we asked 56 university-level music students to complete social support scales by recalling the social support they had received from their parents and a past music teacher before university enrollment, in addition to the social support they were receiving from a current music teacher. The students also recalled their most important public performance in the past six months, and they completed the Revised Competitive State Anxiety Inventory-2 and a performance evaluation scale. The results showed that social support from the past teacher positively predicted pre-performance self-confidence and performance quality. By contrast, social support from the current teacher positively predicted only performance quality and not pre-performance self-confidence. These findings highlight the differential roles of music teachers at different developmental stages of student musicians. Social support received from teachers by middle adolescence may be crucial for enhancing pre-performance self-confidence among student musicians.

KEYWORDS

music performance anxiety, stage fright, social support, music education, musician

1 Introduction

Music performance anxiety (MPA) is a form of anxiety triggered by public music performance situations (Salmon, 1990; Steptoe, 2001; Kenny, 2011; Gomez et al., 2023). MPA afflicts many musicians at different stages, including student musicians. Previous surveys indicated a high prevalence of MPA in this population (Fehm and Schmidt, 2006; Studer et al., 2011; Zakaria et al., 2013; Orejudo et al., 2018; Paliaukiene et al., 2018; de Lima et al., 2024). For example, 96% of music undergraduates reported experiencing MPA (Zakaria et al., 2013). Music students also reported higher MPA levels than professional musicians (Biasutti and Concina, 2014). MPA is a serious issue for student musicians, because it can negatively affect their music studies and careers (Fehm and Schmidt, 2006; Orejudo et al., 2018; Paliaukiene et al., 2018).

Previous literature suggests that social support from parents and teachers, which plays a crucial role in music learning (Gruber et al., 2008; Lehmann and Kristensen, 2014; Orejudo et al., 2021a), is also important in dealing with MPA. In several surveys, music students with MPA expressed the need for more support, especially from their teachers (Fehm and Schmidt,

2006; Studer et al., 2011; Ryan et al., 2021). An interview study also showed that student musicians relied on social support from parents and teachers to cope with MPA symptoms (Irie et al., 2023). Recent studies have indicated the effectiveness of social support in the management of MPA among student musicians. For example, Tahirbegi (2022) showed that positive teacher attitudes toward MPA management promoted help-seeking efforts among student musicians. Orejudo et al. (2021b) found that support from parents and teachers enhanced self-efficacy for learning, which further predicted self-efficacy for public performance, among students enrolled in advanced music schools. Kirsner et al. (2023) found that parental encouragement and support were associated with lower MPA levels. Moreover, Huang and Yu (2022) showed that social support from teachers helped student musicians improve their MPA coping skills.

These findings suggest the importance of social support from parents and teachers in MPA management. However, it remains unknown whether the social support received in the past affects pre-performance mental states and performance quality of student musicians. Orejudo et al. (2021b) recently found that social support from parents and teachers positively affected self-efficacy among student musicians aged 18 years or younger. However, the same study showed no evidence of the positive effects of social support from parents and teachers on self-efficacy among student musicians aged 19 years or older (Orejudo et al., 2021b). These results indicate that current social support can positively influence the mental states of student musicians at least until middle adolescence. Nevertheless, whether the positive effects of social support received by middle adolescence are retained after student musicians reach late adolescence or early adulthood remains underexplored. To address this, the present study aimed to examine whether and how past social support from parents and teachers affects pre-performance mental states and performance quality among university-level music students. More specifically, we examined whether the social support received from parents and teachers before university enrollment would influence students' current levels of pre-performance anxiety, pre-performance self-confidence, and self-rated performance quality. Additionally, we examined whether social support from past and current teachers would have differential effects on the mental states and performance quality of music students.

2 Methods

2.1 Participants and procedure

Fifty-six undergraduate and postgraduate students majoring in music (50 women and six men; $M_{age} \pm SD = 21.5 \pm 1.9$ years; range: 18–28 years) at a university in Japan volunteered to participate in the present study. The proportion of men among the present participants (10.7%) was comparable to that among music students enrolled at this university, which ranged between 7.3 and 27.4% in the past ten academic years (2015–2024). According to a recent survey (Asaka, 2024), the proportion of men among graduates of music universities in Japan was 12.9% (academic years 1968–2020). Therefore, the gender ratio among the present participants was also comparable to that among music university students in Japan.

Of the 56 participants, 33 reported majoring in piano, 17 reported majoring in singing, four reported majoring in wind instruments, and two reported majoring in string instruments. On average, the participants started to play their major instrument or sing at the age of 8.8 ± 5.4 years. All the participants were classically trained musicians, but 32 reported playing other types of music (e.g., pop music and jazz) as well. The present study was approved by the National Institute of Advanced Industrial Science and Technology (AIST) Ethics Committee. All the participants provided written informed consent.

We asked the participants to recall the social support they had received from a past music teacher (i.e., a teacher who had given them lessons on their major instrument/singing) before entering university, and to complete the *teachers* subscale of the Social Support Scale developed by Ryan et al. (2000). Given that music students usually start to take lessons from a new teacher (e.g., professor) at the time of university enrollment in Japan (typically at the age of 18), the participants were also asked to complete the same questionnaire while recalling the social support they were receiving from their current teacher of their major instrument/singing. In addition, we asked the participants to recall the social support they had received from their parents before entering university, and to complete the *parents* subscale of the Social Support Scale (Ryan et al., 2000). Considering that a significant proportion of Japanese university students start to live separately from their parents at the time of university enrollment, we focused on parental support in the past (i.e., before entering university).

Additionally, the participants were asked to recall the most important public performance in the past six months. Of the 56 participants, 27 recalled concerts, 20 recalled exams, and nine recalled competitions. Given that MPA can sometimes lead to an actual impairment of performance quality (Yoshie et al., 2009a; Sokoli et al., 2022), the participants were asked to evaluate the quality of the recalled public performance. To assess the levels of anxiety and self-confidence experienced before the recalled public performance, we asked the participants to complete a modified version of the Revised Competitive State Anxiety Inventory-2 (CSAI-2R; Martens et al., 1990; Cox et al., 2003; Yoshie et al., 2009b).

2.2 Self-reported measures

2.2.1 Social support

We assessed the level of perceived social support received from teachers by using a modified version of the *teachers* subscale of the Social Support Scale developed by Ryan et al. (2000). To investigate the influences of both past and current teachers, we asked the participants to recall two of their teachers: (1) a teacher who had given them lessons on their major instrument/singing before entering university (*past teacher*), (2) a teacher who was giving them lessons on their major instrument/singing (*current teacher*). If they had taken or were taking lessons from more than one teacher, they recalled the most influential teacher in the past and present. The participants were then asked to answer each of the original nine questions (e.g., "How much do/did you think your teacher is/was pleased with the work you do/did in music class?") and nine additional questions (e.g., "How

Abbreviations: MPA, music performance anxiety; CSAI-2R, Revised Competitive State Anxiety Inventory-2.

much do/did you think your teacher gives/gave you opportunities to rehearse in performance settings similar to actual public performances?") on a scale ranging from 1 (*not very much*) to 7 (*a lot*), for each of the two teachers. Three experts from the domains of psychology, music pedagogy, and music performance discussed and devised the additional questions based on previous literature on MPA (e.g., Wolfe, 1990; Fehm and Schmidt, 2006; Osborne and Kenny, 2008; Klickstein, 2009).

To assess the level of perceived social support from parents, we asked the participants to complete the *parents* subscale of the Social Support Scale developed by Ryan et al. (2000). We asked the participants to recall the parental support they had received before entering university. The participants were then asked to answer each of the 12 questions (e.g., "How much did you think your parents would want you to pass music exams?") on a scale ranging from 1 (*not very much*) to 7 (*a lot*). As the questionnaire survey was conducted in Japanese, we used a back-translation procedure to ensure translation validity.

2.2.2 Pre-performance anxiety and self-confidence

Pre-performance anxiety and self-confidence were assessed by using a modified version of the CSAI-2R (Martens et al., 1990; Cox et al., 2003; Yoshie et al., 2009b). It includes three subscales: *cognitive anxiety* (five items; e.g., "I am concerned about choking under pressure."), *somatic anxiety* (seven items; e.g., "My heart is racing."), and *self-confidence* (five items; e.g., "I am confident I can meet the audience's expectations."). The CSAI-2 was originally developed to assess competitive state anxiety among athletes based on the multidimensional anxiety theory (Martens et al., 1990). Research in sport psychology has investigated the relationship between the three subscales of the CSAI-2 and athletic performance, and found that self-confidence positively and most significantly influences athletic performance (Craft et al., 2003; Woodman and Hardy, 2003). Several attempts have been made to apply the CSAI-2 or CSAI-2R to music performance situations (Miller and Chesky, 2004; Yoshie et al., 2008, 2009b; Yao and Li, 2022). Corroborating the findings of sport psychology research, self-confidence has been shown to positively and significantly affect performance quality among musicians (Yoshie et al., 2008, 2009b). By contrast, cognitive anxiety has been found to negatively affect the technical aspects of performance quality (Yoshie et al., 2009b).

In the present study, the participants were asked to recall the most important public performance in the past six months, and then to complete the modified version of the CSAI-2R. The participants were instructed to recall their feelings experienced during the two-week period prior to the specific public performance that they identified. For each item, the participants rated the symptom intensity level on a scale ranging from 1 (*not at all*) to 4 (*very much so*). The scores were averaged across items for each subscale. The mean score was multiplied by 10, leading to intensity scores ranging from 10 to 40 (Cox et al., 2003).

2.2.3 Performance quality

The participants rated the quality of the recalled public performance by using a performance evaluation scale adapted from Yoshie et al. (2009a). The scale included ten items concerning both technical and artistic aspects (i.e., *accuracy*, *technical dexterity*, *tempo and rhythm*, *memory*, *artistry*, *interpretation*, *expressiveness*, *structural strength*, *melodic and harmonic balance*, and *tone quality*). The participants rated the quality of their public performance in relation to their normal level of performance quality (i.e., performance quality *during practice*). The scale ranged from 1 (*much worse*) to 9 (*much better*), with 5 indicating *the same level* as performance quality during practice. We employed this scale to capture intra-individual fluctuations in performance quality. We computed the mean scores for the ten items.

3 Results

Table 1 shows the means (SDs), internal consistency (Cronbach's alpha coefficients), and inter-correlations among the CSAI-2R subscales, performance quality scale, and three social support scales. All the scales showed sufficient internal consistency, with Cronbach's alpha coefficients ranging from 0.758 to 0.934.

First, we examined the relationship between the CSAI-2R subscales and performance quality. Pre-performance cognitive and somatic anxiety, measured using the CSAI-2R, were negatively correlated with performance quality ($r = -0.269$, $p = 0.045$; $r = -0.289$, $p = 0.031$). By contrast, self-confidence was positively correlated with performance quality ($r = 0.395$, $p = 0.003$). Therefore, lower levels of cognitive and somatic anxiety and higher levels of self-confidence during the two-week period before an important public performance were associated with better performance quality.

TABLE 1 Descriptive statistics and intercorrelation matrix for the primary variables.

Variables	Mean	(SD)	α	1	2	3	4	5	6
1. Cognitive anxiety	21.23	(6.43)	0.758						
2. Somatic anxiety	21.10	(5.97)	0.778	0.678***					
3. Self-confidence	18.86	(5.87)	0.818	0.002	−0.010				
4. Performance quality	5.01	(1.27)	0.915	−0.269*	−0.289*	0.395**			
5. Past teacher	5.20	(0.82)	0.840	−0.079	−0.214	0.350**	0.410**		
6. Current teacher	5.18	(0.74)	0.837	−0.057	−0.047	0.290*	0.356**	0.313*	
7. Parents	5.17	(1.27)	0.934	−0.002	0.193	0.232	0.269*	0.270*	0.128

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

We then examined the relationship between the social support scales and the CSAI-2R subscales. Of the three CSAI-2R subscales, only self-confidence was significantly correlated with social support (Table 1). We found that social support from the past teacher was positively and significantly correlated with pre-performance self-confidence ($r = 0.350$, $p = 0.009$). Additionally, social support from the current teacher was positively and significantly correlated with pre-performance self-confidence ($r = 0.290$, $p = 0.030$). None of the social support scales showed a significant correlation with pre-performance cognitive or somatic anxiety. We subsequently performed a stepwise multiple regression analysis with the social support scales as the independent variables and the self-confidence subscale of the CSAI-2R as the dependent variable (Table 2). The social support scales accounted for a statistically significant portion of the self-confidence variance ($F(1, 53) = 7.421$, $p = 0.009$). We found that only social support from the past teacher significantly predicted pre-performance self-confidence ($\beta = 0.350$, $t = 2.724$, $p = 0.009$).

Finally, we examined the relationship between the social support and performance quality scales. Performance quality during the important public performance relative to practice was positively and significantly correlated with all three social support scales (Table 1). Social support from the past teacher was most strongly correlated with performance quality ($r = 0.410$, $p = 0.002$). Social support from the current teacher was also significantly correlated with performance quality ($r = 0.356$, $p = 0.007$). In addition, social support from parents was weakly correlated with performance quality ($r = 0.269$, $p = 0.045$). A stepwise multiple regression analysis with the social support scales as the independent variables and the performance quality scale as the dependent variable (Table 2) demonstrated that the social support scales accounted for a statistically significant portion of the performance quality variance ($F(2, 52) = 7.831$, $p = 0.001$). We found that social support from both the past and current teachers significantly predicted self-rated performance quality ($\beta = 0.327$, $t = 2.554$, $p = 0.014$; $\beta = 0.265$, $t = 2.071$, $p = 0.043$).

4 Discussion

The present study examined how social support from parents and teachers could influence pre-performance anxiety, pre-performance self-confidence, and the quality of public performance among university-level music students. The finding that pre-performance self-confidence was positively associated with self-rated performance quality is consistent with previous studies demonstrating the positive influences of pre-performance self-confidence on both athletic performance (Craft et al., 2003; Woodman and Hardy, 2003) and music performance (Yoshie et al., 2008, 2009b). Although social support from past teachers positively predicted both pre-performance self-confidence and performance quality, social support from current teachers positively predicted only performance quality. We also found that social support from parents did not predict pre-performance self-confidence or performance quality.

TABLE 2 Results of multiple regression analyses.

Variables	β	t	p
Self-confidence ($R^2 = 0.123$)			
Constant		1.147	0.256
Past teacher	0.350	2.724	0.009
Performance quality ($R^2 = 0.231$)			
Constant		0.008	0.994
Past teacher	0.327	2.554	0.014
Current teacher	0.265	2.071	0.043

These findings potentially highlight the differential roles of music teachers at different developmental stages of student musicians. The present participants typically entered university at the age of 18 years and were in late adolescence or early adulthood. Social support from teachers who had given students music lessons before university enrollment (i.e., by middle adolescence) enhanced both pre-performance self-confidence and the quality of public performance. By contrast, social support from current teachers who were giving students music lessons (i.e., during or after late adolescence) enhanced performance quality but did not affect pre-performance self-confidence. These results are consistent with a recent finding that social support from teachers does not significantly affect self-efficacy among university-level music students (Orejudo et al., 2021b). Interestingly, the same study identified an important role of teachers in enhancing self-efficacy among music students aged 18 years or younger (Orejudo et al., 2021b). Another recent study found that adolescent musicians (12–19 years old) with low levels of MPA perceived receiving more positive feedback from teachers than did those with high levels of MPA (Papageorgi, 2021). The developmental model of MPA also suggests the important role of teachers' positive and supportive attitudes in preventing young musicians from developing MPA (Osborne and Kenny, 2008; Kenny, 2011; Patston and Osborne, 2016). Based on these previous studies, we postulate that social support from teachers positively influences the levels of pre-performance self-confidence among student musicians during or before middle adolescence and that this positive influence can remain even when they reach late adolescence or early adulthood.

The present findings imply that the roles of music teachers include not only teaching technical and musical requirements but also helping young musicians boost their self-confidence in public performances and manage MPA. This is consistent with the results of previous studies that have demonstrated the importance of teachers' support in the management of MPA among student musicians (Orejudo et al., 2021b; Huang and Yu, 2022; Tahirbegi, 2022). More importantly, the present findings suggest that the positive influences of teachers' support on students' pre-performance mental states can persist even after students have left their teachers. It seemed that the social support received from teachers by middle adolescence was an important source of pre-performance self-confidence for student musicians. By contrast, the social support received from teachers during late adolescence or young adulthood did not have a significant impact on students' pre-performance self-confidence. Based on these findings, we hypothesize the existence of a critical period for MPA interventions by music teachers. Therefore, we suggest that MPA management programs should be incorporated into music education for young learners during or before middle adolescence.

Unexpectedly, the present results failed to show any significant effects of past parental support. Perceived social support from parents was only weakly correlated with self-rated performance quality and did not predict pre-performance mental states or performance quality among student musicians. Nevertheless, accumulating evidence suggests the importance of parental support for young musicians (Orejudo et al., 2021b; Kirsner et al., 2023).

Although the reasons for the minimal effects of past parental support in the present study remain unknown, one possible explanation is that the effects of past parental support on the mental states or performance quality of student musicians gradually weaken as the students grow older. Orejudo et al. (2021b) recently found that social support from parents significantly enhanced self-efficacy in student musicians aged 11–15 years. The positive effects of parental support were also found in student musicians aged 16–18 years, but peers also started to influence their self-efficacy. Interestingly, the positive effects of parental support on self-efficacy disappeared in student musicians aged 19 years or older (Orejudo et al., 2021b). These results suggest that parental support can positively influence the mental states of student musicians at least until middle adolescence. However, our results indicate that, unlike social support from teachers, the positive effects of past parental support may attenuate in late adolescence or early adulthood, when students expand relationships outside of their families.

The present study has several limitations. First, we recruited a relatively small sample of Japanese musicians. Reflecting the strong gender gap among Japanese music students, the male-to-female ratio of the sample was unbalanced. Future research should attempt to recruit a larger sample with a balanced gender ratio to examine potential gender differences in the perception of social support. Given that Japanese culture might have influenced the present results, future research should also examine whether these results would be replicated in other cultures. Second, the present findings were based on retrospective self-ratings of social support received in the past. Thus, the participants' responses could be influenced by memory distortion. Future studies should adopt longitudinal approaches to address this issue. Finally, the present study focused only on the influences of parents and teachers. Since recent studies have also indicated the importance of social support from peers (Orejudo et al., 2021b; Huang and Yu, 2022), future research should examine how past peer support or peer learning can affect pre-performance mental states and performance quality among student musicians.

In summary, the present study suggests that the social support received from teachers by middle adolescence plays an important role in helping student musicians manage MPA. Social support from past teachers enhances pre-performance self-confidence and the quality of public performance among university-level music students. The positive influences of teachers can persist even after students leave them and reach late adolescence or young adulthood. These findings highlight the importance of early intervention for MPA by music teachers.

Data availability statement

The deidentified questionnaire data supporting the conclusions of this article will be made available within the scope of consent of the participants. Further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the National Institute of Advanced Industrial Science and Technology (AIST) 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

MY: Conceptualization, Formal analysis, Funding acquisition, Investigation, Writing – original draft. YM: Conceptualization, Formal analysis, Investigation, Writing – original draft.

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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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Pedagogical strategies for the development of improvisation and composition in North Indian classical music

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North Indian Classical Music (NICM) provides a structured context to examine how improvisational and memory-based skills are developed through oral transmission. While improvisation is central to NICM performance, there is limited research on the pedagogical strategies that support its acquisition, particularly in relation to cognitive processes such as memory, pattern recognition, and schema development. This study analysed audio-visual recordings and fieldnotes from music lessons in both music schools and *guru-śiṣya paramparā* settings in India. Lessons were coded thematically with attention to instructional techniques, learner responses, and cognitive strategies including repetition, segmentation, and variation. Students were rarely asked to improvise spontaneously. Instead, learning focused on imitation and memorisation of modelled material, with inexact replication often leading to creative recomposition. Teachers used structured sequences of *palṭās* and *tāns* to support phrase construction, pitch accuracy, and intensification strategies. These techniques scaffolded both domain-specific (musical) and domain-general (cognitive) skills. Findings suggest that improvisational competence in NICM is developed through memorisation, structured variation, and implicit learning. The study contributes to understanding how oral traditions support cognitive development in music and highlights the need for further interdisciplinary research on learning and memory in non-notated musical systems.

KEYWORDS

pedagogy, improvisation, composition, North Indian classical music, ethnomusicology, cultural transmission, music education, performance analysis

1 Introduction

Cognitive aspects of musical learning have long been of interest to researchers in developmental psychology because of the way in which musical learning and performance use so many areas of the brain in their execution (Kraus and Chandrasekaran, 2010; Habibi et al., 2018). The cognitive processes at work when western musicians perform in a variety of different situations have been explored at length in the music education literature, however a paucity of research on learning, practice, memorisation and performance beyond the Western Classical tradition has been identified (Hallam et al., 2016). Within the field of ethnomusicology there is a growing body of work surrounding the cognitive processes of musicians from oral traditions (Pearce and Rohrmeier, 2012) which highlight the differences in cognitive challenge between performing improvised music when contrasted with memorised music or reading music from written notations. This study seeks to build on and develop these ideas relating to North Indian Classical Music (NICM).

Similarly, in the field of music education, the challenges that western musicians face in developing improvisation skills after they have learnt music using pedagogies common to the western classical style of learning are well documented (Kratus, 1991; Sudnow, 2002; Sawyer, 2007; Shevock, 2018). Hadar and Rabinowitch (2023) propose that factors affecting the 'tightness' or 'looseness' of improvisation within a musical style can be understood in terms of their varying levels of structural sparseness, flexible social roles, cultural nonconformity and creative freedom resulting in a continuum of overall looseness with free jazz at one end of the spectrum and western classical music at the other. This demonstrates how important contextual aspects are when attempting to understand improvisation within a style of music. The article continues to argue that NICM occupies an area of the spectrum closer to western classical music than free jazz and is an area for western classical musicians to consider when seeking to broaden their pedagogical strategies for the development of improvisation skills.

This study therefore aims to identify what the improvisatory objects and processes being used in the training and performance of NICM are. This will be achieved by reviewing ethnomusicological literature and analysing video recordings of lessons (*tālīm*). For readers unfamiliar with the context of NICM, the next few sections of the introduction provide a review of what ethnomusicologists have written about improvisation in NICM so far, with a focus on *dhrupad*, *ṭhumrī* and *k̲h̲ayāl* (vocal music styles). Appendix A provides a glossary of key terms at the end of this article for reference.

2 Materials and methods

The lack of comprehensive contemporary literature reviews on improvisation in North Indian classical music (NICM) necessitates an explanation of the improvisatory objects and processes at work in a performance. Once these have been identified, a short-term, naturalistic, qualitative research design will be employed to identify how these are taught in practice. The theoretical perspective underpinning this research design is interpretivist and it is situated within a social constructivist view of epistemology. The methods of data collection were mainly observations recorded as fieldnotes and videos. Analysis of the data has incorporated aspects of thematic analysis (Braun and Clarke, 2022) leading to schema analysis following the initial coding stages. By looking at these strategies in depth, the aim is to uncover ways that teachers develop the capabilities of their students in relation to the creation of musical performances.

This supports the overall aim to understand the multi-layered complexities of the teaching and learning strategies used using qualitative rather than quantitative methods (Cohen et al., 2018, p. 434). The study seeks to avoid simplifications through the selection of a qualitative methodology to reflect the "contradictions, richness, complexity, connectedness, conjunctions and disjunctions" (Cohen et al., 2018, p. 288) of the social, musical and educational worlds of the research participants.

Researcher positionality requires me to locate my views, values and beliefs in relation to the research process and the research output. To allow me to do this effectively, it was necessary for me to become a learner of NICM so that I could reflect on the activities that I was observing with the insight of a learner (albeit an adult, Western learner). My positionality as a researcher working in an inter-disciplinary way makes it important to ensure that in designing an appropriate methodology and set of methods by which to investigate pedagogical strategies for improvisation in NICM, that the customary approaches of both ethnomusicology and educational psychology were followed. I attempted to carefully manage the issue of me being a white, western educated, middle aged, female teacher-researcher taking my values and biases to modern India. The issues here affect not only the validity and reliability of my research but the ethics of my doing the research in the first place. Three issues in educational research in postcolonial context are highlighted by McKeever:

> "Do I, as a white person have any right to research Indian experience? […] The ethics of knowledge production in a country that has experienced colonization and the dangers of conducting research that perpetuates a colonialist ethics." (McKeever, 2000, pp. 102–103)

There were undoubtedly aspects of my privilege that were unavoidable, but I attempted to mitigate this by presenting myself authentically—as an interested student with a passion for learning from the teachers and students within the music schools, *gharānās* and *gurukuls* where I was permitted access. I felt that I had a responsibility to try not to make students or teachers feel uncomfortable due to my presence, and I attempted to convey this through my dress, my manner and responding to any conventions of behaviour that were expected of students.

Data was generated by observing lessons in six urban centres in India (New Delhi, Varanasi, Kolkata, Bhopal, Lucknow, and Mumbai) during the academic year 2016–17 as part of my PhD research. Initially, records of these were kept using written fieldnotes, but this technique progressed to making dual-perspective video recordings at a later stage in the research once codes and themes were becoming clear in the data. This allowed me to focus one camera on student(s)/*śiṣya(s)* and one camera on teachers/*gurus* which were later combined within the same frame. The written-up fieldnotes and video observations were imported into NVivo—a Computer Aided Qualitative Data Analysis Software (CAQDAS) package which allowed me to assign codes to the data, apply classifications and run queries related to the data generated (Lewins and Silver, 2007).

Participants and field sites were selected by ease of access. Whilst this is not an ideal system in terms of obtaining the widest possible spread of teachers/*gurus*, it did ensure that the collection of data was efficient, and that teachers and *gurus* were willing to give their consent to be recorded. More selective methods posed challenges, due to the presence of gatekeepers who, without a formal introduction from someone they know and respect would not be willing for me to observe their teaching and talk to their pupils. In many situations I felt that teachers were giving a 'demonstration lesson' rather than teaching 'normally', and these observations have been excluded from the data corpus. Duran et al. (2011) also experienced these difficulties and resolved them in the same way. I also excluded lessons where errors in my communication had led to me observing instrumental rather than vocal lessons, because I considered that instrumental techniques for improvisation would be different from those used in vocal lessons.

Once the data from 'demonstration lessons' and instrumental lessons was excluded, I had 19 h and 4 min of recorded lessons/*tālīm*. Once themes had been identified and applied to the timestamps on

the videos, the CAQDAS package also gave the option of moving between episodes in the video data where themes had been identified, to check and compare the places where a particular feature had been coded for. This brought structure to a previously unstructured set of data, allowed me to keep track of (and review) transcripts of lessons and allowed me to see how far I had progressed with the coding of the dataset, and to make a note of emerging notes on the data as I coded. From this data, two illustrative examples were selected, one from a music school and one from the *guru-śiṣya paramparā* (GSP—a lineage of teaching and learning where knowledge is imparted through a relationship between *guru* and *śiṣya*) from which the illustrative examples for this research article are drawn.

3 The practice of North Indian classical music—its grammar and oral transmission techniques

In performance, NICM shares several conventions with western classical music. Performers tune their instruments on stage at the beginning of a concert and sometimes adjust their tuning during the performance too. They perform for a quiet and seated audience, with or without amplification, depending on the venue's size. Those seated near the front often have higher social or artistic status and may call out in admiration at particular features of the improvised performance, to which performers may respond (Clayton, 2007; Clayton and Leante, 2015). Performances typically include an accompanying drone played by an instrument such as the *tānpūrā* and/or an electronic *śruti* box, which serves as a constant reference point, allowing musicians to focus precisely on intonation during performance, rehearsal, *tālīm*, and *riyāz* (practice). A significant emphasis is placed on the accuracy of intonation, which is remarkable given the absence of fixed pitches for tones beyond the natural fourth, fifth, and octave. The other pitches can vary microtonally between *rāgs* (named melodic frameworks for improvisation) and musicians (Bor, 1999). This complexity demands that performers internalise the notes of the *rāg* they are to improvise, resulting in the practice of doing rigorous and repetitive exercises focused on intonation during the initial stages of training. These repetitive exercises (known as *palṭās*) have been extensively described in the literature (Deshpande, 1989; Magriel, 1999), but they can affect the progress and motivation of young students too, particularly when students are reliant on their own auditory perception skills to determine whether they are rehearsing them with accuracy. *Rāg* is an important concept in NICM which is difficult to define, but usually refers to a combination of the melodic mode and vocal/instrumental colour conveyed by the performer. The melodic mode is known as the *thāt* and there are many different *rāgs* in each *thāt* for example *kalyāṇ thāt* which broadly corresponds to the Lydian mode and counts *yaman*, *hindol* and *deś* amongst its *rāgs*.

Rather than performing named compositions, each part of a concert programme will focus on one *rāg*. This intense focus on pitch accuracy highlights another crucial distinction between *rāgs* and scales. A *rāg* is not merely a scale or mode; different *rāgs* may use the same pitches but in varied configurations. The characteristics distinguishing one *rāg* from another include scale, ascending and descending lines, the number of notes, emphasised notes and register, intonation, obligatory embellishments, and the intended time of performance (Jairazbhoy, 1971; Sorrell and Narayan, 1980). The inventory of melodic ingredients of a *rāg* involves the arrangement of *swars* (notes) in ascending and descending orders of pitch, tetrachord configurations, and a hierarchy of melodic importance among the notes. This includes contours and paths for moving through this configuration, the function and aesthetic effect of each *swar*, and microtones and microtonal inflections (McNeil, 2017).

Musicians ascribe different moods and feelings to specific *rāgs*, often linked to the lyrical themes of *bandiśes* (fixed melodic compositions) performed in these *rāgs*. During improvised sections, performers must evoke the emotion of the *rāg* rather than focus on individual pitches and their transitions. Performances are constructed in real-time rather than from notation, requiring extensive memorisation of both fixed elements of the composition and key phrases of the *rāg*. These key phrases, often including distinctive ornamentation, are essential for audience recognition of the *rāg*. The oral tradition in NICM is organised around these antecedent sets of phrases, and the process of weaving them together with consideration of expansion, increase, extemporisation, and gesture is crucial for producing a compelling improvised performance (Neuman, 2012). This use of set patterns aids memory and facilitates elaboration, although the terminology used by ethnomusicologists to describe this elaboration is inconsistent, and further exploration is needed to understand the cognitive processes at work during performance. For example, Neuman (2012, p. 444) uses the terms *pakaḍ, calan*, *vistār, baṛhat* (increase), *upaj* (extemporisation or variation) and *andāz* (gesture/conjecture) but these terms are not universally understood by musicians and ethnomusicologists. McNeil (2017) considers that this elaboration works at three levels *vadi bheda, chalan bheda and uccharan bheda* and conceives of fixed melodic material as 'seed ideas' from which improvised materials grow.

3.1 The classicisation of an oral tradition

Colonial efforts to modernise and categorise aspects of Indian culture significantly influenced educational practices in institutions. Reformers like Bhātkande and Paluskar sought to place music education at the heart of cultural education, especially its theoretical aspects (Bakhle, 2005). Bhātkande envisioned a democratised system of music education that would make music instruction common and universal in India (Bhātkhande, 1934). These reforms have left a lasting impact, with the creation of music colleges which continue to follow their ideas. These reformers, who were often English-educated, high-caste, middle-class Hindus, prioritised a national system of music education with a greater focus on explicit theory teaching compared to the traditional *guru-śiṣya paramparā* (a lineage of teaching and learning where knowledge is imparted through a relationship between *guru* and *śiṣya*). Modern music colleges offer qualifications like the *Sāṅgīt Vishārad*, (equivalent to a Bachelor of Music), which include extensive factual knowledge about NICM and require students to learn numerous *rāgs* for performance (Pradhan, 2009).

This structured, institutional approach focused on amassing a breadth of knowledge quickly, contrasts with the GSP, where learners might spend months on exercises in a single *rāg* under close supervision (Deshpande, 1989). Pradhan questions the ability of students at modern music colleges to retain information long-term due

to the high number of *rāgs* included in institutional syllabi (Pradhan, 2009). Teacher training also faces issues, with teaching roles often given as philanthropic gestures rather than appointments being made based on pedagogical expertise. Neuman (1980) also noted that institutional teaching methods differ significantly from the GSP. However, many private music schools today adopt its principles to promote a particular educational ethos. These schools prefer to recruit their own alumni as teachers, ensuring consistency in expectations, syllabus knowledge, and pedagogical strategies. This practice reflects a modern interpretation of *paramparā* (tradition) where the collective teachings of an institution replace the traditional *guru*. Music schools often advertise the idea of a *gurukul* (training institution run by a *guru*) or GSP as integral to their teaching model. This approach has been highlighted by Krishna as "an ideology rather than a pedagogical reality" (Krishna, 2020, p. 28). In music education, the GSP emphasises enculturation over transmissive strategies, fostering a sense of music as divine rather than a marketable commodity. This approach helps preserve the nature of the tradition and sustainability, ensuring it is passed on to future generations, however the extent to which this ethos is shared by private music schools varies between institutions.

3.2 The improvisatory characteristics of NICM

During a performance, musicians rely heavily on memory to improvise. Nooshin (2003) theorises that memorising models during training teaches compositional principles useful for improvisation and variation. Pressing's cognitive model of improvisation development emphasises the improved efficiency, fluency, flexibility, error correction, and expressiveness that develops with improvisational competence. This model accounts for inventiveness and coherence through specific cognitive changes:

> "Increased memory store: Expanding memory of musical, acoustic, and motor aspects.
> Improved memory accessibility: Building redundant relationships and aggregating constituents into larger cognitive assemblies.
> Refined perceptual attunement: Enhancing sensitivity to subtle and contextually relevant information" (Pressing, 1988, p. 166).

The relationship between memory and perceptual information selection described here, which develops increasingly efficient neural pathways, is key to developing the ability to create compelling and coherent performances of NICM.

Despite the fact that all phrases are open for embellishment in NICM, a clear distinction is made between the composed and improvised sections of a performance (Nooshin and Widdess, 2006). The precomposed parts (*bandiśes*), vary melodically and textually between *gharānās* and have evolved over time, although their themes, lyrics, and *rāgs* have endured for centuries. Performers still ornament the *bandiś*, varying the ornamentation each time a phrase is repeated. The structure of a performance has important implications for developing improvisatory competence in NICM where a performance of a *rāg* can last for 45 min to well over an hour depending on contextual factors. The structure of a *k̲h̲ayāl* performance (a style of vocal music whose literal translation is imagination) is shown in Figures 1a,b. These illustrate the pre-composed and improvised sections of a *baṛā* (long) and *choṭā* (short) *k̲h̲ayāl*.

Whilst the length of time spent on each of these sections varies greatly, is clear from these structures that a performer will be improvising for most of the performance. Whether in terms of

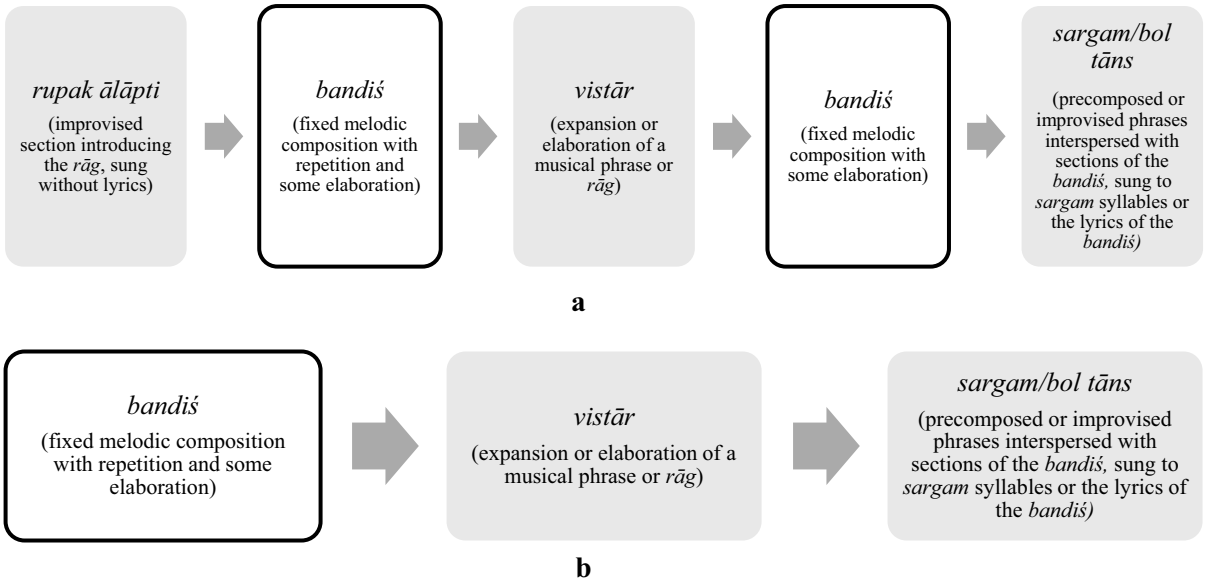

FIGURE 1
(a) The structure of a *baṛā k̲h̲ayāl* (long *k̲h̲ayāl*) in slow-medium tempo demonstrating the improvised sections in shaded boxes and fixed composition sections in bordered boxes. **(b)** The structure of a *choṭā k̲h̲ayāl* (short *k̲h̲ayāl*) which will often follow a *baṛā k̲h̲ayāl* in performance. The improvised sections are shown in shaded boxes and the fixed composition sections are shown in bordered boxes.

embellishment of precomposed material or in the creation and recreation of phrases best suited to expressing the sentiment of the *rāg*. These structures for performance featuring a balance of fixed composition and improvisation form the basis of transmission in NICM. Just as there are a balance of memorised phrases and the rearrangement, combination and creation of new musical ideas in a performance, so this mirrors the pedagogical strategies used to develop improvisatory competence. To the extent that just as a performance will begin with a focus on the drone and slow unfurling of the *ālāp* (opening section of a *baṛā k̲h̲ayāl*) before the more metrically bounded sections of the *bandiś*, *vistār* and *tāns*, the sections of a singing lesson are structured in just the same way.

3.3 Pedagogical strategies used to develop improvisatory competence

Learning *bandiśes* orally by rote puts the focus on the memory of the sounds rather than the memory of written lyrics or the degrees of the scale. This learning is approached very differently in the GSP where repertoire will be learned aurally which stands in contrast to music school teaching where written lyrics and notation will often be used for support. There are key differences between learning a song aurally and from notation. Aural learning develops strong 'associative chains' (Farrell, 2012) where each passage cues the memory of what comes next. This is important not just for the *bandiś* section of a performance, but also for the improvised sections that are text/rhythm oriented. In these sections, a short section of the *bandiś* (usually the first phrase, known as the *mukhṛā*) will be sung, followed by *tāns*. In some styles of music, this can present a problem, because to 'reach for' a specific link in the associative chain a student must start at the beginning. This is not generally an issue in NICM because the first line is returned to many times during the performance and could effectively cue a whole range of different phrases that have been modelled by a teacher and learned by rote. In contrast to this, learning from written notation/lyrics develops a student's 'content addressable' memory (Chaffin et al., 2016) allowing them to answer questions such as 'how does the second line of the *bandiś* go?' without having to sing it in their head from the beginning. These two different ways of accessing memory demonstrate that if a student learns a *bandiś* using written notation and lyrics, these memories are more likely to be content-addressable and explicit/conscious. Learning a *bandiś* aurally will construct associative chains that are implicit/unconscious and involve procedural knowledge that cannot be easily expressed in words. This highlights the difference between learning a *bandiś* and memorising a *bandiś*, a distinction which appears in Western music but not necessarily in NICM, a context in which, to learn a *bandiś* a student must also memorise the *bandiś*.

3.4 Generative and formulaic perspectives on improvisation

The question of whether improvisation in NICM is generative or formulaic is contested within the literature. The generative view suggests that improvisation is driven by associative, moment-to-moment decisions based on preceding material Powers (1980) and Pressing (1988) liken this to language analysis, proposing that improvisation involves stringing together event clusters, akin to constructing a generative grammar for *rāgs*. Clarke (1988, 1993) supports this by linking improvisation to hierarchical and selective elaboration, evident in the structured progression of phrases during *ālāp*. He suggests that generative principles underpin both melody and expression, enabling performers to create infinite variations within a finite framework. In contrast to this, Powers and Widdess (2001) highlight that *rāg* improvisation differs from western tonal systems due to its integration of scale, melodic motifs, and characteristic features (*pakaḍ, calan*). This complicates generative interpretations, as improvisation often elaborates motifs through techniques like prefixing, suffixing and rhythmic manipulation rather than by assembling notes generatively. Generative elements also appear in *vistār*, where musicians construct improvisations by expanding pitch ranges and manipulating rhythmic cycles. Slawek (1998) identifies learned 'programs' driving this process, exemplified in both *tāns* and *vistār*. Performers balance pre-existing schemas with spontaneous adjustments, using freed cognitive resources to focus on expressive nuances.

The formulaic argument posits that improvisation relies on a repertoire of stock phrases and variable strategies adapted to the *rāg* and performance context. Zadeh (2012) critiques generative models derived from western traditions, emphasising the role of 'stock expressions' and 'variable melodic outlines' in the genre of *ṭhumrī*. These formulas, drawn from oral traditions and adapted idiomatically, serve as structural and expressive tools, guiding performers through improvisatory constraints. Ethnomusicological studies of improvisation in NICM such as Zadeh's have contributed evidence to the formulaic argument by documenting techniques such as transposition, chromatic slides and manipulating the audience's expectations by delaying resolutions. Magriel (1997) finds that while NICM artists from a particular *gharānā* share a common 'dialect', their individual 'idiolects' shape distinctive improvisatory styles. This explains why students often inherit stock expressions from their teachers, reflecting the transmission of formulaic knowledge.

3.4.1 Improvisatory objects: ornaments/ embellishments

McIntosh (1993) explores the improvisatory objects and processes involved in embellishing a *bandiś*, suggesting that improvisatory processes occur through the accumulation of components of various sizes. This process operates at different levels, including the construction of embellishments on a single note. In lessons, teachers may add ornaments, alter the rhythm of the *sthāyī*, and emphasise specific words through repetition, articulation, or gesture.

Pearson (2016) analyses both musical and physical gestures in performance, examining the relationship between *svars* (notes) and *gamaks* (ornaments). She demonstrates how musicians link these musical units coherently, likening it to the way joined-up handwriting uses different linkage patterns depending on the subsequent letter. Widdess (2014) similarly views a melodic pitch as part of a larger event, often linked into an expressive whole by glissando and other ornamentation. Pearson (2016) also introduces the term 'coarticulation' to describe this approach, borrowing from phonetics to explain how a phonological segment's vocalisation is context-dependent and influenced by neighbouring sounds.

3.4.2 Improvisatory objects: *palṭās*/*tāns*

Just like the *ālāp* of a performance, the sections of a performance containing *tāns* are also initially memorised. Students begin with simple *palṭā* exercises in *bilāval ṭhāṭ* (Ionian mode) which develop their memory for regular patterns of notes. They then progress to advanced *paḷās* with more unpredictable patterns, often in different *ṭhāṭs*. After mastering these, students copy *tāns* composed by their teacher. Through practice and familiarity with characteristic phrases of the *rāg*, students develop strategies to fill in gaps if they cannot remember a teacher's phrase precisely. This is combined with composing, notating, and memorising their own *tāns*, leading to the ability to improvise their own. An interview conducted by Nicolas Magriel with *guru* Devashish Dey and his son Shubhankar Dey demonstrates these strategies and processes, highlighting how they evolve from memorising and practising difficult patterns to focusing on variation. During the interview Nicolas enquires whether the ability to sing difficult patterns relies on continued *palṭā* repetition:

> **N:** but what about, not just actual tāns but do you ever do this palṭā practice,
> **D:** palṭā practice, yes
> **N:** just some?
> **D:** it depends because in the beginning the student should practice the palṭās more but after that you must deliberately avoid them too, because doing too much of palṭā in higher stage is not only boring but the lustre of the singing is lost something.
> **N:** oh, that's interesting
> **D:** so, my teacher, Kalvinji guruji, always insisted not to do alaṅkār for long a time and always to make sa sa re ga, sa re re ga, sa re ga ga, re re ga ma, re ga ga ma, re ga ma ma, ga ga ma pa… all of these things [demonstrates this by singing very fast] all these things for the younger students, once upon a time he did a lot of practice like this, two hours or one and a half hours of this kind of thing.
>
> Once you have got that [demonstrates some more of these palṭās with gamak] already you have then to think about how to make it more beautiful rather than to make it powerful. (Dey, 2009).

The memorisation of a *palṭā* itself makes it a compositional object, but when reaching for a particular phrase, the *palṭā* training kicks in and allows a musician to grasp it. It is important to note that *palṭās* are content addressable rather than dependent on associative chains because fragments of *palṭās* need to be reassembled automatically without conscious thought. Cognitive evidence for the fact that formulaic patterns are processed more quickly and efficiently to random ones is provided by Pawley and Syder (1983).

3.4.3 Improvisatory objects: formulas: stock expressions, variable melodic outlines and musical gestures

Studies of performance in NICM, particularly vocal styles, have explored the connections between spoken language skills and the ability to improvise musical phrases. As outlined in section 3.4, Zadeh (2012) critiques this application to NICM, arguing that formulas from oral literature, everyday speech, and other musical traditions serve as the building blocks of *ṭhumrī*. She highlights the difference between orality and literacy in performance, noting that formulas provide structural schemes and metrical constraints, much like in oral poetry, enabling poets to draw from a repertoire of conventional phrases rather than creating material from scratch during a performance (Zadeh, 2012, p. 38). In her thesis, Alaghband-Zadeh (2013) provides examples from Rasoolan Bai's *ṭhumrī* performances to illustrate her point and identifies stock expressions that consistently appear in Girija Devi's performances too. Zadeh also notes techniques for manipulating audience expectations by extending or interrupting phrases.

Artists deploy these techniques distinctively, which relates to Magriel's (1997) ideas about dialect and idiolect, suggesting that while artists conform to dialect rules, they construct their *upaj* (improvisations on a theme) according to their personal idiolect. Once a phrase is memorised, it becomes easier to create variations and recombine different phrases imaginatively. Alaghband-Zadeh (2013) suggests that the prevalence of these formulas in performance is likely a result of how students were taught. Whether students inherit formulas implicitly or through direct instruction is crucial in analysing learning situations. Training students to listen attentively to phrases they must reproduce supports memorisation and adaptability, enabling them to 'fill in the gaps' where necessary. The formulas Zadeh identifies, labelled as "stock expressions," "variable melodic outlines," and "musical gestures," (Alaghband-Zadeh, 2013, p. 67), along with the grand structural schemas of *kẖayāl*, dhrupad, and *ṭhumrī* performances, constitute improvisatory objects, as do the modal nuclei of *ālāp* and the pitch ranges of *bandiśes* (see section 3.4.5 and section 3.4.6).

3.4.4 Improvisatory objects: cadential features and overall structural conventions

Cadential features such as *tihāi* (a polyrhythmic technique where a phrase is repeated three times, often used to conclude a section or performance) are also considered to be an important improvisatory object to be learnt. The strategies used to teach these are not discussed in the literature, beyond examples of students learning *tihāis* by rote and teachers composing them for their students to learn (Clayton, 2000).

Having explained that the structure of a performance contains a balance of fixed composition and improvisation, the literature also highlights how these musical structures are reflected in the structure of each lesson (*tālīm*). Where a *guru* will usually focus on the skills required for each section of the performance sequentially. For performers, having a mental map of the whole performance is crucial if one is to be able to sustain a compelling presentation of the *rāg* over 45 min or more (Snyder, 2016). The process of memorisation is expedited by the fact that whatever comes next is heavily constrained by what precedes it. Music is made easier to learn by the number of constraints placed on it, and these combine to make memory reconstruction easier. The capacity to memorise quickly improves over time (Ginsborg and Sloboda, 2007), and therefore children who have been listening to and learning these songs since childhood will find them easier to learn aurally as they get older (Magriel, 1997; McNeil, 2017; Faber and McIntosh, 2020). Sanyal and Widdess (2004) calls this concept 'recreative ability':

> "Accustomed from birth to the sounds of his father and other family members singing and playing in the home, the young

> musician acquires the instinctive ability to recreate those sounds with the aid of whatever materials he has learned formally. This process of tālīm encourages the development of this recreative ability, which can also be acquired by non-family disciples, and underlies the phenomenon of 'improvisation' in Indian music. Recreative ability is a fundamental link between the realms of tradition and performance in Indian music: it is the mastery of processes of improvisation as well as the memorisation of fixed repertory." (Sanyal and Widdess, 2004, p. 130)

The ability to embellish phrases idiomatically therefore improves over time and with repeated exposure to the performances of *gurus*. The aspect of a composition that will not vary, however, is the metrical position of the beginning of the *mukhṛā*. If the *bandiś* begins on the 13th beat of a 16 beat (*tīn tāl*) cycle, the performer will always ensure that it begins at that point, even if the variation on the previous repetition of the *mukhṛā* lasted a few beats longer. This is because, during a performance, a great deal of importance is attached to the arrival of the *sam* (first beat of the cycle), and musicians attach a high degree of importance to ensuring that improvised phrases 'come in *tāl*' (finish on the *sam*). This makes keeping track of the metric cycle within a performance a very important feature of children's learning and explains why teachers ensure that students learn how to count the metric cycle on the joints of their left hand, using their left thumb to keep their place (see Figure 2).

During lessons, this strategy will be used in a variety of ways, sometimes modelled by the teacher with the addition of saying the numbers out loud, but quite often it is used spontaneously and silently by students during *tāns* to ensure that the phrase they are constructing will conclude at the start of the next metric cycle. Teachers also ensure that students learn the cheironomy of metric cycles. This is the system by which each *vibhāg* (duration of rhythmic phrasing within a *tāl*) is marked by a clap or a wave. Students will use this technique during lessons, and in performance. During lessons, it can be helpful for a student who is improvising to see these points in time marked out by their classmates. It is also common to see members of an audience in a concert setting replicating these gestures. By creating structures of this type for improvisation, students are provided with a fixed point in time when they can return to the material from the start of the associative chain, freeing up their working memory to think about the next improvisatory process or object to deploy.

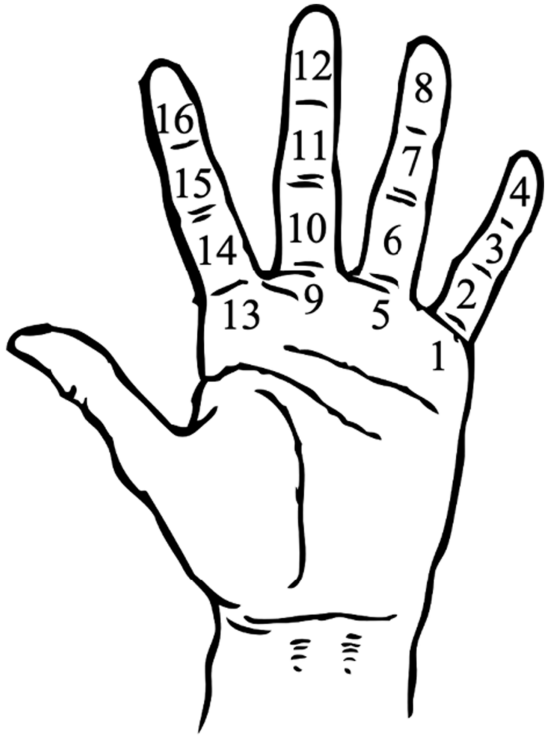

FIGURE 2
Diagram illustrating the areas of the left hand where each beat is signified with a tap from the left thumb.

The implication of *tālīm* being structured in this way means that it becomes virtually indistinguishable from performance. Zadeh describes how the structure of improvisation was taught by her teacher:

> "When I was learning to sing Indian classical music, this overall pattern would inform not only the pieces my teacher taught me, but even the way she structured my lessons. We would start with long, slow exercises focusing on sa, then explore lower register, and then start a series of exercises which reached ever higher notes while increasing in speed and complexity. By learning in this way, this overall structural progression came to seem perfectly natural to me." (Alaghband-Zadeh, 2013, p. 34)

This makes the learning process within NICM highly efficient, as there are essentially no 'easy pieces' that must be mastered before a student is allowed to embark on professional repertoire. This is not to say that a student will be producing professional performances from the beginning of their training, and some *rāgs* are considered more difficult to learn than others, or not suitable for very young students due to the challenges of conveying the *bhāva* (emotion) connected with the *rāg*.

3.4.5 Improvisatory objects: modal nuclei

Modal nuclei are improvisatory objects which contribute to the constraints within which performers improvise. In the sequential phrases of the *ālāp* (the first section of a *k̲hayāl* performance) pitches tend to lie within a specific range, developing according to a particular pattern. This strategy of using modal nuclei gradually reveals the *rāg*, ensuring that all features unique to the *rāg* are highlighted in the *ālāp* (Powers, 2001). Structuring the *ālāp* in terms of these pitch ranges also creates a teachable model for students. The *ālāp* progresses from the lowest to the highest register of a singer's voice, with different scale degrees revealed sequentially. This progression is illustrated in Figure 3 in a diagram created by Widdess (2017), where the '*sa*' of the middle octave and the '*sa*' of the higher octave are represented by 1 and 1′.

Rather than indicating a single melody line, each section of the line in this diagram can be divided into phases. Within each phase, a singer produces several idiomatic phrases within the specific pitch range before moving to the next phase. The diagram shows that the '*sa*' of the middle register is frequently returned to until the phrases approach the upper '*sa*', and at the end of the *ālāp*, there is a return to '*sa*' in the middle octave. This map of pitch contours provides students and performers with yet more constraints within which to improvise.

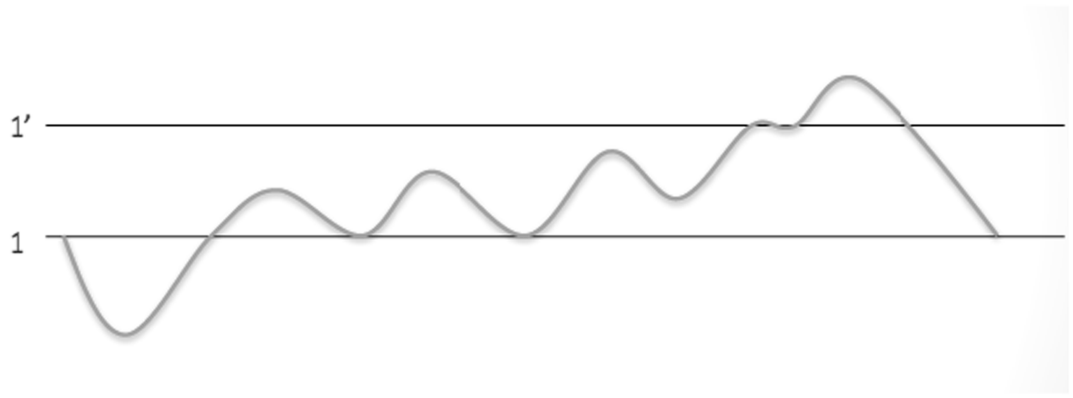

FIGURE 3
Example of the pitch range used in melodic expansion of the *ālāp* from a lecture given by Widdess (n.d.).

3.4.6 Improvisatory objects: pitch conventions of *bandiśes*

The idea that with practice, material becomes easier to learn because it conforms to expectations of other music that has been heard before is an important feature of learning in NICM because it also cultivates melodic expectations for *rāgs*. The idea of learning via exposure is not unique to NICM, and has been explored as one of the possible universal processes involved in learning music beyond the Western tradition. Stevens and Byron note that within a particular culture, perception becomes "attuned to or constrained by the culture-specific regularities and conventions (statistical structures, probabilities) of that environment" (Stevens and Byron, 2016, p. 26). *Śiṣyas* must develop melodic expectations for the *bandiś* to expedite aural learning of melodically complex material. Very early in training a student will become aware that the melody of the *sthāyī* (first section of a *bandiś*) moves in both the lower tetrachord of the middle octave and the lower octave. They will also develop an expectation that the *antarā* (second section of the *bandiś*) will rise to the upper tetrachord of the middle octave and the upper octave (Clayton, 2000, p. 114). Widdess refers to this as the *antarā* formula (Widdess, 1981, p. 161) and finds few exceptions to it in the published compositions and recorded performances examined.

To support students' logical understanding of the shape of a melody, oral notation is frequently used to scaffold aspects of learning, including the *bandiś*. This oral notation is one of the transmissive strategies identified as part of the classicisation of the oral tradition in section 3.1, where teachers sing the note names of a *bandiś* in *sargam* (where pitches are referred to as *sa, re, ga, ma, pa, dha,* and *ni*) to help a student reproduce them accurately. This strategy can be linked to the concept of notational audiation (inner hearing of notated music). Woody (2012) found that this strategy helped musicians to perform on their instrument, with or without a score.

Morris (2005, pp. 52–55) considers that an important factor in developing students' improvisatory capabilities is the number of *bandiśes* that a student knows in a particular *rāg*. He estimates that, whilst a student might know 3–6 *bandiśes* in each *rāg*, an established performer will know something like 10–30. This means that the task of learning compositions over the course of a learning and performing career, will lead to performers developing a repertoire of between 400 and 1,500 *bandiśes*. The more familiar a student is with the process of learning a *bandiś*, the faster they will be learnt, and experienced students have been known to pick up the lyrics and melody of a composition after only 4–5 listens. A teacher will usually break the composition down into sections and get the student to repeat each section until they are able to reproduce them accurately, before reassembling the sections until the whole *sthāyī* and *antarā* can be sung entirely. This strategy undoubtedly develops a student's musical ear for the intricate details and nuances of a melody, and teachers are careful to ensure that students pick up these melodies and sing them accurately and with precise intonation. The extent to which a teacher's rendering of a *bandiś* is consistent from lesson to lesson can be an issue for learners. Some teachers insist that they always sing the *bandiś* in the same way, in opposition to their students' assertions (Morris, 2005, p. 61).

These discrepancies could be attributed to a natural part of the creative process, it is not uncommon for performers to forget lyrics or small parts of a composition and to consult other performers or recorded performances of the *bandiś* for clarification (see example in section 4.2). Given that musicians are used to constructing phrases to fill gaps or joining pieces of melodic material together to create improvisations, it is not too much of a leap to consider that this may also occur in the remembering of a *bandiś*. Morris provides an excerpt from an interview with Sharadchandra Arolkar in which he asserts "A *k̲h̲ayāal* song is not a frozen thing; it's a fluid sculpture…The substance should be there - the expression, the meaning - but [it's] not like tracing. You have to create, not to trace by memory" (Morris, 2005, p. 67). This example demonstrates that there are two ways in which learning compositions helps develop students' improvisation strategies. Firstly, it improves their memories for complex melodic material and their competence in singing ornaments. Secondly, it increases a student's understanding of the *rāg* and the quantity of improvisational objects that they can draw on to manifest the *rāg* in performance. Having a large stock of *bandiśes* can be seen as an alternative strategy to learning the grammar of the *rāg* through the memorisation of the ascending and descending grammar of each *rāg* where certain notes may be omitted or emphasised in ascent or descent.

In pedagogical terms, the impact of the development of *sargam* for use by teachers and students is highly significant to all sections of

performance, including the *bandiś*. By creating strong associations between the name of the note and the pitch of the note, teachers are not only developing singers who can sight read the basic shape of a *bandiś* from notation (as in Kodály pedagogy), but they are also building the foundations for pupils who can perform their own precomposed or improvised *ālāps* and *tāns* sung in *sargam*. For pupils who struggle to pick up phrases from their teacher by ear, compositions notated in this form provide important visual cues for the musical material that comes next.

3.4.7 Improvisatory processes: successive variation strategies, compositional strategies, transposition strategies and subverting the audience's expectations

The idea of syntax of musical units supports a generative view of improvisation in that a performer can string together musical units in novel ways if they conform to the conventional syntax of the musical style. Implicit understanding of melodic syntax is also vital if a listener is to enjoy a performance of Indian music, and if a performer is to use that understanding to reinforce or subvert expectations of how a particular phrase will progress. A musical event that signals that a phrase will be ending warns the listener to expect closure. And, in the same way, musical units can also fulfil a beginning or middle function. Explains that, when formulas are repeated according to the 'successive variation strategy' that she has defined, their function is to remind the listener of their previous occurrences, creating a sense of familiarity with the material that can then be varied in order to add interest and a sense of development to the performance. The formulas themselves delineate the structure of a particular section of the music and create a sense of musical syntax.

Compositional strategies of the type identified by Alaghband-Zadeh (2013) and Clayton (2000) have been identified in the literature that analyses performances, but the strategies used to teach them are not fully understood. There is a greater representation of the strategies used by teachers to develop the process of successive variation strategies and the literature also highlights the prevalence of transposition strategies (Manuel, 1989; Nooshin and Widdess, 2006; Alaghband-Zadeh, 2013). These are often presented to emphasise the role that listening to professional performances by *gurus* and others must play in learning phrases that can be appropriately transposed into different *rāgs*. It is likely that this strategy extends to the way in which students learn the process of subverting the audience's expectations, for example by extending a phrase past the conventional closing figure.

3.4.8 Improvisatory processes: *khaṇḍadmēru*

At the stage of learning to sing *palṭās,* a process called *khaṇḍamēru* is often introduced to students. This involves a mathematical process of singing all the possible combinations of notes in groups (usually 3 or 4). Table 1 demonstrates the permutations for the groups of three notes. Degrees of the scale have been given as numbers as well as the first letter of the *sargam* syllable (S = *sa*, R = *re*, G = *ga*, M = *ma*, P = pa, D = dha, N = ni). Students will sing these phrases column by column.

Once students can sing this combination of notes fluently, teachers will add challenges to apply ornamentation to the permutations of notes. These units of three or four notes can also be combined vertically to produce longer patterns. Tables 2, 3 demonstrate two different formulas by which the *khaṇḍamēru* passages are commonly combined.

This process of developing students' mental agility for all possible combinations of notes supports the development of both memory for precomposed *tāns* and the ability to improvise melodic material in *sargam*. By strengthening the indexical link between the production of the note and the phoneme for notes that do not just follow in step but also contain wider intervals, the *tāns* that students are able to memorise will include greater variety as time goes on. Learning by rote is the pedagogical strategy by which the process of *khaṇḍamēru* is learned, but when deployed in the context of a performance can be incorporated creatively within an improvisation.

3.4.9 Improvisatory processes: *behlāvā*

Another technique used by teachers to develop their students' improvisatory processes is *behlāvā*: decorating the words of the composition with notes that are different from the ones formerly used. By repeating the same phrase, several times, the potential for variation in a single phrase and with a limited range of notes explored. This again demonstrates how teachers set parameters for improvisation in order to support students' creative thinking. McIntosh (1993) explains that another restriction imposed on *behlāvā* is that the improvised phrase should only take one or two metric cycles before returning to the composition, in order to prevent *behlāvā* from losing its artistic effect. *Behlāvā* is an improvisational strategy that lends itself to being taught within the GSP, because it is an exploratory process that can be engaged in during *tālīm* by both *guru* and *śiṣya* concurrently.

3.4.10 Improvisatory processes: intensification strategies

Intensification is a concept referenced in much of the literature as the overarching process by which improvisation occurs in Indian classical music (Clayton, 2000; Henry, 2002; Nooshin and Widdess, 2006; Zadeh, 2012). Clayton considers that the process of intensification during a performance occurs across a number of musical continua—tempo, register and complexity (Clayton, 2000). Nooshin and Widdess (2006) agree that rhythmic intensification through the gradual increase of tempo or rhythmic density is a fundamental process of development in improvisation. Building on the work of Kramer (1988), Clayton considers that the structural aspects of intensification are linear (deductive and sequential), but that, rather than leading to a precise musical climax when the *upaj* is seen as complete (a teleological strategy), it instead intensifies cumulatively, up until the point at which the limit of a performer's technical ability has been reached, the point at which the time allowed for their performance is almost up (and in some cases exceeded) or until a performer becomes bored with the process. This suggests that the overall impression gained by the listener is of a non-linear, holistic, and continuous process. Clayton links this improvisatory process to cultural ideologies, asserting that, whilst there is a Western tendency to theorise and attempt to demonstrate logical organisation and coherence within the cultural phenomenon of music, Indian music theorists are much more likely to assert music's attributes as a state of being. "Thus, a *rāg* simply *is*: the performer's task is to bring the *rāg* to

TABLE 1 Example of permutations of 3 notes when *khaṇḍamēru* process is applied.

		In the *khaṇḍamēru* process, students will sing each of these phrases column by column starting in the top left							
		1 Permutations of SRG	2 Permutations of RGM	3 Permutations of GMP	4 Permutations of MPD	5 Permutations of PDN	6 Permutations of DNṠ	7 Permutations of NṠṘ	8 Permutations of ṠṘĠ
Each row shows a different permutation of the three degrees of the scale specified by each column	a	SRG 123	RGM 234	GMP 345	MPD 456	PDN 567	DNṠ 67i̇	NSṘ 7i̇2̇	ṠṘĠ i̇2̇3̇
	b	RSG 213	GRM 324	MGP 435	PMD 546	DPN 657	NDṠ 76i̇	ṠNṘ i̇7 2̇	ṘṠĠ 2̇i̇3̇
	c	SGR 132	RMG 243	GPM 354	MDP 465	PND 576	DṠN 6i̇7	NṘṠ 7 2̇i̇	ṠĠṘ i̇3̇2̇
	d	GSR 312	MRG 423	PGM 534	DMP 645	NPD 756	ṠDN i̇67	ṘNṠ 2̇7i̇	ĠṠṘ 3̇i̇2̇
	e	RGS 231	GMR 342	MPG 453	PDM 564	DNP 675	NṠD 7i̇6	ṠṘN i̇2̇7	ṘĠṠ 2̇3̇i̇
	f	GRS 321	MGR 432	PMG 543	DPM 654	NDP 765	ṠND i̇76	ṘṠN 2̇i̇7	ĠṘṠ 3̇2̇i̇

TABLE 2 Example of *khaṇḍamēru* patterns combined horizontally.

	Passages sung by students which combine *khaṇḍamēru* phrases					
	1st sung phrase	2nd sung phrase	3rd sung phrase	4th sung phrase	5th sung phrase	6th sung phrase
sargam	SRG, RGM	RSG, GRM	SGR, RMG	GSR, MRG	RGS, GMR	GRS, MGR
Degrees of the scale	123, 234	213, 324	132, 243	312, 423	231, 342	321, 432
Formula using figures from Table 1	1a + 2a	1b + 2b	1c + 2c	1d + 2d	1e + 2e	1f + 2f

Or combined vertically:

the listeners' consciousness and allow us to focus our attention on the *rāg's* qualities" (Clayton, 2000, p. 26). The implication of this for learners is that it highlights the teacher's role in pitching their modelling of intensification at an appropriate level for a student to be able to replicate. It also supports the strategy of seeing *rāg* as a more complex musical entity than can be grasped by memorisation of the ascending and descending phrases of the *rāg*. For students, learning characteristic phrases sung by their teacher therefore helps to develop the precise dialectic and idiolectic sensibilities needed to construct fluent performances.

3.5 A note on the transcriptions

This next section of the article uses numerical notation in place of *sargam* (syllables used to name the notes of a scale in a *rāg*); hence '*sa re ga ma pa dha ni*' is written '1 2 3 4 5 6 7'. Presenting degrees of the scale as numbers helps to demonstrate patterns more clearly to readers less familiar with the *sargam* system. Upper and lower octaves (*saptaks*) are denoted by a dot above or below the number (for example, 7̣, i̇). If the scale has been altered from the *bilāval* scale/*ṭhāt* (or Ionian mode) then this is denoted by a line above or below the number to demonstrate if the note (*svar*) has been raised (*tīvră*) or flattened (*komal*). Hence the ascending *bhairav* scale/*ṭhāṭ* (double harmonic major scale) is notated '1 2 3 4̲ 5 6̲ 7 i̇' and the *kalyāṇ ṭhāṭ* (Lydian mode) is notated '1 2 3 4̄ 5 6 7 i̇'. Where there is a rest, or a note has been held for twice as long in the pattern, this has been transcribed as –.

4 Illustrative examples

The differences between teaching in the GSP and in music schools are identified in section 3.1; however, the way these differences present themselves on a lesson-to-lesson basis in these specific cases is identified through analysis of the video data from observations. Learners are referred to as *śiṣyas* in the GSP context and students in the music school context. This section begins with an analysis of the pedagogical strategies used in two recorded observations: one from a music school and one from the GSP. Following this, a thematic discussion presents the implications for understanding the pedagogical strategies used to develop improvisation skills in NICM. Illustrative example 1 takes place in a music school in Varanasi with a female teacher and eight beginner students. The styles they are learning are *k̲hayāl* and *ṭhumrī* and they cover *rāg yaman kalyāṇ*, *malkauns* and *bilāval* during the lesson. Illustrative example 2 also takes place in Varanasi at the home of a male *guru* with four experienced *śiṣyas* aged 14–17. The styles they are learning are also *k̲hayāl* and *ṭhumrī* and they cover *rāg yaman kalyāṇ* during the *tālīm*.

TABLE 3 Example of *khaṇḍamēru* patterns combined vertically.

	Passages sung by students which combine *khaṇḍamēru* phrases							
	1st sung phrase	2nd sung phrase	3rd sung phrase	4th sung phrase	5th sung phrase	6th sung phrase	7th sung phrase	8th sung phrase
sargam	SRG RSG	RGM GRM	GMP MGP	MPD PMD	PDN DPN	DṄṠ NDṠ	NṠṘ ṠNṘ	ṠṘĠ ṘṠĠ
Degrees of the scale	123 213	234 324	345 435	456 546	567 657	67̇176̇1̇	71̇2̇17̇2̇	1̇2̇3̇2̇1̇3̇
Formula using figures from Table 1	1a + 1b	2a + 2b	3a + 3b	4a + 4b	5a + 5b	6a + 6b	7a + 7b	8a + 8b

TABLE 4 Examples of *palṭās* sung in *sargam* and *ākār* from illustrative example 1 (music school teaching).

	palṭās sung by students during illustrative example 1 (presented using degrees of the scale)	
	Ascending phrases of the palṭās sung by students	Descending phrases of the palṭās sung by students
1st palṭā	1233, 2344, 3455, 4566, 5677, 671̇1̇	1̇766, 7655, 6544, 5433, 4322, 3211
2nd palṭā	121233, 232344, 343455, 454566, 565677, 6,7671̇1̇	1̇71̇766, 767655, 656544, 545433, 434322, 323211
3rd palṭā	1-32132132121321, 2-43243243232432, 3-54354354343543, 4-65465465454654, 5-7-6576576565765, 6-1̇761̇761̇7,6761̇76	5-76576576565765, 4-65465465454654, 3-54354354343543, 2-43243243232432, 1-32132132121321
4th palṭā	13, 24, 35, 46, 57, 6̇1̇	1̇6, 75, 64, 53, 42, 31

TABLE 5 Examples of *ālāp* phrases sung by the teacher and repeated by the students in illustrative example 1 (music school teaching).

	ālāp phrases sung by students during illustrative example 1 (presented using degrees of the scale)		
1st ālāp phrase	ṣ-7-1-4---	6th ālāp phrase	4-6-7-7-6-
2nd ālāp phrase	4----3-	7th ālāp phrase	3-46-7̇----
3rd ālāp phrase	3-4-3-1-	8th ālāp phrase	3̇-1̇-7-1̇-6-
4th ālāp phrase	6-7-1-4---4----3-3-4-3-1---	9th ālāp phrase	7-6-7-7-6-4---
5th ālāp phrase.	1-3-4-6-	10th ālāp phrase	3-4-6-3-4-3-7-ṣ-1---

4.1 Music school teaching

This lesson took place on the evening of March 20, 2018, at a music school in Varanasi. Starting at 6 pm and lasting just over an hour as the sky transitioned from daylight to darkness. The atmosphere was relaxed, with some chatter and laughter among the teacher, students, and parents, yet there was also a clear emphasis on maintaining focus. This session involved only women and children; unlike other lessons I had observed in the music school where the chairman was also present. The class consisted of five girls and three boys aged 7–11, with two mothers sitting at the back, occasionally chatting with the teacher. As a customary practice, students left their shoes in the exterior corridor, touched the teacher's feet upon entering, and had their heads touched by the teacher before sitting. They sat cross-legged in a semicircle with the teacher at the front, boys on one side and girls on the other, although it was unclear if this seating arrangement was enforced or habitual.

The lesson began with the teacher singing a long, slow "sa," joined by the students, followed by "pa." After several repetitions, the students were split into groups of two and three to sing 1,234,567̇1̇17654321 in *sargam* and *ākār* (singing pitches to the syllable 'aa'), with a focus on intonation. Older and more confident students demonstrated better intonation and smoother transitions, as well as greater ease with the faster *palṭās* compared to younger students, who struggled with the phonemes at higher speeds. The pattern 1122334455, 123323443455 (familiar to the group) was sung in *sargam* and *ākār*, with the teacher only needing to start each variation for the students to anticipate the next sequence. Following this, the pattern of singing *palṭās* in *sargam* and *ākār* is illustrated in Table 4.

In this lesson, all *palṭās* were sung with *tablā* accompaniment set at 160 *mātrās* (beats) per minute, which is on the cusp between *drut lāya* (fast tempo) and *madhya lāya* (medium tempo), with each *svar* lasting half a *mātrā*. Despite some students struggling with this tempo, the teacher emphasised the importance of mastering these *palṭās* at this speed in both *sargam* and *ākār*. This approach ensures that students internalise these patterns well enough to recite them fluently at any speed during improvisation, representing an efficient drill method. The melodic features of the *palṭās* include repetition and variation, akin to the *tāns* used in performance. Although the *palṭās*

are simple and in the *bilāval* scale/*ṭhāṭ* (ionian mode), the strategy of internalising these patterns for future use in improvisation is evident. The ascending and descending phrases of the *palṭās*, confined to a narrow pitch range (no greater than a third), also reflect how *tāns* are constructed in performance.

In this lesson, the teacher uses body language and non-verbal cues to indicate satisfaction with students' accuracy during *palṭās*. When correcting errors, she would repeat a short segment to improve students' ability to copy phrases by rote. Although students sing more confidently in unison, this does not necessarily improve their accuracy. The teacher segments challenging *palṭās* for struggling students, modelling an effective practice strategy of breaking down longer phrases into manageable chunks. She speaks very little during the lesson, except for a short section where she tests students' ability to recognise different *tāl* patterns.

Two-thirds of the way through the lesson, students sing a pre-composed *bhajan* (devotional song) in *rāg yaman kalyāṇ*, set to *rūpak tāl* (a 7 beat cycle). This scale/*ṭhāṭ* differs from the earlier *palṭā* activity. After rehearsing the *bhajan*, students move on to a *choṭā kẖayāl*. The teacher begins by asking students to sing the *ārōh* (ascending pattern) and *avarōh* (descending pattern) of *rāg malkauns*. Initially, students struggle with the pitches due to the lingering memory of the *kalyāṇ* scale/*ṭhāṭ* from the *bhajan*. The teacher then sings the *ārōh* and *avarōh* slowly with correct pitches (1-3-4-6-7-i̇-i̇-7-6-4-3-4-3-1), which students repeat. Once this scale/*ṭhāṭ* has been established, students repeat the *ālāp* phrases shown in Table 5.

This sequence demonstrates how the teacher develops students' memories for characteristic phrases that follow the grammar of the *rāg* (unlike *palṭās*). For instance, phrase 4 is a combination of phrases 1, 2, and 3, effectively establishing both memory for phrases and the technique of stringing phrases together incrementally. Key features of the *ālāp* phrases include mostly stepwise motion and small jumps (e.g., intervals of a third and fourth in phrase 10) that involve ornamentation to create a more stepwise route through the *ālāp* phrases. The pitch ranges are characteristic of a *kẖayāl ālāp*, starting low and expanding upwards (up to 3̇) before descending back to 1.

Following a long-held 1 at the end of phrase 10, the class transitions to singing the *bandiś* of the *choṭā kẖayāl*. The teacher adds a *tihāi* based on the first word of the *sthāyī* for students to follow, exemplifying how traditionally improvisatory aspects are composed by the teacher and memorised by students in a music school context. Notably, there is no section for *vistār* in this *choṭā kẖayāl*, and students are not expected to copy the improvisatory phrases demonstrated by their teacher, likely due to their current skill level rather than their age.

4.2 Guru-śiṣya paramparā tālīm

This episode of *tālīm*, conducted on 13th January 2018 at 8:00 pm, takes place in the *guru's* home. The four male *śiṣyas* are dressed in thick western attire due to the cold and were seated on a raised dais facing their *guru*. The itabla app provided drone and *tablā* accompaniment during the lesson, which followed the structure of a full performance of *rāg yaman kalyāṇ*. The session began with the *ālāp* section, where *śiṣyas* repeated phrases sung by the *guru* in *ākār* as a group. The *guru* repeated intricate phrases with verbal explanations to highlight specific expressive features, sometimes singing alongside the *śiṣyas* for support. Head gestures were used by both the *guru* and *śiṣyas* to indicate the accuracy and mastery of the phrases.

Following the *ālāp*, the lesson focused on perfecting a very slow precomposed *bandiś* in *vilambit ektāl* (a slow, 12 beat cycle). The *guru* began by singing the first phrase of the *bandiś* without *tablā* accompaniment, which the *śiṣyas* copied as a group. After starting the itabla app, the *guru* had to reset the *tablā* accompaniment due to a rhythmic issue. He consulted a book of notated *bandiśes* to verify the correct *tāl*, then restarted the *tablā*, and the group continued singing the *sthāyī* in unison. The use of notated *bandiśes*, both printed and handwritten, highlights a distinctive feature of this *tālīm*. While some *gurus* rely solely on memory, in this instance, *śiṣyas* had access to printed materials to aid their learning.

Once the *ālāp* section concluded, the *guru* and *śiṣyas* rehearsed aspects of *vistār*. The *guru* started by singing lengthy phrases that *śiṣyas* struggled to remember, necessitating reminders and breaking

TABLE 6 ***bol tāns*** sung as part of the ***baṛā kẖayāl*** from illustrative example 2 (GSP ***tālīm***).

	tāns sung by students during illustrative example 2 (presented using degrees of the scale)		
1st tān	3-2321765̣23-	13th tān	5̄43̄23̄46̄7̇1̄7̇1̄765̄46̄45̄34̄2321
2nd tān	7̣237̣27̣32321̣723---	14th tān	5̄43̄23̄46̄7̇1̄7̇1̄765̄46̄45̄34̄23217̣67̣23̄43̄
3rd tān	7̣237̣27̣32321---	15th tān	2̇76765
4th tān	4̄43̄432, 332321, 7̣67̣23̄43̄-----	16th tān	5767, 5645, 3̄42321----
5th tān	7̣23̄43̄-	17th tān	333, 777, 3̇3̇3̇, 72̇1̇7, 65̄46̄54̄34̄23̄43̄24̄321
6th tān	4̄43̄432, 332321, 7̣67̣23̄43̄-----	18th tān	7̣23̄432, 7̣23̄45̄432, 3̄46777
7th tān	7̣23̄45̄432, 3̄45̄432, 3̄46̄5̄432343̄-----	19th tān	4̄67̄64̄67̄655̄65̄43̄42321
8th tān	7̣23̄45̄432, 7̣23̄46̄5̄432, 7̣23̄45̄43̄23̄43̄---	20th tān	15̄43̄42321 (x3)
9th tān	3̄47̄65̄432321	21st tān	767̄56̄43̄4321 (x2)
10th tān	5̄43̄23̄46̄76̄57̄64̄6̄45̄34̄2321	22nd tān	7̣23̄43̄-, 767̄56̄43̄4321
11th tān	4̄67̄46̄47̄67̄65̄46̄5̄42323---	23rd tān	333, 777, 3̇3̇3̇, 72̇1̇7, 65̄46̄54̄34̄23̄43̄24̄321
12th tān	3̄43̄23-2321̣76̣23---	24th tān	7̣23̄45̄4̄, 23̄4̄567, 3̇2̇1̇2̇1̇72̇1̇765̄4̄, 65̄43̄42321

TABLE 7 The number of times that common note combinations are repeated during two sections illustrative example 2 (GSP *tālīm*).

	Common note combinations in the *bol tāns*	Number of times phrase is repeated in the *bol tāns* of the *baṛā kẖayāl*	Number of times phrase is repeated in the *bol tāns* of the *choṭā kẖayāl*	Total
Common note combination 1	3232176723	4	10	14
Common note combination 2a and 2b	6453432321 and 654343232 1	6 (4 and 2)	0	6 (4 and 2)
Common note combination 3a and 3b	3217654 32 and 3217654 32	0	12 (8 and 4)	12 (8 and 4)
Common note combination 4a, 4b and 4c	72343 and 72345 and 72354	11 (6 and 5 and 0)	8 (3 and 2 and 3)	19 (9 and 7 and 3)
Common note combination 5a and b	342321 and 32321	14 (7 and 7)	13 (1 and 12)	27 (8 and 19)
Common note combination 6 a and b	543234 and 23467	15 (11 and 4)	10 (6 and 4)	25 (17 and 8)
Common note combination 7a, b and c	654654 and 654664 and 654645	6 (6 and 0 and 0)	6 (3 and 2 and 1)	12 (9 and 2 and 1)
Common note combination 8a, b, c and d	6543 or 65432 or 645334 or 654334	12 (1 and 3 and 4 and 4)	23 (0 and 17 and 5 and 1)	35 (1 and 20 and 9 and 5)

the phrases into smaller chunks. Sometimes, the *guru* sang along with the students for support, while at other times he listened and corrected them by interjecting. In the second part of the *vistār* section of the *baṛā kẖayāl*, individual *śiṣyas* sang their own improvisations interspersed with the first phrase of the *sthāyī*. The *guru* listened and provided musical suggestions, modelling and explaining as needed. When one *śiṣya* missed the correct beat of the *tāl* to start the *sthāyī*, the *guru* demonstrated an alternative phrase before moving on to the next student. The *śiṣyas* recorded their *tālīm* on their phones, allowing them to review the improvisations later. Each student incorporated aspects of the *guru's* phrases into their improvisation, and all listened intently to each other.

In the next section of the *baṛā kẖayāl vistār*, the *guru* modelled variations on the *sthāyī*, which *śiṣyas* repeated either as a group or individually. Sometimes, the *guru* focused on a single word of the lyrics, constructing phrases for individual *śiṣyas* to repeat. The individual sections were interspersed with the *sthāyī*, and some phrases were repeated as a group. Those not singing paid close attention to each other's phrases, sometimes shaping the air with hand gestures to reflect the melodies. As the lesson developed, the pitches expanded into the upper register, continuing into the higher octave and including the characteristic long-held high *sa*. The *śiṣyas* copied their *guru's* phrases in unison using the text of the first line of the *antarā*. The format continued with the group singing the *sthāyī* of the *baṛā kẖayāl bandiś* in *ākār*, interspersed with variations on the *antarā*, and finished with the first line of the *sthāyī*.

The next section of the *tālīm* focused on *sargam* and *bol tāns* as part of the *baṛā kẖayāl*. The *tāns* shown in Table 6 are demonstrated by the *guru* and copied in unison by all *śiṣyas*. Later *tāns* in the sequence are focused on individual *śiṣyas*, but for the purpose of this analysis, that detail has been omitted from the transcription below.

In order to demonstrate the number of times that key fragments are repeated within the improvised *bol tāns*, Table 7 records the number of repetitions of key phrases within illustrative example 2. This demonstrates how melodic material is being repeated in the *bol tāns* of both the *baṛā* and *choṭā kẖayāl*.

In this example, the *guru* used a method of constructing improvisations with increasing intensity that closely resembled aspects of a *kẖayāl* performance. This approach involved the repetition of small melodic fragments and entire *tāns*, creating familiar patterns. Key techniques included reusing previously sung *tāns* within longer *tāns* and employing specific phrases for syntactic functions, such as ending or beginning motifs. For instance, *baṛā kẖayāl tān* 1 (3232176723) appeared within *tān* 4, 6 and 12, while *tān* 2 (7237232321) reappeared in *tān* 3. *Tān* 4 (443432, 332321, 7672343-----) is repeated within *tān* 6. Furthermore, certain phrases seem to fulfil specific syntactic functions for example, *tān* 5 (72343-) is repeated within *tān* 4, 6, 14, 18 and 22 as a motif by which to end the phrase. As well as *tāns* that end idiomatically, there are motifs that are frequently used at the beginnings too. For instance, *tān* 10, 13 and 14 start in similar ways (although they are not identical) but they do end in the same way (6453432321). *Tān* 11 and 19 start in the same way (4676464476) as do *tān* 17 and 23 (333,777,333).

Variation was another strategy used, for example, *tān* 7 and 8 were similar but not identical, with *tān* 8 developing the phrase from *tān* 7 while maintaining the same ending. This technique of combining or altering phrases allows for expressive possibilities and increased intensity in the improvisation. Advanced *śiṣyas* apply these ideas in different contexts, such as within the *bol tāns* of the *choṭā kẖayāl*. The *tāns* maintained a consistent fast speed and showed little rhythmic variation, indicating that the *śiṣyas* had mastered slower speeds and were now developing their skills at a higher tempo. The pitch range expanded throughout the sequence, mirroring the *ālāp* and intensifying the improvisation. The *tāns* typically ended on 1, 5, or 3, with only one exception (18), which upon closer inspection, was part of a longer phrase ending on 1.

Following the *sargam tāns*, the work was consolidated through the *ākār tāns*, reinforcing the strategies and techniques learned during the

session. This methodical approach highlighted the importance of both repetition and variation in developing *śiṣyas*' improvisational skills.

5 Results and discussion

The illustrative examples from music school and GSP highlight strategies for developing improvisation skills in students at both early and advanced stages of training. In music schools, lessons for younger students are divided into smaller sections, allowing frequent repetition of characteristic *rāg* phrases to aid long-term memorisation. As described by Sanyal and Widdess (2004) and Alaghband-Zadeh (2013), lessons are structured to mirror performances, helping students form expectations and schemas which comply with conventions such as pitch ranges and phrase variation. High expectations for focus and respect are common across teaching settings, whether in music schools or in the GSP in line with the conventions observed by Kippen (2008, p. 131). Students are expected to listen silently and learn from others and their teacher, without asking questions. If students struggle, teachers use repetition, segment material or adjust the pace.

More experienced students improvise their own *tāns*, balancing repetition and variation to avoid unstructured phrases, a strategy that is discussed by teachers and recorded in an archive recording (Dey, 2009) but does not appear in the literature. Strategies for *tāns* include maintaining pitch range parameters, using melodic and rhythmic variations, and rearranging note combinations like *khaṉḏamēru* (Qureshi, 2007, p. 92). Imitation of modelled phrases is the predominant teaching strategy (Mirza Maqsud Ali cited in Qureshi, 2007, p. 190). Even advanced students rarely demonstrate spontaneous improvisation, focusing instead on memorising long phrases. This practice helps them eventually create their own phrases. Advanced students develop the ability to improvise through familiarity with the repertoire and understanding the construction principles of patterns, rather than just memorising note sequences (Powers, 1980; Neuman, 2012; McNeil, 2017). Teachers demonstrate the expansion of phrases in *ālāp* and *tāns*, showing students how to develop and extend phrases. While *palṭās* act as maps of tonal space (Magriel, 1999), the *ālāp* and *tāns* enable performers to explore both familiar and new pathways through the tonal space, ultimately guiding students towards independent improvisation.

5.1 The foundational skills of simple scale exercises

The simple scale exercises observed in music schools serve multiple functions in musical training, such as developing students' voice control, precise intonation, breath control, and secure positioning of *s*vars in memory. These exercises help create an indexical link between the notes and their names within the *sargam* system and support the development of simple *alaṅkārs* (ornaments), where repeating notes often leads to the natural addition of *gamak* to embellish each note (Magriel, 2002). Intonation is particularly challenging for young vocal music students, so secure positioning of *s*vars within a child's comfortable singing range is emphasised from the first lesson. This involves drilling *palṭās* alongside singing long, slow notes while focusing on listening to the *tānpūrā* drone or *śruti box* to check intonation. *Palṭās* are efficient in training pitch control due to the wide range of note permutations within a scale. The repetitive nature of these drills allows teachers to assess whether students have internalised the pitches and can accurately reproduce them in any order, even when their minds wander during the exercises.

5.2 Transition from scale exercise to *palṭās*

Once students/*śiṣyas* have mastered simple scale exercises, the introduction of *palṭās* further develops their voice control, internalisation of complex pitch patterns, ability to transpose pitch patterns, and cognitive mapping of scale structures, independently of *rāg*. *Palṭās* are initially sung slowly in *sargam*, then in *ākār*, before speeding up, showing the precise strategies used for internalising these patterns over time. By incorporating *palṭās* with different leaps over a sequence of lessons, and expecting practice between lessons, students develop precise intonation of various intervals. Once the routes to *svars* become automatic, students gain ease in sequencing and varying melodic material, a crucial skill for fluent improvisation. As students internalise numerous patterns, they can recall them and produce or link specific musical phrases. These patterns, useful for starting, linking, or ending phrases, are vital tools for memorisation in preparation for performance (Magriel, 1999).

In a *k̲ẖayāl* performance, the final section which incorporates *tāns*, relies heavily on a performer's ability to improvise. Teachers use various strategies to develop students' skills to compose and improvise *tāns* that are complex yet conform to the *rāg's* grammar. The basic skills for performing *tāns*, both compositional and technical, are taught through *palṭās*. In advanced training, students learn to memorise, compose, and eventually improvise *tāns* that retain many features of the earlier *palṭās* and reflect the *rāg's* grammar. This progression illustrates how the strategy evolves from a pedagogical drill to a key feature of improvisation.

5.3 Memorising *bandiśes* supports improvisational competence

The *bandiś* material is crucial for students to internalise key phrases of a particular *rāg*, whilst capturing the expressive nuances of melodic and rhythmic phrases. Teachers and *gurus* emphasise the accurate rendering of the *bandiś*, including ornamentation and pronunciation, ensuring precise knowledge construction (Morris, 2005). While variation in performance is valued, the faithful reproduction of *bandiśes* as taught by the *guru* is prioritised. This reflects the respect for *gurus* and the cultural values associated with musical learning.

Students develop schema-based expectations for the pitch direction of *bandiśes* through enculturation. They learn early that the *sthāyī* melody moves in the lower tetrachord of the middle and lower octaves, while the *antarā* rises to the upper tetrachord and upper octave (Widdess, 1981; Clayton, 2000), aiding efficient learning. Although classificatory knowledge of the *rāg* is less prioritised in the GSP than in music schools, modern GSP teaching often includes theoretical aspects. *Gurus* may publish and print *bandiśes* they learned

and share performances online, blending traditional aural learning with modern resources.

Learning *bandiśes* aurally develops associative memory chains (Farrell, 2012), while written notation aids content-addressable memory (Chaffin et al., 2016). Internalising the structure of the *bandiś* is essential for improvisation, with a rule-governed approach emphasised for younger students. Teachers in the illustrative examples adapted their teaching in real time, checking individual students' progress. Over time, performers can develop an extensive repertoire of 400–1,500 *bandiśes* (Morris, 2005). This extensive repertoire offers an alternative to explicitly learning *rāg* grammar, potentially influencing the speed at which improvisational skills develop.

5.4 The importance of practising *ālāps* of developing length and complexity

The internalisation of *rāg* conventions extends beyond the memorisation of bandiśes to include *ālāp* phrases learned over time. These phrases help students grasp *rāg* grammar, incorporating the expansion of phrases, range, and development of musical ideas. Performance conventions of the *ālāp* section vary, with some *gurus* emphasising analytical skills while others do not. Teachers often retain *sargam* syllables in lessons to highlight these patterns and develop students' analytical abilities.

Beginners are often encouraged to improvise within a limited note range in individual *tālīm*, more so than in group settings. *Gurus* vary in their approach: some teach precomposed *ālāp* phrases for memorisation, while others encourage constructing and improvising phrases from the start. The reordering of phrases, as described by Magriel (2002), applies to both *ālāp* and *tāns*. Expectations may differ based on students; for instance, foreigners might memorise fixed phrases while enculturated learners improvise from the beginning. This aligns with observations by Nooshin and Widdess (2006) suggesting that years of practice are needed before going beyond memorised material. Teachers assess students' abilities to memorise and repeat *ālāp* phrases, organising groups by skill level rather than age. Differentiating the length and complexity of phrases according to each student's stage of learning is a key strategy in both music schools and GSP.

5.5 Memorisation of *palṭās* supports the creation of *tāns*

The ability of students to repeat phrases modelled by their teacher enhances their capacity for rapid memorisation and instant replication of complex pitch sequences in *rāg* and *tāl*, known as *tāns*. This skill, along with the development of musical ideas and pitch range, is supported by memorising *palṭās*. The principles of repetition, sequence, and variation in *palṭās* also apply to *tāns*. Advanced techniques in *palṭās*, such as combining shorter phrases or repeating steps, help students extend and develop phrases within a metrical structure, aiding performance skills. The potential cognitive differences in enculturated learners, which might necessitate a less structured approach, present an interesting area for further study.

5.6 The impact of lesson structure mirroring a performance

The GSP is regarded as the gold standard for musical transmission in NICM. However, both music school settings and GSP share common teaching features, particularly following the *dhrupad* or *k̲h̲ayāl* structure by starting with *ālāp* or *bandiś*. This sequence models the concept of intensification, a key process in NICM, every time students engage in *tālīm*. Over time, this consistent strategy builds students' confidence in their performance trajectory, allowing them to focus on intensification details across pitch, rhythm, tempo, melodic complexity, and emotion. Learning various improvisatory techniques enhances students' abilities to create increasing intensity in performance. The structure of *tālīm* varies with student levels; advanced learners may focus on one *rāg* in detail, while younger or less advanced learners might study a variety of *rāgs*, including film songs and *bhajans* in music schools.

Magriel's (2002) analysis of young singers' performances revealed that they used the same melodic material but varied the frequency and sequence of phrase repetitions. This reordering of memorised material is a crucial stage of improvisational competence, allowing students to experiment with intensification using familiar patterns. For example, in illustrative example 1 students initially struggled with the *ārōh* and *avarōh* of *malkauns*, indicating they might find independent improvisation challenging. This mirrors performance structures for pedagogical reasons. The teacher likely uses familiar *bandiś* to establish *s*vars, suggesting that increased familiarity with the repertoire will correct students' mistakes and improve their improvisational skills.

5.7 Prevalence of improvisation in lessons/*tālīm*

An important finding from the illustrative examples is that students, particularly those in music schools, are rarely asked to improvise in lessons/*tālīm*. Instead, they focus on memorising and instantly replicating their teachers' materials. These materials, composed and improvised by the teachers, exemplify the compositional methods and skills needed for improvisation rather than requiring students to construct novel phrases spontaneously. However, teachers' strategies might be more subtle than they appear. When students' replications are not exact due to memory limitations, they are indirectly encouraged to recompose their teachers' phrases spontaneously. This approach, which may seem like rote learning, fosters students' creative problem-solving abilities in the moment. Teachers may accept inexact replications if they retain the original's overall intentions and correctness in *rāg* and *tāl*, supporting this assertion. NICM literature supports the idea that memory recall is a creative process, with memories modified and restructured upon recall and influenced by pre-existing schemas that shape expectations. In the

observed situations, very advanced students might start creating their own *tāns* in class or independently, though this is primarily a feature of GSP *tālīm*.

6 Conclusion

This article set out to identify what the improvisatory objects and processes being used in the training and performance of NICM are through the analysis of qualitative data, generated through video supported observations and fieldnotes. Through this process, seven themes have been identified:

1 The foundational skills of simple scale exercises
2 The transition from learning simple scale exercises to learning *palṭās*
3 The supportive strategy of learning many *bandiśes*
4 Developing the length and complexity of *ālāps*
5 Memorising *palṭās* supports the ability to construct *tāns*
6 Lesson structures mirror performance structures
7 Memorisation is a precursor to improvisation

This article also highlights several pedagogical strategies in NICM that warrant further exploration, particularly the relationship between skills needed for embellishing fixed compositions (*tāns*) and those for improvising non-fixed sections (*ālāp*). Further study is needed to bridge the gap between ethnomusicologists and psychologists in defining music perception and cognition processes in oral traditions. Interdisciplinary work could enhance our understanding of musical development in these contexts. The research also suggests investigating the role of non-verbal gestures in *dhrupad*, *ṭhumrī*, and *k̲hayāl* that may support learning and performance.

The cognitive differences between learners enculturated in NICM and those from other musical traditions are likely significant. This research has implications for teachers across various musical styles and traditions. For instance, the lack of performance anxiety observed by Qureshi (2007, p. 292) in NICM students, despite the challenging repertoire and high expectations, suggests that a schema-based pedagogy could be beneficial for musicians in all styles. Such a pedagogy could help students from different disciplines develop confidence in their improvisational abilities, addressing an issue common in classical traditions where improvisation is not prioritised.

Data availability statement

The datasets presented in this article are not readily available because I do not have written permission to share videos of children and young people beyond the scope of the illustrative examples used in my PhD thesis. Requests to access the datasets should be directed to emily.sayers@canterbury.ac.uk.

Ethics statement

The studies involving humans were approved by School of Oriental and African Studies (SOAS) Doctoral School. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because of the challenges of obtaining consent from all parents and guardians in an informal educational setting.

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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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Appendix A: Glossary of key terms

Hindī/Urdū terms	Definition
ākār	singing pitches to the syllable 'aa'
alaṅkār	musical ornament
ālāp	opening section of a *rāg* in North Indian Classical music, a melodic improvisation that introduces the *rāg*
andaz	style/how we express ourselves to the world
antarā	second section/line of a song, after the *sthāyī*
ārōh	ascending scale of notes in a *rāg*
avarōh	descending scale of notes in a *rāg*
bandiś	fixed melodic composition in North Indian Classical music, usually for voice but also used for instrument
baṛā k̲h̲ayāl	large (in the context of *baṛā k̲h̲ayāl* this means long)
baṛhat	exposition of the *rāg* through melodic expansion
behlāvā	strategy for elaborating on a *bandiś*
bhairav	name of a *rāg* and *ṭhāṭ* (sung at dawn) features a flattened 2nd and 6th
bhajan	devotional song
bhāva	emotional state
bilāval	*ṭhāṭ* with intervals similar to the ionian mode
bol tān	precomposed or improvised phrases interspersed with sections of the *sthāyī* and *antarā* phrases of the *bandiś*, sung to the words of the *bandiś*
calan	the way the *rāg* goes, conventions of the *rāg*
choṭā k̲h̲ayāl	small (in the context of *choṭā k̲h̲ayāl* this means short)
deś	*rāg* in *khamāj ṭhāṭ* (a *ṭhāṭ* similar to the mixolydian mode)
dhrupad	oldest surviving form of North Indian classical vocal music
drut laya	Fast tempo (between 160 and 320 beats per minute)
ektāl	12 beat *tāl*
gamak	vocal trill/oscillation
gharānā	system of social organisation linking musicians (and often dancers) to a particular artistic style and way of learning
guru	teacher, guide, mentor
gurukul	residential education establishment following principles of the *guru-śiṣya paramparā*
guru-śiṣya paramparā	denotes a lineage of teaching and learning where knowledge is imparted through a relationship between *guru* and *śiṣya*
hindol	*rāg* in *kalyān ṭhāṭ* which has similar intervals to the lydian mode
kalyāṇ	*ṭhāṭ* with intervals similar to the lydian mode
k̲h̲ayāl	literally 'imagination', a modern genre of North Indian Classical Vocal Music (see also *dhrupad*, *ṭhumrī*)
khaṇḍamēru	process where 3 or 4 notes patterns are selected, and all the possible permutations of those notes are rendered
komal	flattened note
madhya lāya	medium tempo (between 80 to 160 beats per minute)
malkauns	a pentatonic *rāg* in *bhairavī ṭhāṭ* (where all *svars* are *komal*)
mukhṛā	first phrase of a composition
pakaḍ	generally accepted musical phrase (or set of phrases) thought to encapsulate the essence of a particular *rāg*
paḷṭā	permutational routines of notes sung to *sargam* syllables (*sa re ga ma pa da ni*) or *ākār*
riyāz	musical practice (in contrast to *tālīm*—musical training)
rūpak tāl	7 beat *tāl*

(Continued)

Appendix A (Continued)

Hindī/Urdū terms	Definition
sam	first beat of a rhythmic cycle
Sāṅgīt Visharad	lengthy text detailing all the information that a student should know to pass the qualification of the same name. School music teachers are usually required to have this qualification
sargam	syllables used to name the notes of a scale in a *rāg*
saptak	octave
śruti	microtone
śruti box	common name for an electronic *tanpūrā*
śiṣya	a pupil learning a craft from a *guru*
sthāyī	first section of a *bandiś*
svar	musical note
tablā	pair of drums used widely in modern North Indian Classical music styles
tāl	musical metre (the name given to rhythmic cycles)
tālīm	musical training, instruction or education (in contrast to *riyāz*—music practice)
tān	precomposed or improvised phrases interspersed with sections of the *sthāyī* and *antarā* phrases of the *bandiś* (see also *bol tān*) sung in *ākār* or using *sargam* syllables
tānpūrā	long necked plucked string instrument used for creating a drone
ṭhāt	heptatonic scale/mode
ṭhumrī	light romantic form of North Indian Classical music (in this context, 'light' does not denote 'simplified')
tihāi	polyrhythmic technique found in Indian classical music where a phrase is repeated three times, often used to conclude a piece
tīn tāl	16 beat cycle played on a percussion instrument
tīvrā	sharpened note (only applied to ma)
upaj	extemporisation or variations on a theme
vibhāg	duration of rhythmic phrasing within a *tāl*
vistār	expansion or elaboration of a musical phrase or *rāg*
yaman	name of a *rāg* in *kalyāṇ ṭhāṭ*, often taught in the beginning stages of a student's training
yaman kalyān	name of a *rāg* like *yaman*, except that in the descent, it gently touches the flat ma using a ga ma ga pattern

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Validation of the Japanese version of the Kenny Music Performance Anxiety Inventory-Revised

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The Japanese version of the Kenny Music Performance Anxiety Inventory-Revised (K-MPAI-R) has been developed but not yet been validated. This study aims to validate and certify the Japanese version of the K-MPAI-R. Data were collected from 400 participants (250 men, 149 women, and one identifying as other), aged between 18 and 64 years (M = 46.84, SD = 10.45). The sample included 200 professional and 200 amateur musicians, comprising 309 instrumentalists and 91 vocalists. An exploratory factor analysis with promax rotation extracted seven factors that explained 55.8% of the total variance, demonstrating a structure similar to the original version. The scale showed high internal consistency, with a Cronbach's alpha of 0.93. Criterion-related validity was supported by correlations with the State-Trait Anxiety Inventory (r = 0.67) and Performance Anxiety Questionnaire (r = 0.75). These findings indicate that the Japanese version of the K-MPAI-R is a reliable and valid measure of music performance anxiety. This validated instrument enables further investigations into music performance anxiety among Japanese musicians.

KEYWORDS

music performance anxiety, K-MPAI, factor analysis, validation, anxiety inventory, musician

1 Introduction

Music performance anxiety (MPA) is the experience of marked and persistent anxious apprehension related to musical performance, typically arising from specific anxiety conditioning experiences (Kenny, 2009b). MPA is accompanied by various symptoms, classified into the following three categories: physiological (e.g., increased heart rate, dry mouth, and sweating), mental (e.g., difficulty concentrating and memory-related issues), and behavioral (e.g., tremors and technical difficulties) (Burin and Osório, 2017; Steptoe, 2001; Salmon, 1990; Irie et al., 2023). MPA is a common issue among musicians (Fernholz et al., 2019) regardless of their cultural or national background. For example, 24% of musicians in Brazil reported experiencing MPA (Barbar et al., 2014). Van Kemenade et al. (1995) have found that 59% of musicians in a Dutch orchestra reported experiencing MPA, and Studer et al. (2011) have revealed that 22% of music students in Switzerland failed an exam because of MPA. Yoshie et al. (2011) have also identified MPA indicators in 64% of both professional and amateur musicians in Japan.

Various questionnaires have been developed to quantify an individual's level of MPA as a stable trait, often including items about physiological and psychological changes experienced in past performance situations (Yoshie and Morijiri, 2024). These questionnaires include the Kenny Music Performance Anxiety Inventory (K-MPAI and K-MPAI-R) (Kenny et al., 2004; Kenny, 2009a), Performance Anxiety Questionnaire (PAQ) (Cox and Kenardy, 1993), Mazzarolo Music Performance Anxiety Scale (Mazzarolo and Schubert, 2022) and Music Performance Anxiety Inventory for Adolescents (Osborne and Kenny, 2005). Some of such questionnaires, including the PAQ (Kobori et al., 2011) and the Competitive State Anxiety Inventory-2 for Musicians (Yoshie and Shigemasu, 2006; Yoshie et al., 2009), have been used to measure MPA levels among Japanese musicians. Although each questionnaire offers distinct strengths, the K-MPAI and K-MPAI-R (Kenny et al., 2004; Kenny, 2009a) have been widely adopted in research involving both professional and amateur musicians across various genres, instrumentalists, singers, and ensemble or orchestra participants (Robson and Kenny, 2017; Kenny et al., 2013; Kenny and Ackermann, 2015; Paliaukiene et al., 2018); it has also been translated into 22 languages (Kenny, 2023).

The K-MPAI was developed by Kenny et al. (2004), and is based on Barlow's emotion-based theory of anxiety (Barlow, 2000). Barlow (2000) has described the following three vulnerabilities related to the development of anxiety, anxiety disorders, and emotional disorders: generalized biological vulnerability, generalized psychological vulnerability, and specific psychological vulnerability. Generalized biological vulnerability describes a basic anxiety tendency driven by genetic influences. Generalized psychological vulnerability is shaped by early experiences with uncontrollability, which later amplify stressful events. Specific psychological vulnerability, influenced by early learning experiences, predisposes individuals to focus their anxiety on specific objects or events and influences which object or situation becomes the focus of fear in specific phobias. The K-MPAI comprises 26 items designed to assess such vulnerabilities indicated in Barlow's theory and pre-performance experience, aiming to contribute to the comprehensive conceptualization of MPA and provide an appropriate focus for the development of more suitable treatments (Kenny, 2009a).

Kenny later revised the K-MPAI, incorporating additional factors related to the etiology and maintenance of MPA with a broad focus. This led to the development of the K-MPAI-R with 40 items (Kenny, 2009a). Kenny et al. (2012) explored the factor structure of the K-MPAI-R using a sample of 377 professional orchestral musicians in Australia. A factor analysis identified the following six distinct factors: proximal somatic anxiety and worry about performance; worry/dread (negative cognitions/ruminations) focused on self/other scrutiny; depression/hopelessness (psychological vulnerability); parental empathy; concerns with memory; generational transmission of anxiety; and anxious apprehension and biological vulnerability, a weaker additional factor.

The K-MPAI-R has been translated into Spanish (Peru) (Chang-Arana et al., 2018), French (Antonini Philippe et al., 2022), Korean (Oh et al., 2020), Portuguese (Dias et al., 2022), Italian (Antonini Philippe et al., 2023), Polish (Kantor-Martynuska and Kenny, 2018), Turkish (Çiçek and Güdek, 2020) and Romanian (Faur et al., 2021), with reliability testing conducted through internal consistency coefficients. In addition, validity testing has been conducted through factor structure examination via exploratory factor analysis (EFA) (Chang-Arana et al., 2018; Antonini Philippe et al., 2022, 2023; Oh et al., 2020; Dias et al., 2022; Kantor-Martynuska and Kenny, 2018; Faur et al., 2021), and correlation analyses with related measures such as the State-Trait Anxiety Inventory (STAI) (Chang-Arana et al., 2018; Antonini Philippe et al., 2022, 2023; Oh et al., 2020; Dias et al., 2022; Kantor-Martynuska and Kenny, 2018). Among the factors derived by Kenny et al. (2012), "proximal somatic anxiety and worry about performance", "depression/hopelessness (psychological vulnerability)", "parental empathy", and "concerns with memory" were also observed in a similar form across multiple language versions (Antonini Philippe et al., 2022, 2023; Dias et al., 2022; Faur et al., 2021; Chang-Arana et al., 2018; Oh et al., 2020; Kantor-Martynuska and Kenny, 2018). However, variations in the factor structure have also been found among different language versions of the K-MPAI-R. For example, factors related to "worry/dread (negative cognitions) focused on self/other scrutiny" were only found in French (Antonini Philippe et al., 2022), and Korean (Oh et al., 2020) versions. Factors related to "generational transmission of anxiety" were found only in Italian (Antonini Philippe et al., 2023) and Korean (Oh et al., 2020) versions. These results potentially indicate that differences in languages and/or cultures can influence the factor structure of the K-MPAI-R.

The various language versions of the K-MPAI-R have contributed to a better understanding of MPA, especially personality traits related to MPA. For example, a study conducted on Brazilian musicians found that the group with higher K-MPAI scores had lower self-assessment (Barbar et al., 2014). The K-MPAI-R was also used to evaluate the effectiveness of Acceptance and Commitment Therapy treatment on MPA management (Juncos et al., 2017).

The development of a Japanese version of the K-MPAI-R would lead to a deeper understanding of the characteristics of MPA among Japanese musicians and allow for comparisons with studies using other language versions. The authors have created the Japanese version of the K-MPAI-R (Kenny, 2023); however, it has yet to be validated. This study aims to develop a validated Japanese version of the K-MPAI-R. Responses from 400 musicians to the Japanese version of the K-MPAI-R were analyzed through the examination of both reliability (e.g., internal consistency) and validity (e.g., EFA). The validity of the Japanese version was assessed by comparing its factor structure with the English version (Kenny et al., 2012) and results from other language versions. Furthermore, its relationships with the STAI (Spielberger et al., 1970) and the PAQ (Cox and Kenardy, 1993) were examined.

Abbreviations: K-MPAI-R, Kenny Music Performance Anxiety Inventory-Revised; MPA, music performance anxiety; K-MPAI, Kenny Music Performance Anxiety Inventory; PAQ, Performance Anxiety Questionnaire; EFA, exploratory factor analysis; STAI, State-Trait Anxiety Inventory; KMO, Kaiser-Meyer-Olkin; MAP, Minimum Average Partial; TLI, Tucker-Lewis index; RMSEA, root mean square error of approximation.

2 Method

2.1 Measures

2.1.1 Kenny Music Performance Anxiety Inventory Revised version (K-MPAI-R)

The K-MPAI was developed to assess anxiety symptoms and other associated constructs within the context of music performance. The original version includes 26 items (Kenny et al., 2004), which was later revised and expanded to include 40 items (Kenny Music Performance Anxiety Inventory Revised version: K-MPAI-R) (Kenny, 2009a). The questionnaire is answered on a seven-point Likert-type scale, ranging from 0 ("strongly disagree") to 6 ("strongly agree").

The Japanese version of the K-MPAI-R, developed by the authors through a back-translation process, was approved by Kenny (2023); however, it has yet to be validated. A revision of the Japanese version of the K-MPAI-R was conducted to identify any issues overlooked during the translation process and to improve the comprehensibility and cognitive equivalence of the scale. Established guidelines for scale translation recommend that revision processes include cognitive debriefing with multiple individuals from the target population (Wild et al., 2005). We therefore recruited seven musicians from the target population of the K-MPAIR, namely five professionals (a singer, pianist, trombonist, percussionist, and cellist), a university-level music student (a violist), and an amateur musician (a saxophonist), comprising four men and three women, including one bilingual speaker of English and Japanese. Following these interviews, the revisions were made with a focus on consistency with the original version and naturalness in Japanese. During this process, discussions were held among the authors, including experts in music psychology, to determine the final wording. Out of the 40 items, 22 were modified. These items were back-translated again to ensure consistency with the original version. The revised questionnaire is available in the Supplementary Data 1.

2.1.2 State-Trait Anxiety Inventory (STAI)

The STAI (Spielberger et al., 1970) is a 40-item self-report questionnaire comprising 20 items each for trait anxiety and state anxiety, with responses provided on a four-point Likert-type scale, ranging from 1 ("not at all") to 4 ("very much so"). Participants completed the Japanese version of the state scale of the STAI (Hidemi and Kuniharu, 1981). To assess their mental state during musical performances, the following instruction was added: "Imagine the most important performance you have had within the past five years and indicate how much you felt each of the following statements during that time."

2.1.3 Performance Anxiety Questionnaire (PAQ)

The PAQ (Cox and Kenardy, 1993) comprises 20 statements, with 10 describing cognitive feelings and 10 describing somatizations during musical performances. It measures how frequently participants experience these cognitive and somatic responses across the following three performance settings: practice, group public performances, and solo public performances. Participants rate each statement on a five-point Likert-type scale, ranging from 1 ("Never") to 5 ("Always") for each setting. All PAQ items were translated into Japanese through a back-translation process by Kobori et al. (2011). In this study, participants completed the Japanese version of the PAQ, responding to the statements specifically in the context of public performances, without distinguishing between solo and group performances.

2.2 Participants

A total of 400 individuals participated in this study. Among the participants, 250 were men, 149 were women, and one individual identified as other. The participants were between 18 and 64 years old, and their mean age was 46.84 years (SD = 10.45). All participants were native speakers of Japanese. Eligibility criteria required that participants be currently engaged in musical performance activities, specifically playing a musical instrument ($n = 309$) or singing ($n = 91$), and have given a public performance within the past five years. Public performances included situations where the performance was subject to evaluation, such as in music exams, competitions, or auditions, as well as performances before general audiences; however, it excluded performances limited to family, close friends, daily practice, classes, or lessons. The sample was evenly divided between professional ($n = 200$) and amateur ($n = 200$) musicians. The criteria for being classified as a professional were either (a) earning income from music or (b) having studied music at a university or specialized music school. This category also included school teachers with a music teaching license for junior high or high school or those who taught music as a specialized subject in elementary school.

2.3 Procedure

An online survey was conducted. The participants were recruited through an online panel maintained by a marketing research firm. Before participating, they read an explanation of the study and provided their informed consent. Those who consented were asked to complete the K-MPAI-R, STAI, and PAQ.

The study was conducted with the approval of the Ethics Committee of the National Institute of Advanced Industrial Science and Technology.

2.4 Data analysis

All participants answered all questions, and there was no missing data. Some items (1, 2, 9, 17, 23, 33, 35, 37) were reversed following Kenny (2009a). For the 40 items, means, standard deviations, skewness, and kurtosis were calculated. To assess the adequacy for factor analysis, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was calculated, and Bartlett's test of sphericity was conducted. An EFA with a maximum likelihood and promax rotation was conducted to examine the factor structure of the data. The results of the parallel analysis and Minimum Average Partial (MAP) were used as a reference for determining the number of factors. To assess the model fit, the Tucker-Lewis index (TLI) and root mean square error of approximation (RMSEA)

were calculated. To assess scale reliability, the internal consistency coefficient, specifically Cronbach's alpha, was used. The procedures were developed by drawing on the methods of Antonini Philippe et al. (2022, 2023).

We calculated means and standard deviations for the STAI and PAQ. The items 1, 2, 5, 8, 10, 11, 15, 16, 19, and 20 were reversed for the STAI-state following Spielberger et al. (1970). The items 4 and 8 were reversed for the PAQ. To evaluate the reliability of the scales, we performed correlation analyses to investigate several key relationships. We calculated the correlations for the following using Pearson's correlation coefficient: the total scores of the K-MPAI-R and STAI; each factor score of the K-MPAI-R with the total score of the STAI; the total scores of the K-MPAI-R and PAQ; and each factor score of the K-MPAI-R with the total score of the PAQ.

Data analysis was conducted using R Core Team (2024) and psych package (v4.4.1; William Revelle, 2024).

3 Results

3.1 Descriptive analysis

The mean values and standard deviations for each item of the K-MPAI-R are shown in Table 1. Skewness and kurtosis coefficients were calculated for all 40 items. According to Tabachnick and Fidell (2007), skewness and kurtosis coefficients should be within ±1.5 when performing factor analysis on items measured using a Likert scale. The analysis indicates that all 40 items met this criterion.

3.2 Exploratory factor analysis

The KMO assesses sampling adequacy. The KMO value was 0.93, indicating excellent adequacy. Furthermore, the KMO values for each item were above 0.6, confirming the suitability of the data for factor analysis. Bartlett's test of sphericity also confirmed the data's adequacy, with $\chi^2(780) = 9,593.6$, $p < 0.001$.

A factor analysis using maximum likelihood estimation and promax rotation was performed on the 40 items of the K-MPAI-R. To determine the number of factors, both parallel analysis and the MAP criterion were used. The parallel analysis suggested a seven-factor solution, while the MAP criterion recommended five factors. Accordingly, EFA was conducted for the five-, six-, and seven-factor models. The fit indices for the models were as follows: for the five-factor solution, $\chi^2(590) = 1,508.05$, $p < 0.001$, ratio $\chi^2/df = 2.56$, TLI = 0.86 and RMSEA = 0.062; for the six-factor solution, $\chi^2(555) = 1,283.15$, $p < 0.001$, ratio $\chi^2/df = 2.31$, TLI = 0.88 and RMSEA = 0.057; and for the seven-factor solution, $\chi^2(521) = 1,127.42$, $p < 0.001$, ratio $\chi^2/df = 2.16$, TLI = 0.90 and RMSEA = 0.054. A TLI value above 0.90 and RMSEA value below 0.08 are generally considered acceptable (Bader and Moshagen, 2022). Considering both the fit indices and content of each factor, the seven-factor solution was determined to be the most appropriate.

The factors were named based on the items with factor loadings of 0.40 or higher.

F1: Music performance anxiety symptoms (10 items: 10, 12, 15, 16, 22, 24, 26, 30, 34, 36; $\alpha = 0.91$);

F2: Psychological vulnerability (8 items: 3, 4, 6, 8, 13, 19, 20, 31; $\alpha = 0.89$);

F3: Worry/dread focused on self/other scrutiny and evaluation (6 items: 18, 21, 25, 28, 38, 39; $\alpha = 0.89$);

F4: Parental support (3 items: 9, 23, 33; $\alpha = 0.79$);

F5: Memory and self-efficacy (3 items: 17, 35, 37; $\alpha = 0.67$).

F6: Uncontrollability (2 items: 7, 11; $\alpha = 0.75$).

F7: Generational transmission of anxiety (2 items: 5, 29; $\alpha = 0.67$).

We calculated Cronbach's alpha to measure internal consistency. The alphas for factors 1 through 7 were 0.91, 0.89, 0.89, 0.79, 0.67, 0.75, and 0.67, respectively, indicating good reliability for each factor. The overall scale had a reliability of $\alpha = 0.93$.

The seven factors explained 55.8% of variance (Table 2). The correlations between the seven factors are provided in the Supplementary Figure 1.

The six items with factor loadings of less than 0.4 (1, 2, 14, 27, 32, and 40) were not included in any factor. Similarly to previous literature (Antonini Philippe et al., 2023), we used the total score of all 40 items in the subsequent analyses, rather than refining the scale by removing items.

3.3 K-MPAI-R and STAI

The average score of the STAI-state was 46.67 (SD = 10.35) and Cronbach's alpha was 0.89. The K-MPAI-R scores were positively correlated with the STAI score (Table 3).

3.4 K-MPAI-R and PAQ

The average score of PAQ was 54.24 (SD = 14.53) and Cronbach's alpha was 0.94. The K-MPAI-R scores were positively correlated with the PAQ score (Table 4).

4 Discussion

This study developed a validated Japanese version of the K-MPAI-R. The results demonstrated that the developed questionnaire is reliable for measuring MPA. This conclusion is supported by a Cronbach's alpha coefficient of 0.93, which indicates strong internal consistency.

The Japanese version of the K-MPAI-R showed a moderate level of correlation with the STAI-State ($r = 0.67$, $p < 0.001$), indicating its construct validity. The results are consistent with previous studies that showed moderate levels of correlations (r = 0.52 − 0.79) between other language versions of the K-MPAI-R and STAI-State (Antonini Philippe et al., 2022, 2023; Dias et al., 2022). The Japanese version of the K-MPAI-R also showed a moderate level of correlation with the PAQ (r = 0.75, $p < 0.001$). Since the PAQ measures the frequency of cognitive and somatic responses experienced during musical performances, its correlation with the K-MPAI-R further reinforces its criterion-related validity. The correlation was particularly strong for factors directly related to public performance, such as F1 and F3.

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TABLE 1 Descriptive statistics.

Item		Mean	SD	Skewness	Kurtosis
1*	I generally feel in control of my life.	2.65	1.58	0.43	−0.12
2*	I find it easy to trust others.	3.14	1.45	0.11	−0.23
3	Sometimes I feel depressed without knowing why.	2.72	1.80	0.08	−0.93
4	I often find it difficult to work up the energy to do things.	2.96	1.58	−0.15	−0.64
5	Excessive worrying is a characteristic of my family.	2.73	1.64	0.09	−0.65
6	I often feel that life has not much to offer me.	2.08	1.66	0.45	−0.64
7	Even if I work hard in preparation for a performance, I am likely to make mistakes.	3.17	1.57	−0.15	−0.47
8	I find it difficult to depend on others.	3.32	1.63	−0.04	−0.73
9*	My parents were mostly responsive to my needs.	2.74	1.65	0.26	−0.59
10	Prior to, or during a performance, I get feelings akin to panic.	2.08	1.63	0.31	−0.89
11	I never know before a concert whether I will perform well.	3.31	1.61	−0.22	−0.48
12	Prior to, or during a performance, I experience dry mouth.	2.84	1.67	−0.07	−0.73
13	I often feel that I am not worth much as a person.	2.42	1.76	0.31	−0.78
14	During a performance I find myself thinking about whether I'll even get through it.	2.56	1.78	0.09	−0.98
15	Thinking about the evaluation I may get interferes with my performance.	2.36	1.66	0.18	−0.83
16	Prior to, or during a performance, I feel sick or faint or have a churning in my stomach.	1.91	1.67	0.47	−0.79
17*	Even in the most stressful performance situations, I am confident that I will perform well.	3.42	1.60	−0.20	−0.60
18	I am often concerned about a negative reaction from the audience.	2.80	1.68	0.09	−0.72
19	Sometimes I feel anxious for no particular reason.	2.60	1.74	0.11	−0.88
20	From early in my music studies, I remember being anxious about performing.	2.43	1.65	0.19	−0.75
21	I worry that one bad performance may ruin my career.	2.27	1.83	0.35	−0.87
22	Prior to, or during a performance, I experience increased heart rate like pounding in my chest.	3.10	1.67	0.00	−0.72
23*	My parents almost always listened to me.	2.79	1.63	0.10	−0.64
24	I give up worthwhile performance opportunities.	2.34	1.66	0.21	−0.80
25	After the performance, I worry about whether I played well enough.	3.14	1.66	−0.15	−0.69
26	My worry and nervousness about my performance interferes with my focus and concentration.	2.56	1.58	0.06	−0.72
27	As a child, I often felt sad.	2.77	1.71	0.08	−0.78
28	I often prepare for a concert with a sense of dread and impending disaster.	2.39	1.74	0.22	−0.87
29	One or both of my parents were overly anxious.	2.28	1.69	0.31	−0.75
30	Prior to, or during a performance, I have increased muscle tension.	2.66	1.64	0.08	−0.63
31	I often feel that I have nothing to look forward to.	2.29	1.73	0.27	−0.82
32	After the performance, I replay it in my mind over and over.	2.91	1.65	0.10	−0.63
33*	My parents encouraged me to try new things.	3.06	1.61	0.15	−0.59
34	I worry so much before a performance, I cannot sleep.	2.32	1.65	0.18	−0.85
35*	When performing without music, my memory is reliable.	2.73	1.61	0.10	−0.68
36	Prior to, or during a performance, I experience shaking or trembling or tremor.	2.47	1.69	0.22	−0.72
37*	I am confident playing from memory.	3.21	1.66	−0.11	−0.59
38	I am concerned about being scrutinized by others.	2.93	1.69	−0.04	−0.69
39	I am concerned about my own judgment of how I will perform.	3.08	1.62	−0.07	−0.48
40	I remain committed to performing even though it causes me great anxiety.	3.50	1.59	−0.03	−0.57

*Reversed scored items.

TABLE 2 Factor loadings of the K-MPAI-R Japanese version.

Item		Factor 1 Music performance anxiety symptom	Factor 2 Psychological vulnerability	Factor 3 Worry/dread on self/other scrutiny and evaluation	Factor 4 Parental support	Factor 5 Memory and self-efficacy	Factor 6 Uncontrollability	Factor 7 Generational transmission of anxiety	Communality
36	Prior to, or during a performance, I experience shaking or trembling or tremor.	**0.769**	−0.130	0.081	0.037	−0.049	0.066	−0.062	0.551
30	Prior to, or during a performance, I have increased muscle tension.	**0.748**	−0.187	0.110	0.080	−0.026	0.154	0.041	0.585
10	Prior to, or during a performance, I get feelings akin to panic.	**0.737**	0.095	−0.198	−0.025	0.167	0.170	0.129	0.589
16	Prior to, or during a performance, I feel sick or faint or have a churning in my stomach.	**0.736**	0.352	−0.285	−0.020	0.000	−0.103	−0.038	0.708
12	Prior to, or during a performance, I experience dry mouth.	**0.608**	0.125	−0.155	−0.091	−0.005	0.267	−0.193	0.415
22	Prior to, or during a performance, I experience increased heart rate like pounding in my chest.	**0.599**	−0.208	0.197	0.005	−0.046	0.311	−0.057	0.569
34	I worry so much before a performance, I cannot sleep.	**0.598**	0.136	0.100	−0.025	−0.035	−0.105	0.017	0.587
26	My worry and nervousness about my performance interferes with my focus and concentration.	**0.504**	−0.011	0.360	0.045	0.055	0.055	0.135	0.686
15	Thinking about the evaluation I may get interferes with my performance.	**0.452**	0.276	0.183	−0.087	0.169	0.045	0.031	0.678
24	I give up worthwhile performance opportunities.	**0.430**	0.331	−0.010	0.097	−0.154	−0.102	−0.016	0.488
4	I often find it difficult to work up the energy to do things.	−0.118	**0.825**	−0.058	−0.032	−0.100	0.269	−0.022	0.585
13	I often feel that I am not worth much as a person.	0.089	**0.770**	−0.049	0.078	0.019	0.137	−0.014	0.674
3	Sometimes I feel depressed without knowing why.	−0.169	**0.765**	0.053	0.020	−0.049	0.223	0.015	0.539
6	I often feel that life has not much to offer me.	0.111	**0.739**	−0.223	0.057	0.036	0.005	0.132	0.595
19	Sometimes I feel anxious for no particular reason.	0.113	**0.661**	0.144	−0.024	−0.074	0.146	−0.140	0.684

(Continued)

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TABLE 2 (Continued)

Item		Factor 1 Music performance anxiety symptom	Factor 2 Psychological vulnerability	Factor 3 Worry/dread on self/other scrutiny and evaluation	Factor 4 Parental support	Factor 5 Memory and self-efficacy	Factor 6 Uncontrollability	Factor 7 Generational transmission of anxiety	Communality
31	I often feel that I have nothing to look forward to.	0.120	**0.639**	−0.023	−0.022	−0.068	−0.046	0.146	0.603
20	From early in my music studies, I remember being anxious about performing.	0.322	**0.499**	0.018	−0.066	−0.070	−0.075	−0.022	0.579
8	I find it difficult to depend on others.	−0.079	**0.403**	0.067	0.086	−0.067	0.391	−0.015	0.330
38	I am concerned about being scrutinized by others.	−0.043	0.023	**0.834**	−0.069	−0.041	−0.053	0.063	0.667
39	I am concerned about my own judgment of how I will perform.	0.053	−0.128	**0.790**	−0.039	0.007	0.149	0.040	0.703
25	After the performance, I worry about whether I played well enough.	0.038	−0.044	**0.725**	0.021	0.047	0.104	0.126	0.623
28	I often prepare for a concert with a sense of dread and impending disaster.	0.390	0.069	**0.469**	0.052	−0.026	−0.144	0.093	0.681
18	I am often concerned about a negative reaction from the audience.	0.129	0.335	**0.434**	−0.197	−0.004	0.016	−0.164	0.592
21	I worry that one bad performance may ruin my career.	0.301	0.179	**0.417**	−0.021	−0.040	−0.152	0.119	0.637
9*	My parents were mostly responsive to my needs.	0.176	−0.116	−0.117	**0.835**	−0.020	−0.028	0.025	0.659
23*	My parents almost always listened to me.	−0.008	0.085	−0.218	**0.805**	0.008	0.051	0.063	0.655
33*	My parents encouraged me to try new things.	−0.218	0.096	0.024	**0.565**	0.145	0.013	−0.060	0.493
35*	When performing without music, my memory is reliable.	−0.003	−0.024	−0.044	−0.012	**0.712**	−0.080	0.151	0.481
37*	I am confident playing from memory.	0.002	−0.073	−0.036	0.057	**0.674**	0.184	0.023	0.457
17*	Even in the most stressful performance situations, I am confident that I will perform well.	−0.030	−0.165	0.245	0.086	**0.548**	0.199	−0.153	0.476
11	I never know before a concert whether I will perform well.	0.388	0.110	0.126	0.042	0.117	**0.545**	0.003	0.695

(Continued)

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TABLE 2 (Continued)

Item		Factor 1 Music performance anxiety symptom	Factor 2 Psychological vulnerability	Factor 3 Worry/dread on self/other scrutiny and evaluation	Factor 4 Parental support	Factor 5 Memory and self-efficacy	Factor 6 Uncontrollability	Factor 7 Generational transmission of anxiety	Communality
7	Even if I work hard in preparation for a performance, I am likely to make mistakes.	0.048	0.306	0.110	−0.097	0.319	**0.497**	0.143	0.553
29	One or both of my parents were overly anxious.	0.171	0.101	0.220	0.041	0.051	−0.106	**0.596**	0.622
5	Excessive worrying is a characteristic of my family.	−0.120	0.357	0.132	−0.089	0.187	0.129	**0.505**	0.486
1*	I generally feel in control of my life.	0.032	0.113	0.068	0.127	0.142	−0.208	−0.294	0.242
14	During a performance I find myself thinking about whether I'll even get through it.	0.380	0.327	0.202	−0.083	0.156	0.060	0.006	0.656
2*	I find it easy to trust others.	−0.006	−0.020	0.173	0.377	0.074	−0.005	−0.164	0.254
27	As a child, I often felt sad.	0.118	0.192	0.181	0.300	−0.206	0.166	0.179	0.411
32	After the performance, I replay it in my mind over and over.	0.186	0.131	0.193	−0.030	−0.205	0.186	0.100	0.397
40	I remain committed to performing even though it causes me great anxiety.	−0.098	−0.113	0.274	−0.088	−0.437	0.239	−0.030	0.418
	Percentage of variance explained	15.1	13.8	9.9	5.2	4.5	4.2	3.0	

Factor loadings greater than 0.4 are in bold. *Reversed scored items.

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TABLE 3 Descriptive statistics and correlations between K-MPAI-R factors (seven factors and total score) and STAI.

Variable	Number of items	M (SD)	Correlation with STAI
F1	10	24.64 (12.23)	0.58***
F2	8	20.83 (10.17)	0.52***
F3	6	16.60 (8.21)	0.59***
F4	3	8.60 (4.11)	0.04***
F5	3	12.86 (3.5)	0.26***
F6	2	6.48 (2.84)	0.48***
F7	2	5.01 (2.89)	0.40***
KMPAI-R	40	109.04 (34.63)	0.67***
STAI	20	46.67 (10.35)	–

F1:Music performance anxiety symptoms, F2:Psychological vulnerability, F3:Worry/dread on self/other scrutiny and evaluation, F4:Parental support, F5:Memory and self-efficacy, F6:Uncontrollability, F7:Generational transmission of anxiety.
*** $p < 0.001$.

TABLE 4 Descriptive statistics and correlations between K-MPAI-R factors (seven factors and total score) and PAQ.

Variable	Number of items	M (SD)	Correlation with PAQ
F1	10	24.64 (12.23)	0.75***
F2	8	20.83 (10.17)	0.58***
F3	6	16.60 (8.21)	0.64***
F4	3	8.60 (4.11)	− 0.03***
F5	3	12.86 (3.50)	0.11*
F6	2	6.48 (2.84)	0.52***
F7	2	5.01 (2.89)	0.41***
KMPAI-R	40	109.04 (34.63)	0.75***
PAQ	20	54.24 (14.53)	–

F1:Music performance anxiety symptoms, F2:Psychological vulnerability, F3:Worry/dread on self/other scrutiny and evaluation, F4:Parental support, F5:Memory and self-efficacy, F6:Uncontrollability, F7:Generational transmission of anxiety.
* $p < 0.05$. *** $p < 0.001$.

These findings highlight the positive relationships between the K-MPAI-R and other measures of anxiety, strengthening the instrument's validity.

The factor structure of the Japanese version of the K-MPAI-R was derived through EFA. Factor 1, "Music Performance Anxiety Symptoms," includes both somatic symptoms (Items 36, 30, 16, 12, and 22) and cognitive symptoms (Items 15, 26, 34, and 10) that appear before or during a performance. Factor 2, labeled "Psychological Vulnerability," includes items related to low self-esteem (Items 6 and 13), lack of energy or motivation (Items 4 and 31), vague or unexplained anxiety (Items 3 and 19), performance-related anxiety (Item 20), and difficulty depending on others (Item 8). Factor 3, titled "Worry/Dread Focused on Self/Other Scrutiny and Evaluation," contains items reflecting traits related to a general concern about being evaluated by others (Items 18, 38, and 39) and behaviors or emotions driven by the fear and worry associated with scrutiny (Items 21, 25, and 28). Factor 4, "Parental Support," concerns whether parents were supportive and responsive, specifically regarding their responsiveness to needs, active listening, and encouragement for trying new things. Factor 5, "Memory and Self-Efficacy," reflects a sense of confidence in one's memory and ability to perform well, even in stressful environments. Factor 6, "Uncontrollability," expresses uncertainty about performance outcomes and the likelihood of making mistakes, regardless of effort or preparation. Factor 7, "Generational Transmission of Anxiety," comprises items 5 and 29.

The factor structure of the Japanese version of the K-MPAI-R was generally consistent with other language versions, including English (Kenny, 2009a; Kenny et al., 2012), Spanish (Peru) (Chang-Arana et al., 2018), French (Antonini Philippe et al., 2022), Korean (Oh et al., 2020), Portuguese (Dias et al., 2022), Italian (Antonini Philippe et al., 2023), Polish (Kantor-Martynuska and Kenny, 2018) and Romanian (Faur et al., 2021). Among the extracted factors, Factors 1, 2, 4, and 5 were globally shared across multiple language versions. In addition, for the remaining factors, each had corresponding factors in other language versions (Supplementary Table 1). There were no factors derived only in the Japanese version. These findings suggest a consistency in the factor structure of the K-MPAI-R across languages. Overall, the factor structure of the Japanese version of the K-MPAI-R is closely aligned with that identified by Kenny et al. (2012). A comparison of the factors and the items they include can be found in the Supplementary Table 2.

This study involved 400 participants, including 309 musical instrument players and 91 singers, with an equal distribution between professional and amateur musicians. The results obtained from this diverse sample showed that the internal consistency, factor structure, construct validity, and criterion-related validity of the K-MPAI-R were all sufficient, demonstrating the reliability of the Japanese version of the K-MPAI-R. However, this study has several limitations. First, the Japanese version of the K-MPAI-R was validated using a sample of adults aged 18–64 years. Therefore, further investigation is needed to determine its applicability for individuals under 18. Second, while the factor structure of the Japanese version was generally consistent with the original English and other language versions, several differences were observed in the identified factors and/or the items included in them (Supplementary Table 2). Similar discrepancies can also be found between the English and other language versions (Supplementary Table 1). Future research should explore the factors underlying these differences, including potential cultural influences. Third, the present study collected responses from a broad sample, including both amateur and professional musicians, as well as instrumentalists and singers. Further research should analyze the K-MPAI-R scores within specific subgroups to explore individual characteristics associated with vulnerability to MPA.

Understanding MPA and its related factors in Japanese musicians using the K-MPAI-R may provide insights into both globally shared and Japanese-specific mechanisms underlying MPA. The Japanese version of the K-MPAI-R would lead to a deeper understanding of the prevalence and characteristics of MPA among Japanese musicians, contributing to the development

of more effective interventions and support systems tailored to their needs.

Data availability statement

The deidentified questionnaire data supporting the conclusions of this article will be made available by the corresponding authors upon request. Further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved by the Ethics Committee of the National Institute of Advanced Industrial Science and Technology (AIST). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their informed consent to participate in this study.

Author contributions

ST: Conceptualization, Investigation, Data curation, Formal analysis, Writing – original draft. MY: Conceptualization, Investigation, Supervision, Writing – review & editing. AM: Conceptualization, Investigation, 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.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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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.2025.1543958/full#supplementary-material

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Adding to the knowledge of the TPACK framework: a case study of female identity in performance, education, and technology

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Introduction: The Technological Pedagogical Content Knowledge (TPACK) framework, developed by Mishra and Koehler, has served as a foundational model for aligning technology with pedagogy in educational research and practice. While TPACK emphasizes the integration of content, pedagogy, and technology in teacher knowledge, it often overlooks the role of teacher identity in shaping instructional decisions and technology use.

Methods: This study extends the TPACK framework by incorporating teacher identity as a critical component. Using a qualitative case study approach, we examined the experiences of an accomplished female music performer and educator. Data were collected through interviews and observations to explore how her musical background and personal identity intersect with her use of technology in piano teaching and performance.

Results: Findings reveal that the participant's knowledge and identity significantly influenced her pedagogical choices and technology integration.

Discussion: These results suggest that teacher identity plays a pivotal role in how educators engage with technology. By extending the TPACK framework to include identity, this study provides a more holistic understanding of teacher knowledge and offers implications for teacher education by enabling teachers to remove obstacles to technology use and adoption.

KEYWORDS

teacher identity, technology in music teaching, gender in music education, music technology, TPACK, group piano, piano performance, piano teaching

1 Introduction

As technology is ubiquitous in everyday life, its presence is found in all facets of music, whether it be performing, practicing, composing, improvising, producing, listening, or teaching. Hitchcock (2017) delineated four broad categories of technology in music education: educational, administrative, social, and music technologies. Educational technologies work to support learning and assessment, including learning management systems and virtual classrooms, while administration technologies support the management of people and resources. Social technologies facilitate interactions between individuals within communities. Music technologies are usually linked to music composition or production in which particular hardware and software (music technology) are used distinctly by the music industry to create music and by music educators to train emerging music technologists, as well as in general music classrooms. Following UNESCO's definition of Information and Communication Technologies (ICT), Merrick and Joseph (2023) delineated the term ICT as *technological tools*

and resources used to transmit, store, create, share, or exchanges information (p. 191) while defining music technology as *"any existing or emerging digital device or tools, the use of hardware and/or software and/or web-based applications in any way to support learning about, the creation of, and the performance of music"* (191). For the purposes of this study, we embrace a broad viewpoint of technology to include both delineations alongside acknowledging Hitchcock's categories for which these technologies function.

1.1 Technology use in music education

Music teacher technology use has been examined with projects such as Sound, Electronics, and Music, in which participatory workshops related to sound and music technology were provided to approximately 900 schoolchildren in Scotland evidencing "the assertion that computer music and music technology have a place within the preuniversity classroom" (Hayes, 2017, p 46). However, it was also noted that due to a lack of familiarity with the technology and content, teachers found it difficult to include the project in their curricula. Humberstone (2017) pointed out that music educators whose musical backgrounds are practically based, such as performers or directors, are less likely to include tasks such as composition in part due to a lack of access to and experience with technology. This lack of experience with technology may include educational technology and music technology. For example, Upitis et al. (2017) surveyed 1,468 independent teachers about their beliefs and studio practices, including how music teachers make use of technology in their teaching. Most of these teachers appeared to be quite comfortable with using technology and reported having Internet access in their studios. There were strong views expressed by teachers both in support of and in opposition to the use of technology to enhance specific aspects of music pedagogy and student learning. This lack of support for certain activities is not to be seen as a lack of support for technology, in general, as more than two-thirds of these teachers agreed that technology improves student learning and motivates students to learn. Rather, it would appear that some teachers were unwilling to exchange the benefits of face-to-face interaction with the benefits of technology. Merrick (2018) stated that "technophobia" still explains why many music teachers are reluctant to use new technologies (p. 314). Lack of technology integration was also found in Waddell and Williamon's (2019) survey on the use of music technology in instrumental learning, which investigated how teachers' use technology in their roles as teachers and as music learners. They found that the music teachers were generally more receptive to technology in their roles as teachers than as learners; however, their use of technology was mostly outside of instructional time and instead for scheduling lessons or advertising.

1.2 Impact of COVID-19

It has been found that COVID-19 and the pandemic substantially affected music teaching and learning due to music teaching delivery's reliance on multisensory and auditory-motor interactions (Cheng and Lam, 2021), which requires both theoretical and applied (practical) skills (Biasutti et al., 2021). Daugvilaite (2021) pointed out that although online teaching had been available prior to the COVID-19 pandemic, music teaching had overall avoided the adoption of online delivery due to its participatory nature. In effect, due to the restrictions imposed by lockdown measures, music teachers were required to not only adapt to new technologies but also immensely modify their pedagogies within this new context. Daubney and Fautley (2020) reported that not all teachers were prepared with adequate educational and technical knowledge to teach online; however, there has been an acknowledgment of the value of online teaching for certain aspects of music education, such as the community of practice for sharing pedagogical approaches and education strategies (Biasutti et al., 2021). As Calderón-Garrido and Gustems-Carnicer (2021, p.141) stated, "In short, COVID represented both an opportunity and a threat for music education".

Investigations of readiness to teach online thus far have found that the role of the institution has an important responsibility to provide support and a common view of expectations for online learning and teaching to compensate for individual perceptions of readiness (Howard et al., 2020; Martin et al., 2019; Scherer et al., 2021). Calderón-Garrido and Gustems-Carnicer's (2021) "greatest findings" in their examination of adaptations by primary and secondary music teachers were "marked by lack of methodological and instrumental preparation," while more support from conservatory level music educators' institutions and greater opportunities for professional development were also found (Biasutti et al., 2021). Music teacher readiness or unfamiliarity with the new technologies of online teaching has been found to cause fear, anxiety, and uncertainty about teaching performance, which in turn leads to frustration and depression (Cheng and Lam, 2021). These findings suggest that teachers must be supported to continue the development of skills and knowledge and "pursue transformative teacher professionalism to cope with crises and challenges that arise in the future" (Cheng and Lam, 2021). Camlin and Lisboa (2021) maintained that as the limitations of online technology are overcome, there will be more choices in how to consume and learn music, and music educators need to adapt to this progress. Merrick and Joseph's (2023) study on what technologies music teachers used and their confidence in using technology during COVID-19 found that teachers had increased their levels of competence and confidence through increased use of technology during the pandemic. He stated, "*the more confident teachers became, the more routinely they shifted between technology devices…*" (p. 203) and further mentioned that this integration of technology had a significant influence on their confidence to use it.

1.3 Music teacher education and technology use

Music teacher education has been examined in support of the integration of technology. An online survey in the USA regarding the role, nature, and efficacy of technology instruction in music teacher education programs revealed proficient levels of readiness to integrate technology, but not for classes that were fully technology-based (Bauer and Dammers, 2016). Participants responded that a lack of time and/or space, along with a lack of funding and/or access to technology, were challenges impacting teaching preservice music teachers about technology. It was recommended that preservice teachers experience technology in authentic music teaching and learning contexts throughout their teacher education, not only a single class or

experience. Gall (2013) noted that as undergraduate courses in the UK do not all require engagement with music technology, students can begin their teacher education year with no skills at all in this area because students are developing their teaching skills alongside knowledge and skills in their subject area, all within the year of teacher education. She stated, "*Helping student teachers develop personal music technology skills and the confidence to use technology in classroom settings within one year—at the same time that they are acquiring other subject knowledge and competences, honing learning and teaching skills, and completing masters level written assignments—is a difficult undertaking*" (Gall, 2017, p. 570). As Dorfman (2017) stipulated, "Developing technology skill is a different thing entirely from developing teaching skills" and further recommended the TPACK framework as a way of bringing forward that "content, pedagogy, and technology are distinct; when these three elements overlap, more sophisticated teaching may result" (p. 527).

1.4 TPACK framework

Educators and researchers seeking effective use of technology in teaching through the alignment of technology, pedagogy, and content have utilized Mishra and Koehler's Technological Pedagogical Content Knowledge (TPACK) framework (Mishra and Koehler, 2005; Mishra and Koehler, 2006). As frameworks have been developed to help educators and researchers in their efforts to integrate technology into teaching and learning in order to guide future research and practice (Hamilton et al., 2016), TPACK has provided a structure for research on and implementation of the effective use of technology in teaching and learning. Utilizing three main components of teachers' knowledge—content, pedagogy, and technology—it is the interactions between and among these bodies of knowledge which form an understanding beyond the three components individually (see Figure 1). TPACK functions to provide the basis of effective teaching with technology and understand the variance in levels of technology integration, seeks to assist the development of better teaching techniques, and promotes focused research in the use of technology in a more ecological way (Koehler et al., 2013). Pedagogical knowledge (PK) is required to effectively help students learn, while content knowledge (CK) is needed to have a well-developed understanding of the subject matter. Pedagogical content knowledge (PCK) involves both this specialized subject knowledge alongside the skills to use a variety of teaching strategies appropriate for the content. Technology content knowledge (TCK) would include an understanding of suitable technologies utilized to support or experience the content, such as software applications for composing or recording music. Technological pedagogy knowledge (TPK) would subsume technologies that fit pedagogical processes, such as interactive presentation software applications to engage students. Combining all three constructs (TPACK) is intended to support the learning of specific content through pedagogies appropriate for the content, which therein is supported by technology suitable to the pedagogy and content. For example, the use of audio-visual media (T) to model (P) correct performance technique (C).

This framework has become well established in the research on technology use in education and utilized by practitioners, teacher educators, and researchers. Zou et al.'s (2022) analysis of 1,608 empirical research studies of TPACK between 2000 and 2020 identified trends and research topics, finding that the number of studies employing the TPACK (technological, pedagogical, and content knowledge) framework had increased over the two decades which would indicate that the framework is both beneficial and effective. However, this framework has been criticized for lack of progress toward the original goals of TPACK (understanding the knowledge that educators need to teach effectively with technology) with a call to the refocusing of TPACK research (Saubern et al., 2020). Schmid et al. (2020) reported that others have questioned its lack of conceptual clarity and specificity leading to a body of literature based on a wide range of definitions and interpretations of TPACK.

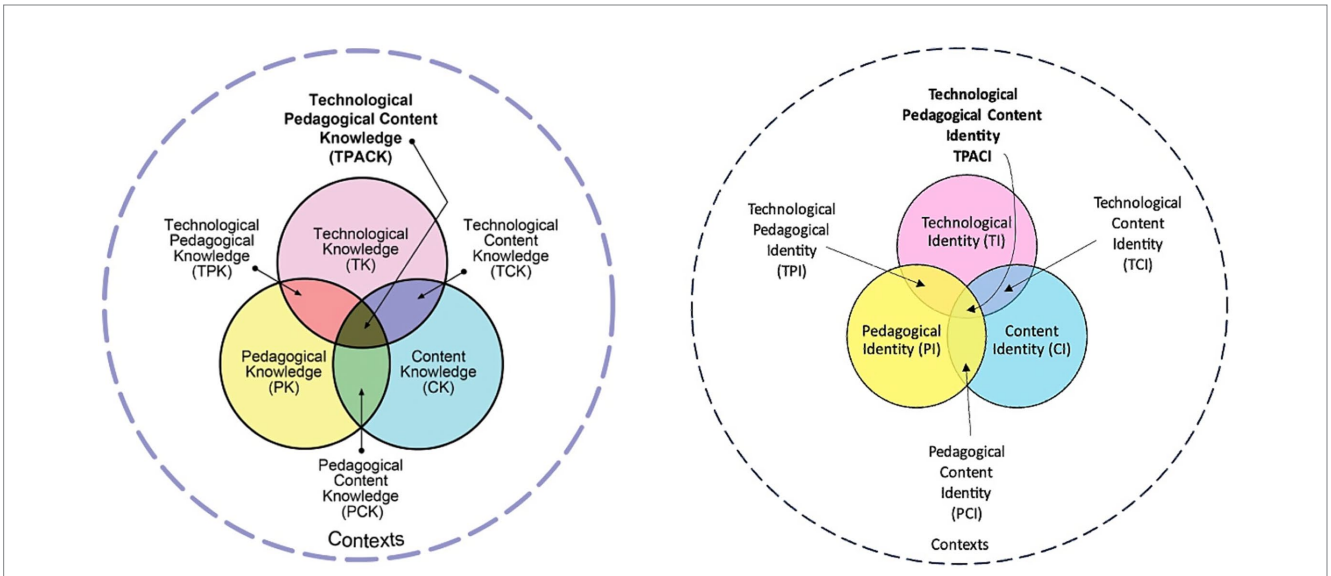

FIGURE 1
TPACK and TPACI framework. Adapted with permission from Koehler and Mishra (2009), licensed under CC BY-NC.

1.5 Teacher identity and extending the TPACK framework

As discussed above, teacher confidence has been found to improve with the increased use of technology. Might teacher self-efficacy and beliefs be a significant factor in teacher use and integration of technology? The TPACK framework considers *knowledge* in the areas of content, pedagogy, and technology without consideration identity. Teacher professional identity is commonly defined as, "…the perceptions, views, beliefs, emotions, motivations, and attitudes that teachers have about their own role" (Suarez and McGrath, 2022, p. 8). The extensive body of research on teacher identity has found that a strong professional identity is positively related to emotional well-being and the quality of teaching, which in turn can improve teachers' confidence in their decision to work in education, as well as commitment to the profession (Hanna et al., 2019). Their systematic literature review revealed six domains of teacher identity:

1. Self-image—how and in what way do individuals view and feel as teachers
2. Motivation—to be or to become a teacher
3. Commitment—dedication and responsibility to teaching profession
4. Self-efficacy—belief in their capability to organize and perform their daily teaching activities effectively
5. Task perception—beliefs about what a teacher considers to be good teaching
6. Job satisfaction—how teachers feel about the school or institution they work for and of the relevant aspects of the work and work situation

A complex and multidimensional concept, teacher identity changes over time dependent upon personal and professional experiences (Suarez and McGrath, 2022).

New technologies have disrupted traditional modes of teaching and learning and, by doing so, transformed the ways in which content and pedagogy intersect. Teacher professional identity has provided a lens for examining the impact of the transition to new technologies and online teaching. Teacher identity and the challenges of COVID were examined from the first year of lockdown measures (Chen et al., 2020; Jones and Kessler, 2020; Kim and Asbury, 2020) finding that teacher identities were indeed affected. Nazari and Seyri (2023) state that less is known about teacher identity within an online context compared to in-person teaching contexts and examined the effect of the transition to online teaching on teacher identity during COVID ("covidentity"). They found that restructured teachers' technology beliefs, enhanced interpersonal relationships with the students, and increased reflectivity were positive impacts on teacher identity during the transition. Through a thematic analysis of the literature, Foreman-Brown et al. (2023) found that the transition to online delivery threatened existing professional teacher identity within universities as teachers had to acquire new knowledge and skills while relational pedagogies, reflection and collaboration supported emergency remote teaching.

Previous discussions on the use of technology had centred around knowledge of technology, self-efficacy, pedagogical beliefs and school culture (e.g., Ertmer and Ottenbreit-Leftwich, 2010) and less so on teacher identity. Ertmer et al. (2012) further investigated the pedagogical beliefs and classroom technology practices of teachers who were recognized for their technology use and found that the teachers' attitudes and beliefs facilitated technology integration; however, teacher identity was not examined as a factor impacting or being impacted by the technology and pedagogies used. We propose that the role that teacher identity plays in technology integration should be considered in the TPACK framework. Phillips' (2016) case study investigation of the enactment of TPACK through a Community of Practice (Wenger, 1998) lens illustrated a connection between identity and practice which, as he stated,

> *"broadens out our understanding of context beyond the established considerations of context as the location of TPACK enactment. This draws attention to the socially mediated processes that shape practice and identity development and demonstrates TPACK as both current knowledge and prospective knowledge in the making"* (p. 1794).

Golzar et al. (2023) recognized the relationship between the TPACK model and teacher identity and used 'teacher identity tensions' to discuss conflicts which shape teacher self-perception, roles, and professional identities when faced with challenges or transformative events. They found that the TPACK and teacher identity tensions have a significant relationship particularly relevant to institutional, pedagogical and sociocultural constraints alongside a lack of professional support. They conclude that teachers can reduce and manage identity tensions through a TPACK-informed classroom which could provide continued education access through use of online learning.

To reveal 'hidden' teacher identities and the possible impact of teacher identity on technology use and integration, we propose furthering the knowledge of the TPACK framework to include identity within each of the constructs: content identity, pedagogical identity, and technology identity (see Figure 1). Teacher content (or subject) identity (CI) can be an influential and important part of professional identity directing the moral and ethical dimensions of a teacher's decisions. It enables teachers to operate beyond the classroom in developing curricula, engage widely in education, and reflect on their practices (Brooks, 2016). Peterman's (2017) review of literature on teacher identity as a content expert found that (1) personal history as a learner in the subject, (2) evolution of content identity when challenged and supported, and (3) the educational context were factors in the development of teacher content identity. As Olsen et al. (2023) state, "Development of teacher subject identity involves the knowledge required to teach a subject and an understanding of how to engage young people with this knowledge" (p. 854). In addition to subject matter knowledge, pedagogy involves knowledge about how to help students learn in a particular subject, as well as what is important to learn (Thompson, 2023). Bernstein (2000) discusses pedagogical identity (PI) as the selective teaching values, beliefs, norms and practices that teachers develop as to what best caters to student learning further dividing into both instructional and regulatory pedagogies. Brosseuk (2022) encapsulates pedagogic identity as a "reflexive, learning process by which pedagogic beliefs, values, attitudes, and thoughtful choices and actions accumulate over time" (p. 31), further stating that it is stable/unstable, shifting, and situated. Carter and Grover's (2015) construct, IT (information

technology) identity, advocates the relationship between technology use and identity. Information technology identity (TI) represents the extent to which individuals view the use of IT as an integral part of the self, proposing that,

> *"those who view their interactions with an IT as integral to their sense of self are likely to express a much stronger sense of connection than those who feel that these interactions are unrelated to who they are. Further, those who feel a strong sense of connection with an IT are likely to enact their IT identity across a variety of situations"* (p. 15).

In our previous investigation of teacher identities and their impact on technology use (Stephens-Himonides and Young, 2023), we incorporated teacher identity within the constructs of pedagogy, content, and technology (TPACI) of Mishra and Koehler's TPACK framework (Mishra and Koehler, 2005; Mishra and Koehler, 2006) (see Figure 1). The authors developed and utilized a measurement instrument questionnaire using Hanna's six domains of teacher identity—which include self-image, motivation, commitment, self-efficacy, task perception and job satisfaction—and integrated these with content, pedagogy, and technology. Music teachers in England ($n = 98$) representing a wide variety of teaching contexts, settings, and student ages and abilities completed the questionnaire. We found significant correlations between participants' knowledge and identity within the domains of technology, pedagogy, and content. We also found significant differences between participants identifying as males and those as females with respect to both identity and knowledge. These results led to this investigation on how content, pedagogy, and technology *knowledge* and *identity* are formed through using an extended TPACK framework and the possible impact of gender on this knowledge and identity.

Regarding gender and music education, Strong and Raine (2019) stated that "…education for the music industry is increasingly becoming formalized, with courses in this area growing exponentially in the last ten to fifteen years. This growth has not been gender-neutral; many of these new courses have a technology focus that is associated with lower enrolments of women" (p. 5). Savage (2017) cited that the differences in terms of gender within the A Level Music Technology intake are stark, noting the separation of the study of music technology from the study of music in the United Kingdom's curriculum and examination framework has created a significant gender imbalance. Peters (2017) pointed to five different issues found in music education technology—curricular, socio-cultural, ecological and economic, access, and gender issues—further stating that gender is "one example of how accessibility to music technologies is connected to social and cultural contexts" (p. 285). She recommends that teachers be mindful of the different ways in which girls and boys approach music technology to integrate strategies that might result in more inclusive pedagogical practices. Culp and Robison, 2022 echoed this recommendation and provided strategies specifically for general music teachers in order to support students of all genders. However, this issue may not be considered at the practitioner level, and educators "may not understand how their instruction can favor particular students' learning preferences or how students might frame peer expertise through gendered norms" (Tobias, 2017, p. 300), although investigations spanning the last 40 years evidence practices that lead to or reinforce differences and cause females to be neglected and disadvantaged in the area of music technology (Armstrong, 2001, 2008, 2011, 2014; Born and Devine, 2015; Caputo, 2021; Comber et al., 1993; Shibazaki and Marshall, 2013).

TPACK's consideration of teacher knowledge only within pedagogy, content, and technology intersections does not take into account teacher identity. Our findings point to the need to not only investigate teacher *knowledge* of pedagogy, content, and technology but also teacher *identity* in relation to pedagogy, content, and technology. Is *knowledge* enough? Are there hidden identities with not found within this framework? Could teacher identity formation and the possible impact of teacher identity on technology use and its integration be revealed by incorporating this domain within the TPACK framework? How might identity impact both teacher integration of technologies (educational or music) in music instruction and how technology use may impact gender differences?

2 Methods

A case study was chosen as the method to examine how knowledge and identity in technology are formed. We chose to investigate the issues of technology use and integration and gender through the lens of a female musician who is known in her field not only as an experienced performer and teacher but also as a leader of technology use and integration. The participant was invited based on her diverse musical career as a performer, educator, leader, and co-creator of a company which provides multimedia resources and curricula for teaching piano and is currently in use in K-12 schools, colleges, universities, and conservatories. This online source has been used for distance and e-learning, as well as for use in classrooms and in the private teaching studio. Recently retired as Professor Emeritus, she taught applied piano, group piano, and piano pedagogy, lectured in the Interdisciplinary Humanities program, and directed the Pedagogy Lab Program, an internship program for piano pedagogy students. She is active as a performer, both solo and chamber musician, throughout the United States and in Canada, Europe, Mexico, the Caribbean, and Ghana. She has been featured on radio and television, and she has been acknowledged in the field as an active clinician and scholar, a leader in professional organizations, and a recipient of many honors. The participant functioned within a performance classroom and studio setting in which digital technologies, including digital libraries, e-readers, video recording and playback, and internet technologies, are used for piano performance and teaching. Piano pedagogy's environment of electronic and digital keyboards, musical instrument digital interface (MIDI), online curricula, and computer software applications (including web-based) for classroom and studio performance teaching was the landscape of the participant's work.

The case study involved the participant's responses to a TPACK and TPACI questionnaire and in-depth interview. The TPACK quantitative measurement instrument was created by the researchers upon a systematic review of the TPACK research and adapted to music teachers. To integrate identity into the TPACK framework, we combined the TPCI constructs with the domains of teacher identity (Hanna et al., 2019) as used in our previous study. We chose to use a quantitative measurement for a single case study participant in order to connect the interview question responses with the questionnaire responses. A Likert-type scale from 1 (strongly disagree) to 5 (strongly agree) was used for 35 agreement statements

encompassing knowledge of content, pedagogy, and technology and identity within these constructs. Examples of the measurement statements are found in Table 1. The semi-structured interview questions were devised around the standardized measurement statements found on the questionnaire, and they included the areas of experience and relationship with technology, impacts of technology on music teaching, the role of technology in designing music instruction and how to approach issues arising, motivations for and challenges of using technology, and leadership and innovative roles in technology use in music (see Table 2). By constructing each of these areas from the TPACK and TPACI frameworks, the interview served to further probe the results of the questionnaire. A thematic analysis of the qualitative data was coded using the extended framework (TPACK and TPACI) constructs. The researchers independently coded all of the data until agreement. Further themes were agreed between the researchers. Another review of data to verify agreed coding and further themes found was undertaken again by the researchers.

3 Results

Using an extended TPACK framework with the inclusion of identity, we investigated how content, pedagogy, and technology *knowledge* and *identity* are formed to reveal possible teacher identities in the use and integration of technology. The questionnaire quantitative data revealed that the mean rating of the 35 agreement statements was 4.8 (out of 5), with 28 of the statements given the highest rating (5) and seven statements rated 4 out of 5 by the case study participant. Those which were rated 4 instead of 5 included a technology construct (TK, TI, TPI, and TCK) with the exception of one PCK statement, which also received a rating of 4. Table 3 illustrates the aggregate means of the participants' responses across the various domains of the extended TPACK framework. This extended TPACK measurement instrument illustrates the participant's self-perception of her knowledge and identity in content, pedagogy, and technology, and the intersections of these constructs were especially positive. The findings from this qualitative data illuminate further insight into these ratings, which are presented using knowledge and identity intersections with the TPACK and TPACI framework constructs of content, pedagogy, and technology, in addition to further themes revealed from the analysis.

TABLE 1 Sample questionnaire agreement statements.

Statement	Category
I can use a wide range of teaching approaches with my students.	PK
I feel committed to my role as a music teacher.	PI
My music knowledge and skills are valued by others.	CI
I feel secure in my music skills and knowledge.	CK
I know how to solve my own technical problems.	TK
I feel confident using technology.	TI
I know how to select effective teaching approaches to guide student thinking and learning in music.	PCK
I can choose technologies that enhance the teaching approaches for a lesson or class.	TPK
I feel confident in choosing technologies that enhance teaching approaches for a lesson or class.	TPI
I know how to use essential technologies which are specific to music.	TCK
I feel satisfied learning about new technology in music.	TCI
I can teach lessons or classes that appropriately combine technologies, teaching approaches, and music skills and knowledge	TPCK
I feel confident choosing technology that enhances the content and pedagogy for a lesson or class.	TPCI

3.1 Technology, pedagogy and content knowledge (TPACK)

The interview responses revealed knowledge of content, pedagogy, and technology and the intersections of these constructs. Providing further understanding of the responses to the questionnaire ratings, the participant's interview evidence her high ratings of technological and pedagogical knowledge with specific examples and explanations.

The participant discussed pedagogical knowledge (PK and PCK) from a broader perspective:

> *"There's a lot of instruction available, but a lot of it's not quality. And the average user cannot differentiate between … and then there are other philosophical questions, you know, and we have always taught in a global kind of a way where we think that we are teaching*

TABLE 2 Case study interview questions.

1	Tell us about your music learning/training and background.
2	Describe your current role.
3	What is important to you when you design instruction for students?
4	Can you describe your experience with technology? What brought you to use technology in your teaching?
5	What is important to you when choosing (and how do you choose) technologies to support the teaching approaches you use?
6	Which technological developments have made an impact on music and music teaching?
7	Can you describe what technologies you have used or those that you currently use? (Software, hardware, etc.)
8	What challenges have you faced when choosing technologies or implementing new technologies into your teaching?
9	Can you tell us about an instance when you used technology to address a teaching challenge or new opportunity? What was the situation? What motivated you to use technology to address that need? What was the outcome?
10	What importance does technology plays to your teaching practice?
11	What are some of the motivating factors and attitudes that led you to accept and use/not use technology in your teaching practice?
12	In what ways do you provide leadership in helping others to coordinate their content, technologies and teaching approaches? (Do others come to you when they need help with technology?)

TABLE 3 Aggregate means of participant's responses to the quantitative instrument.

Category	Mean
CK	5
PK	5
TK	4
PCK	4.67
TPK	5
TCK	4.5
TPCK	5
CI	5
PI	5
TI	4.67
PCI	5
TPI	4.67
TCI	5
TPCI	5

> *you skills that you can move forward with versus a trend that I see in piano teaching which is to teach things like, I'm going to teach you a song."*
>
> *"I do not mean technique by the playing of scales, arpeggios and chord progressions, I mean technique by how do you use your body at the piano or how do you move? How do you get around? How do you coordinate your hands?"*

Responses concerning the intersection of pedagogical and content knowledge (PCK) were shared by the participant when discussing the development of eNovative Piano online learning platform, such as,

> *"and the main thing that students need to be able to have is some kind of skill that they can adapt to their situation, whatever that situation is. And really what that comes down to is. I'm gonna say I'm old-fashioned saying this, but I'm going to say it comes down to piano coordination…"*

Statements supporting the participant's knowledge of how to select effective teaching approaches (PCK) were detected, such as,

> *"…we have the content of scales and chord progression, but what we usually promote are these other drills where we play a melody in one hand with a chordal accompaniment in the other, and then we vary the accompaniment style and we switch hands and we do all the keys and we were trying to wrap around all those elements, we are trying to integrate everything."*

Responses also included statements regarding PCK e, in which the participant further added the technology intersection (TPCK).

> *"I'm not talking about playing two-octave scales hands together. I'm talking about a melody and an accompaniment or a two-handed accompaniment while singing or even knowing what chords to play. If you are in an elementary music class and you have got a song they want…you do not know what the chord progression is because it's not written in front of you. and you need to do all these things, you know, the real-life skills…we decided would best be taught through demonstration like audio or video."*

Technological knowledge was evident throughout the participant responses. Technological content knowledge (TCK) was apparent through discussions in which the participant shared devices and software integrated into her teaching practice (one-to-one and group) and online learning platform, eNovative Piano. She brings forward instances of solving technical problems, such as,

> *"…So, something does not work or it's not the right tool for the job… this did not work because sometimes that helps me to find a better solution because I tried something that did not work. I think that there are things that I've wasted my time totally…but I learned from that, and I do not resent that…"*

Regarding how to use essential technologies specific to music (TCK), the participant speaks of the use of playlists and what platforms are utilized by students stating,

> *"So I might have a Spotify playlist that has 10 different versions of Midnight Special. Students can be exposed to these artists and can learn different things about style. You know, there might be a jazzy version, a bluesy, you know, there's all kinds of different versions, right? But now I've discovered that while that used to be really cool and hip, what people do more than Spotify is YouTube…"*

Her technological knowledge is revealed in her consideration of digital poverty and what students can or are willing to access and stated,

> *"So we have to learn what the challenges are, so. You know it's what's on the user end and what they are comfortable doing…Those are the main challenges. If the student cannot use it, then it's not usable. It's not worth using. Well, you'll have to find a way to help the student to get that whatever it is."*

Technology and pedagogy knowledge (TPK) intersections were found in the participant's reflection on the uses of a specific technology for pedagogical approaches. In choosing technologies that enhance teaching approaches, she stated that when conceiving of eNovative online learning platform, "*the real-life skills we decided would best be taught through demonstration like audio or video.*" and integrated OBS (Open Broadcaster software) to display multiple camera angles of piano playing and the score on the screen alongside shared notebooks, such as Evernote to take notes during lessons. These were mentioned as technologies useful during COVID-19, as well as the use of social media,

> *"I think the existence of Facebook Groups. Piano, piano teaching groups. And there's a piano teaching group for all kinds of stuff. And some of them are more credible than others. And you can tell the quality of the discussion can vary depending on the group."*

However, she also discusses the use of social media as a tool for the development of a piano teacher's course.

> *"…And there was a lot of real interesting discussion about bartering and trades and, you know, just fascinating stuff, wonderful, wonderful interviews. And that would not have been possible without social media 'cause I did not know most of these teachers… and I think that's an amazing thing about social media."*

In discussing the use of multimedia on the eNovative Piano platform, she describes the role of technology (TPK) stating that,

> *"Oh, I would say this is the thing that I noticed the most with using multimedia…if you have good content. It frees you up as a teacher, so the content does not replace the need for a teacher. It provides material for a teacher to use, it frees them up to then be able to do more complex tasks."*

The intersections of content, pedagogy, and technology knowledge (TPACK) were evident in the participant's responses, particularly in her discussion about her thinking in designing instruction.

> *"…first the content, then pedagogy, then technology…So what does that mean? That means I want to have something oral. I wanna have something physical, something tactile. I wanna have something intellectual or theoretical. And then I look for media to support all those things…"*

She additionally discusses the development of instructional videos demonstrating do's and don'ts for student viewing and reviewing both in and out of class, stating that this is content she does not have to go over in class.

> *"And because that content is there, when I come into class, I'm already starting from a different point. A higher point if I did not have that content, I would be starting with that lower point of teaching that content right and then I would get so far. …I'm going to get farther. I think it definitely extends what I can cover in class."*

Her responses explained the ways in which her use of technology afforded her the opportunity to engage differently with students in class. The intersection of technology and pedagogy (TPCK) brought about a change in instructional goals and outcomes that would not have been possible without technology. When describing the conception and beginnings of eNovative Piano learning platform, the intersections of these constructs were also apparent.

> *"We should be teaching them to use their ears and that these things are best done by video and audio. So we went out and bought a video camera…the power of multimedia teaching…So multimedia gave us the ability to focus on under-taught skills, and we saw tremendous improvement in our proficiencies after three semesters."*

The participant also mentioned her pedagogical approach of teaching sound before symbol and how technologies allow this to be achieved by extending notation-based teaching (TPCK).

> *"So they* [teachers] *do not have time to listen to an audio track and have their students, you know, play it back. I think that's really important. Here's an audio file. I want you to listen to it and play. Here's the key. OK, listen to this and be able to play it back in 5 min. That's really an important skill…but a lot of teachers are still heavily into notation-based as the main thing. And there's all these technologies that can allow you to be more than that."*

Finally, the TPACK framework illuminates the participant's use of technology to solve pedagogical challenges (a theme to be discussed below) of teaching the content of piano playing skills.

> *"…but we thought if we really wanted to teach things how to, like, coordinate their hands to where one could move and the other could move in a different way. And you had to break down those things into component skills and then make videos because we are in a piano lab and they could not see. They could not see us play anyway, right? We did not have webcams. We did not have any of that technology. They could not see us play. And if they were not in class, you know, they would never see us play. So we decided that the key would be to make some really short videos and audio."*

3.2 Technology, pedagogy, and content identity (TPACI)

The participant's identity in the content, pedagogy, and technology were detected in the interview responses, particularly in terms of commitment, confidence, enjoyment, task perception, and responsibility to the teaching profession (Hanna et al., 2019). As with the knowledge domain, her positive identity with technology, pedagogy, and content was evidenced in the qualitative as well as quantitative responses.

Her commitment and responsibility to the profession (PI) is evidenced in her strategic plans for eNovative piano, she stated,

> *"So we are thinking about that going forward as a way to grow our business. I do not frame it, only it is something about growing the business. But I also wanna frame it as a way to make quality instruction accessible to anybody in the world."*

In reference to pedagogical self-efficacy (PI) in designing instruction, she identifies teaching away from the piano (with and without technology) as part of what she always did while also indicating confidence and enjoyment within instructional design and technology integration. Additionally, she reveals her confidence within music (piano performance) content (CI) when describing her piano performance skills during her formative years.

> *"I've never had any serious injuries. I do play quite a bit and I attribute that to that early intervention by teachers who said no, this is really how you have to play to keep yourself from getting hurt. And so I learned a lot about, you know, technical approaches as well as musical approaches."*

Further to this discussion in describing what motivated her to integrate technology, her enjoyment of technology (TI) is made clear as she stated,

> *"I'm real comfortable with it* [technology]. *I've always been comfortable with it. I enjoy it. I always liked it. And I'm still interested in it. And I do really well with it. And I like it, some people*

> *do not like it when things change. Let us say you are using some platform and it changes and people go, 'why did you have to change that?' I kind of love the change."*

Responsibility and leadership in piano teaching (PCI) were evident through the development of a piano course on diversity, equality and inclusion, as presented above. She also demonstrates her responsibility and commitment to the profession (TPCI) in her work with other group piano teachers using the eNovative Piano platform and offering this platform for free during COVID-19. She stated,

> *"…that was, I regard that, as a high watermark in terms of leadership in helping others because we gave it away free through June of that year. So they could go all the way through that current semester and then if they wanted to continue to and use it, they would adopt it. And we did get a lot of new users through that. So it was a good business move, but honest to God, we did not think of it as a business move. We just thought… no piano teachers are gonna struggle with this."*

Early in the interview, when asked about her educational background, she revealed her enjoyment of technology (TI) in her response,

> "*And it was, it was really made possible by technology. The technology of recordings. And I think that it is important that we do not forget that everything is technology, you know, recordings or technology, the piano is technology. The acoustic piano is a kind of technology, you know. So I think I've always been pro-technology even before I knew that word."*

Finally, technological pedagogical identity (TPI) is evident in the participant's discussion about choosing the tools for instruction. She stated,

> *"And I think that's what problem solving really is, is whatever you need to solve a problem. If it's technology, if there's no technology there for you to use. I mean, I think it's preferable to use whatever is convenient and whatever you are most familiar with; but I think that technology is, it's there. It's there."*

Following this, she points to student use of technology and the importance of problem-solving skills, again evidencing a TPI identity (task perception).

> *"So I think really the fundamental thing here is teaching problem-solving skills to people. And I see kids give up real quickly if something they try does not work, then they just, oh, I cannot do it. Instead of going well, I mean, first place, why did not it work? What is it about the problem for which that was not the correct solution? You know you have not identified the problem to come up with a good* [solution]. *I mean I think that that problem-solving thing is the under-taught thing."*

Her identity in technology and pedagogy intersections (TPI) was iterated when reflecting on technology's importance in teaching, but this is followed by her pedagogy identity (PI).

> *"I think I always would use what's there…that's the point I'm making…if I have a beach ball in my office, and I decide your pulse is not very good, I might get that beach ball and we might throw it in time or do something in time. I'm going to use whatever I have access to help to make a point. And if it's technology, great. If it's a drum, great. If it's a beach ball, great. we had all kinds of games… You would not call that technology, but it's a mindset."*

The participant's technology identity (self-efficacy) was revealed when discussing attendance at a music board meeting where a college-aged intern spoke about a social media platform. She stated,

> *"…that's important because this is what people are using. It's not Facebook…All the action now is TikTok. I felt like he was saying to me as a board member, but also as a business owner, he was saying, you know, get with the programme, you are getting old to do some work for us."*

Identity in technology (task perception) was further noted when the participant reflected again on the perspective of younger users. She stated,

> *"He said, 'Young people do not talk about technology. It's just what is there? It's just there.' They do not have to learn how to use technology. They do not have to learn how to teach with technology. It's just there. They've grown up with this…but I got it from him, and it was the idea that if you are talking about technology, you are not quite thinking about it right."*

3.3 Further themes revealed

Further themes were found in the participant's discussions pertaining to adaptability, curiosity, problem-solving, and navigating barriers. She discussed the importance of adaptability within the context of evolving technologies, support of her pedagogies, and adaptation of her identity in the field. In discussing various piano lab hardware and software technologies and how the technology in the lab evolved over the years, a willingness to experiment and adapt to new technology was evident. She stated,

> "*So I wrote a kind of a big grant for a newer piano lab with whatever the updated controller was, we put in. I think we got five Disklaviers on that grant and a computer for every piano station. So this was one of the earliest piano labs that was equipped with student computers that I knew of at the time…I'm not going to say we are the first one, but we were one of the very first ones."*

Adjusting to students' use of technology outside of the classroom was evidenced in her responses as she stated,

> *"…but we have to keep in mind what do students use now…and you know what they use. They use their phones for everything. They use their phones to complete classwork. They do not use e-mail. They text, you know, or they chat. They do not use videos now. There's a real trend…You'll see it in marketing, and I think you'll start to see it in educational content too where they use animations instead of real video…"*

Additionally, she shows an openness to new technology chosen by students, as she stated here,

> *"…but there are things that have caught the imagination of learners like those videos that have the notes that kind of fall out of the sky. Synthesia. And kids seem to absolutely love those. I had a guy in my piano class during COVID who whenever he recorded a video for an assignment, he used Synthesia."*

She also describes an instance in which she discovered a new use for an older technology during remote piano teaching during COVID-19 and has continued using it. She stated,

> *"on that monitor I…could project whatever I want from my house, but what I projected a lot was my overhead camera with my hands…and they got so much value from that. And in a live lesson in my office, I had two pianos, I could have had that set up for 30 years. Where instead of saying 'let me show you how to do this and move over, get it and watch me do this' or 'come over here and watch me do this,' they could just be sitting at the piano watching me do it and they could kind of do it at the same time.that's not complicated technology, it's a camera and a TV."*

There was also a sense of adapting her identity from that of a pianist and teacher to that of one who develops and runs an online learning platform. Her growth in this role is apparent stating that,

> *"We're educators, we are pianists and teachers. We have very little real technology experience except making PowerPoint videos…so that having a team that can help you to build your site out in a more useful way is really important and I think we did not do this early enough."*

As mentioned above, she later discusses that she follows social media groups to learn about what teachers are experiencing, what their needs are, and in what ways they are expanding their market to the self-learner.

Within this role of owner of an online learning platform, her role as an educator has also been adapted to the situation, going from teacher of piano students to guiding others who teach piano, specifically online teaching. There is also evidence of an awareness of others' pedagogical and technological intersections and identities with technology. She shared that,

> *"…since eNovative piano is a business where we interact regularly with our teachers who have adopted it. You know, they feel comfortable calling me on the phone… And so because they can communicate with us directly we get to have a real sense of what their things about technology are and how easily they can adapt to going from a textbook…and they get the pedagogy, but they also get the technology. Some people cannot even get the pedagogy because they are so, you know, stymied by the technology…"*

The lack of adaptability within the field was also mentioned when describing participation in a conference panel presentation as she described,

> *"I did an MTNA session…called inclusive activities for group piano… One of the things I was talking about was how teachers aren't very willing to work with kids who want to learn stuff off a YouTube video, but that's how kids want to learn now you know. So as a teacher, you need to kind of get with the programme…But there's a whole pedagogy there that nobody's talking about. Nobody as a pedagogy person is talking about how you can effectively use those very appealing tools in your teaching. Well, we think we are right about everything. You know and a lot of those things that we have been thinking we are right for 1,000 years are being challenged."*

In addition to the theme of adaptability, problem-solving was also key to the participant's use of technology to support her pedagogies and integration of that technology. For example, she stated,

> *"…if you are trying to do anything aurally, you know you absolutely have to have multimedia materials. It's either gotta be a video or an audio and so the creation of those files uses different technologies…I'm trying to figure out how to make it, create something."*

Her problem-solving skills are apparent as she describes the use of the audio-video content created, how they were shared, and how these led to their online learning platform.

> *"You know, and we made these little videos and…we put them on our LMS because that was the only place we could house them… these videos were popular, and our students were getting better. And we went to a conference…were showing these videos and people said things to me like 'how can we get these?'. So then we realised, well, maybe there was some commercial value…we had developed* [an]*entire curriculum around group piano teaching with multimedia support and including an emphasis, or we thought, areas were under-taught…"*

As mentioned above concerning her pedagogical technological identity (PTI), problem-solving was key stating that,

> *"And I think that's what problem solving really is, is what are what are whatever you need to solve a problem…So I think really the fundamental thing here is teaching problem-solving skills to people…"*

Her problem-solving approach was supported by a sense of curiosity fostered by one of her teachers and mentors during her postgraduate studies, who was also a leader in music teaching and technology. She described,

> *"Martha Hilley, in her programme…was always very interested in technology. Technology was there…So I learned that kind of curiosity, and not just from her. I mean, curiosity is one of the things I learned from my most important teachers…it was just like, 'oh, there's something new. Let us look at it'…"*

This curiosity was seemingly a driver in her problem-solving when working with technology, which again reveals her technology identity (enjoyment), as she describes,

> *"Where I am really like. 'OK, let me try this. Oh, that did not work. OK, let me try this.' And what I enjoy about that is I enjoy all the*

> *information that I get. So something does not work or it's not the right tool for the job, you know. 'I go. OK. Well, this did not work because…' and sometimes that helps me to find a better solution because I tried something that did not work."*

Related to problem-solving, another theme found in the participant's responses was navigating barriers. At times, the barrier was the technology itself, as she describes a new piano lab,

> *"not very many people had a lab like this…I put this whole thing together. The computers finally came. And as soon as I connected into the keyboards, I got this 60-cycle through the headphones. That's all you heard… I tried everything…but I still had this hum. I called electricians. I called, you know, live audio guys, people that had rock rock'n'roll bands 'cause I knew they would know…I called Yamaha. I called computer people…*

From here, she used technology to find the solution to this barrier,

> *I went to a Clavinova listserv group. And I joined it and I just started reading posts. I was looking for somebody that seemed smart…I'm going to read these posts and when I get read a post by somebody who seems like they know what they are talking about, I'm going to message them. And that's what happened. I messaged this guy. Well, guess what? He turned out. He was a consultant for Yamaha, but nobody at Yamaha was able to tell me that there's a product called The Hum eliminator. And I got rid of the hum."*

This reflection on her experience illuminated her technology identity in the discussion stating that,

> *"I think that says a lot about me, you know, about how I've said that I like technology and I'm always trying to figure out how I can make it work, because I'm not exaggerating when I said I'm going to read these blog posts to find somebody smart. And that was a really smart thing to do. And I did find somebody smart and he solved my problem."*

Although her identity with technology is positive, she still felt that there were stereotypes about her ability to solve this problem due to her gender. She stated,

> *"…I had tried…the most frustrating thing is when you call up somebody and they tell you 'cause you are female, they'll tell you, 'Oh well, you should get one of those plugs, you know …a little ground wire. It's a ground problem'. And of course, that's the first thing I tried. But all I would get from people was like the first thing I tried and nothing sophisticated, and anyway that was my take… So it's always, it's always solving a problem."*

4 Discussion

The use of the TPACK and TPACI framework revealed the participant's knowledge and identity in music content, pedagogy, and technology, as well as the intersections of these constructs in both the quantitative and qualitative data. The participant's interview responses clarified and confirmed her high ratings on the extended TPACK measurement instrument. Using this framework, the participant's views were able to be critically examined with a lens through which a salient and beneficial understanding of how the participant's knowledge and identity factored into her successful use and integration of technology throughout her career.

In the interview, she shared her content and pedagogical knowledge, which she discussed from both a broader perspective of these constructs and a focused perspective with regard to the development of her online teaching platform. Her technological knowledge was apparent through her discussions on technology devices and software and how she integrated these into her teaching, which led to the development of the online learning platform. In addition to her knowledge of technology, she discussed her knowledge of how to use this technology to support her pedagogies and solve pedagogical challenges with technology. In aligning the content, pedagogy, and technology knowledge, she spoke about her thinking in designing instruction using technology for her classes (online and offline), the development of instructional videos, and pedagogy of sound before symbols and the technologies affording this. Woven through her responses were references to the various types of technologies described by Hitchcock (2017). This teacher described her development of an educational technology that integrated administrative, social, and musical capabilities. The results obtained through the TPACK framework regarding the participant's knowledge of the intersecting constructs of content, pedagogy, and technology provided insight into her effective use of technology.

However, is the participant's knowledge enough to fully discern and realize how and why technology is used and integrated into teaching? Did the participant's identity impact the use and integration of technology and approaches to any barriers or issues within this integration? Using an extension of the TPACK framework, evidence of the participant's identity in the constructs (and intersections) of content, pedagogy, and technology were found as well as how they impacted her pedagogical and technological approaches. She revealed pedagogical self-efficacy when discussing instructional design, a commitment to the profession in supporting other teachers, and confidence in her knowledge of performance. Her responses showed a clear self-awareness of her identity with technology, alongside an identity of leadership, commitment and responsibility to the profession. Her pedagogical technological identity was evident in discussions about choosing the tools for instruction, being aware of student use of technology, and the importance of technology in teaching. Through consideration of her teacher identity, we found that the participant's knowledge was driven and led by her identity in that she was keen on working toward meeting both technological and pedagogical challenges through any means. She alludes to problem-solving in the interview as "a mindset." This was a further theme found in the qualitative data as she brought this forward throughout the interview, whether it be solving a problem in designing instruction or what technology tools to use. Problem-solving came to the forefront of discussions around the challenges of using technology, particularly when it was not performing as expected. As previous examinations of technology in music teaching have reported its underuse, these results might lead music teacher educators to consider aligning the teaching of technology use in music not only with the pedagogies but also developing preservice teachers' identity with technology alongside a mindset of problem-solving. Nykvist and Mukherjee (2016) stated,

> *"In an era where the use of digital technologies should be synonymous with teacher pedagogical practices and transforming education, there is a growing need for pre-service teachers to develop an identity that resonates with pedagogical practices that engage and connect with students in a positive and productive way" (p. 851).*

In addition to problem-solving, adaptability was also found frequently throughout the interview. Adapting instruction for a learner-centred approach and adjusting the choice of technology tools was based on student preference and their use of devices or software. She exhibited an openness to consider what students prefer or what they discover on their own (e.g., Synesthesia). The participant shared examples of adapting to new technologies and the importance of this flexibility; however, she also described instances of using older technology in new ways. As with her knowledge and identity, her adaptability in pedagogies to meet her students' needs and to evolve technologies to align with her pedagogies were a factor in the effective use of technology. We also found that her technology knowledge and identity were extended throughout her career, for which adaptability was needed due to her changing roles in music, from predominantly that of a pianist and teacher to one who develops and runs an online learning platform and educates other teachers. She also pointed out the importance of adaptability and noted the lack of this within the field with regard to new technology.

In light of the COVID-19 pandemic and the transformational effect it has had on teaching and teachers, we have the opportunity to elevate and critically examine how and why we use technology to support music learning. The evidenced inequities in technology use by females in music is a cause for action. By exploring the identity and knowledge of a leading music teacher, we can use her experiences to inform teacher practices and teacher preparation programs for a more equitable future. With a strong identity in teaching with technology, we found that she navigated barriers through problem-solving, whether they be within technology or gender stereotypes, which she mentioned in her interview. Central to her understanding of a technology identity was her exposure to female mentors across her career. These impactful teachers fostered in her a sense of curiosity and an acumen for problem-solving. These two skills, alongside her TPC knowledge, helped forge her identity. Mentors have a demonstrable effect on the development of preservice teacher identities (McIntyre and Hobson, 2016) and are known to increase confidence, a stronger commitment to the profession, and improve pedagogical practices (McIntyre and Hobson, 2016; Simmonds and Dicks, 2018).

Another component to consider is the context of the participant's music career, particularly in light of Peters' (2017) research highlighting the importance of social and cultural contexts. The context of group piano classes is unique among other music learning environments in that this setting elevates the use of music and educational technologies. The growth of group piano teaching occurred alongside the development and accessibility of technology bespoke to this setting alongside other music and educational technologies (Stephens-Himonides and Hilley, 2017). As a leading figure in this technology-rich teaching and learning environment, our participant successfully navigated technological developments and served as a teacher leader for others in the field of group piano classes. Rosenberg and Koehler (2015) emphasized the importance of context as being an integral factor influencing the use of technology in teaching. If technology use is "woven together with" the teaching and learning, then the impact of our participants' teaching context must be taken into account. The rich technological history of group piano classes, alongside our participant's knowledge and identity, created the ideal conditions for her to emerge as a leader of music teaching with technology.

Central to our investigation was the question of whether knowledge was sufficient to explain why or how teachers utilize technology in their work. Following an examination of our participants' responses, it appears that knowledge and identity can create a virtuous cycle. With increased music, teaching, and technology knowledge, our participant developed an improved sense of self-efficacy alongside a more positive perception of the teaching tasks she undertook. This improvement then enhanced her confidence in using technology, which likely motivated her to gain more knowledge and experience and inspired her to gain more knowledge. Given the current research identifying a gender gap in the use of technology, it is plausible that the absence of any one of those conditions could create a vicious cycle. If teachers do not have opportunities to gain knowledge of music, teaching, and technology, then they are not likely to develop the confidence and self-efficacy necessary to continue developing their skills. Similarly, if they do not develop an interest or openness to technology, then they likely will avoid gaining the knowledge and skills necessary to effectively integrate music, pedagogy, and technology. How then do we socialize technology use, foster curiosity and enjoyment, and enable preservice teachers the opportunity to form a technology identity? Kirkup (2002) argued that "It is easier to change an activity with which you are simply associated than change your relationship with something that constitutes a key aspect of your identity" (p. 5). Further research is needed to examine how teacher educator programs could support the formation of a content, pedagogy, and technology identity alongside the development of content, pedagogy, and technology knowledge.

Due to the importance of identity in our results, future researchers may consider comparing the results found here with other gender identities. Furthermore, additional research is necessary to validate the extended TPACK framework. Additional questions regarding age and technology use should be undertaken. At the time of the interview, the participant stated that she was 67 years old and did not feel that choosing to use and integrate technology was age-related. However, she does reflect on the perspective of younger users and whether her teaching practices and technologies remain relevant to her students. This could be another area of examination of technology use and stereotypes. Could identity in a later age determine technology use more than knowledge of how to use it?

4.1 Limitations

While the case study methodology offered rich, in-depth insights into the development of participant's identity and knowledge, it also presents notable limitations when attempting to generalize findings beyond the specific context of this project. Case studies are inherently situated in particular contexts—shaped by the individual's background, experiences, and environment—which limits their

applicability to broader populations. The unique personal and professional trajectory of our participants may not reflect the experiences of other musicians, educators, or individuals with differing gender identities, cultural contexts, or stages of expertise. Additionally, the interpretive nature of case study research introduces subjectivity, both in data collection and analysis, which may influence how findings are understood and applied. As such, while this study yields valuable, nuanced understanding, it should be viewed as illustrative rather than representative, and its insights should inform—not define—broader theories of identity development and TPACK integration in music education.

5 Conclusion

Due to the seismic shift experienced by educators around the globe, the COVID-19 pandemic affords us the opportunity to view our teaching practices with technology differently. At the highest level of the TPACK framework, teachers are encouraged to select appropriate technologies that support the learning of their discipline. To do so requires that teachers not only have the knowledge to select technologies and pedagogies appropriate for effective teaching but also the confidence and belief that those choices will positively impact their students. Our participant's effective integration of content, pedagogy, and technology, alongside her steady focus on students' learning needs and their experiences, could be used as a model for practitioners and teacher educators. Cultivating a positive identity with music, pedagogy, and technology (and their intersections) could enable teachers to remove obstacles to technology use and adoption, leading to more equitable access and successful learning outcomes for students.

Data availability statement

The datasets presented in this article are not readily available because data is not anonymized. Requests to access the datasets should be directed to c.stephens-himonides@kingston.ac.uk.

Ethics statement

The studies involving humans were approved by Kingston University London Ethics Review Board. 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 potentially identifiable images or data included in this article.

Author contributions

CS-H: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. MY: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Perceived vibrato and the singing power ratio explain overall evaluations in opera singing

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In opera singing competitions, judges use an overall score to evaluate the singers' voices and determine their rankings. This score not only guides the singers' technique and expressiveness but also serves as a crucial indicator that can significantly influence their careers. However, the specific elements captured by this overall score remain unclear. To address this gap, the present study analyzed opera singing recordings to identify the factors that explain the overall score. Ten trained female Japanese singers performed "*Caro mio ben*" under standardized recording conditions. Four experts evaluated the recorded performances by assigning an overall score of 100 points and rating six vocal attributes: vibrato, resonance, timbre, diction, intonation, and expressiveness. The recordings were then analyzed to calculate specific acoustic and audio features, including the singing power ratio (SPR), harmonic-to-noise ratio (HNR), and loudness units full scale (LUFS). We developed two linear mixed models: the first regressed the overall score on the subjective vocal attributes, whereas the second predicted the overall score from the acoustic features. Evaluator identity was included as a random effect in both models. The results showed that vibrato was a significant predictor of the overall score in the first model. In the second model, only SPR emerged as a significant predictor. These findings suggest that vibrato, which reflects emotional expressiveness and vocal control, and SPR, which indicates the relative power in the high-frequency band (2–4 kHz) and assists a voice clearer than the accompaniment, are key factors in explaining the overall score in opera singing.

KEYWORDS

voice, opera singing, overall score, vibrato, singing power ratio

1 Introduction

In opera singing competitions, judges evaluate the performances and determine rankings. Although specific judgment criteria vary among competitions, many use scoring systems to assess the overall performance. For instance, in the vocal division of The Music Competition of Japan, each judge assigns a score out of 25 to the singer's overall performance, and the final ranking is determined by summing these scores after excluding the highest and lowest (The Music Competition of Japan Secretariat, 2024). In the International Vocal Competition Tokyo, judges allocate separate scores out of 50 for overall technique and expressiveness, and the combined total of 100 determines the ranking (International Vocal Competition TOKYO Guideline, 2024). A similar approach is used in the International Chopin Piano Competition, where participants receive an overall score (18th Chopin Competition Warsaw Rules, 2021). In all of these competitions, the overall score plays a pivotal role in determining rankings, which can have a substantial impact

on musicians' careers. In vocal competitions, judges are typically selected based on their expertise in the field. Most have extensive professional experience, often spanning 10–40 years, including careers as vocal instructors, international performers, and faculty members at music conservatories or universities. Hence, their evaluations are considered to carry substantial weight in determining the final rankings. However, detailed judgment criteria are rarely disclosed, and evaluations inevitably reflect the judges' individual preferences and experiences. Consequently, it remains unclear which specific elements of a singer's voice contribute to the overall score.

Previous research has investigated the subjective attributes that contribute to superior singing evaluation. These attributes include the singing technique (Subotnik, 2003, 2004), perceived potential or talent based on voice (Davidson and Da Costa Coimbra, 2001; Hollien, 1993; Watts et al., 2003), and vocal quality (Geringer and Madsen, 1998). A survey of 1,000 vocal instructors identified vocal quality, intonation, and musicality as the most important factors (Watts et al., 2003). Notably, the study by Wapnick and Ekholm (1997) provides valuable insights into which subjective evaluation scale items might explain the overall score. In their research, experts repeatedly evaluated recorded singing performance, and the consistency of evaluations within and between judges was assessed. Their findings revealed correlations between the overall score and attributes such as vibrato, resonance, timbre, and diction. However, this study did not employ statistical modeling to determine which specific attributes could predict the overall score, leaving the underlying determinants of the overall score unclear.

In addition, because judges assign overall scores based on the sound of the voice, objective acoustic features are considered important in evaluations, particularly when assessments are based on audio recordings. Quantitative studies of subjective singing evaluations began in the 1920s (Seashore and Metfessel, 1925). Since then, researchers have investigated acoustic features that characterize high-quality voices and their correlation with subjective evaluations (Ekholm et al., 1998; Robison et al., 1994; Wapnick and Ekholm, 1997). One particularly important aspect of opera singing is the ability of the voice to resonate throughout a large hall without amplification (Sataloff, 2017; Sundberg, 1990). One key acoustic feature that supports this ability is the "singer's formant" (Bartholomew, 1934; Sundberg, 1990), a cluster of harmonics centered around ~2.5 kHz for male singers and 3.16 kHz for female singers (Bloothooft and Plomp, 1986). The singer's formant can be quantified using the Singing Power Ratio (SPR), which measures the harmonic balance of a voice by comparing the strongest harmonic peak in the 2–4 kHz range with that in the 0–2 kHz range (Omori et al., 1996). Higher SPR values, indicating a smaller difference in power between the 2–4 and 0–2 kHz ranges, are associated with a bright, ringing tone (Omori et al., 1996). Research has shown that trained and untrained singers can be distinguished based on SPR-related values (Watts et al., 2003). These results suggest that SPR likely plays a critical role in determining overall scores in opera singing.

Other indicators that may influence the overall score include the harmonic-to-noise ratio (HNR) and integrated loudness units full scale (LUFS). HNR measures the amount of periodic (harmonic) energy in the voice and serves as an indicator of voice clarity (Murphy et al., 2008; Qi and Hillman, 1997). A higher HNR signifies a lower noise level, which listeners typically perceive as a clearer voice (Ferrand, 2002). In this context, "noise" refers not to external recording artifacts, but to intrinsic aperiodic and nonlinear components of the voice, such as irregular vocal fold vibrations, turbulent airflow, or features associated with vocal pathology. Trained opera singers typically produce very little noise in their vocal outputs (Ikuma et al., 2022). Integrated LUFS is a standardized metric used in audio for normalization purposes. This metric is designed to reflect the long-term perceived loudness of an entire recording, rather than short-term fluctuations, and is therefore more closely related to the overall perceptual impression of the piece. Therefore, in addition to SPR, both HNR and LUFS are likely to influence the overall opera singing scores. In this study, we selected objective acoustic and audio metrics based on their ability to be consistently extracted from the entire recording. All three indices met this criterion as they could be applied to full-length waveforms. However, it remains to be determined which of these features best accounts for the overall scores.

This study aimed to identify the factors that contribute to the overall scores in opera singing. To this end, we recorded opera performances, obtained evaluations from expert judges, and collected both overall scores and ratings for the six vocal characteristics identified in previous research (Wapnick and Ekholm, 1997). We also extracted acoustic features, including the SPR, HNR, and LUFS. Two linear mixed models were constructed: the first examined the relationship between overall scores and subjective vocal characteristics, whereas the second used acoustic and audio features, SPR, HNR, and LUFS, as predictors of overall scores. LUFS was used mainly because the acoustic metric of SPL was not available. By integrating the results of these models, we aimed to clarify the key determinants of opera singing scores from both the subjective and objective perspectives.

2 Materials and methods

2.1 Participants

Ten female Japanese singers specializing in classical vocal music (mean age ± SD = 25.10 ± 4.41) participated in this study. All participants were either currently enrolled at a music university, had graduated from a music university, or had received equivalent professional training. Table 1 provides detailed information on the participants' voice types and years of vocal experience.

The recordings of the ten singers were evaluated by four vocal instructors, all professional singers (four females; mean age ± SD: 47.75 ± 12.26 years, range: 35–61 years). Their professional musical careers and vocal teaching experience are summarized in Table 2. Prior to the experiment, all vocal instructors confirmed that they had no history of hearing impairment, and none of them reported any hearing difficulties.

Ethical approval for the study was obtained from the Research Ethics Committee of Keio University Shonan Fujisawa Campus (Approval Number: 441). All participants were thoroughly informed of the experimental procedures and written consent was obtained prior to the experiment.

TABLE 1 Singers' voice type, age, and vocal experience.

Singer's ID	Voice type	Age (years)	Vocal experience (years)
1	Soprano Leggero	30	13.0
2	Soprano Leggero	24	12.0
3	Soprano Lirico	25	10.0
4	Soprano Lirico	22	5.0
5	Soprano Lirico	22	0.5
6	Soprano Lirico	20	1.5
7	Mezzo-Soprano	26	11.0
8	Mezzo-Soprano	24	6.0
9	Soprano Lirico	23	8.0
10	Soprano Lirico	35	0.5

TABLE 2 Judges' age, professional musical career, and vocal teaching experience.

Judge's ID	Age (years)	Professional musical career (years)	Vocal teaching experience (years)
1	40	20.0	17.0
2	35	15.0	10.0
3	61	37.0	28.0
4	55	33.0	25.0

2.2 Procedure and data acquisition

The participants completed vocal exercises in a soundproof room before singing the assigned musical piece. The recorded data were used for acoustic analysis, and a separate evaluation session was conducted in which judges assessed the performance based on predefined criteria.

2.2.1 Procedure for singers

Recordings were conducted in a sound-isolated booth with interior dimensions of 1.60 × 1.60 × 2.12 m (W × D × H). The walls and ceiling were fitted with soundproof panels to minimize external noise, and the floor was covered with a tile carpet to reduce the impact noise and surface reflections. Although the room was not fully anechoic, these treatments created a controlled recording environment with low ambient noise and limited reverberations. This room was specifically designed with an elevated floor to prevent the transmission of footstep vibrations, and silencers were installed in the air conditioning and ventilation ducts to eliminate ambient noise.

Although opera singers are typically accustomed to performing in large, reverberant spaces, such as concert halls and auditoriums, the present recordings were conducted in a small, low-reverberation booth to minimize ambient noise and acoustic interference. While this setting did not replicate the acoustic conditions of typical performance venues, it was intentionally chosen to ensure precise and consistent measurement of vocal acoustic features under controlled conditions.

Before recording, the singers completed a questionnaire regarding their vocal experience. They were then given 10 min of vocal warm-up in the soundproof room to acclimatize to the recording environment. Following the warm-up, each singer performed the assigned piece, *Caro mio ben*, a cappella. Before singing, a starting pitch was provided using a digital piano. The singers used music sheets placed on a stand during their performance, rather than singing from memory. Each singer performed the piece only once. *Caro mio ben*, composed by Tommaso Giordani in 1859, was selected for its accessibility, manageable vocal range, and low technical difficulty, making it suitable for singers with varying levels of experience. In addition, this piece is commonly used by vocal students in Japan.

The recording setup included a computer (MacBook Retina 12-inch, 2017, macOS Monterey, Apple, Inc.) connected to an audio interface (M-TRACK 2X2M, M-AUDIO) and a microphone (AT2035, Audio-Technica). The microphone, which had a frequency response range of 20–20,000 Hz, was positioned 20 cm from the singer's mouth. The frequency response of the microphone is relatively flat between 200 Hz and 4 kHz, with a gradual roll-off below 200 Hz (Audio-Technica, 2008). Given that the lowest note sung in *Caro mio ben* was D4 (293 Hz), the influence of the frequency characteristics of the microphone on SPR measurements was considered minimal. Audio recordings were captured using the Audacity software (ver. 3.4.2), with a standardized sampling frequency of 192 kHz. The preamplifier level of the audio interface was fixed and held constant across all singers to ensure consistent input levels, enabling appropriate calculation of the LUFS. LUFS was used in this study because of the unavailability of SPL.

2.2.2 Procedure for judges

The evaluation sessions were conducted in the same soundproof room used for recording. Audio recordings were played on a computer (MacBook Retina 12-inch, 2017, macOS Monterey, Apple) connected to headphones (HD280pro, SENNHEISER). Before the session, the judges adjusted the playback volume to ensure consistent listening conditions across all the recordings.

Before beginning the evaluations, the judges completed a questionnaire detailing their vocal experiences and professional careers. They then listened to the recordings of the 10 singers, presented in a randomized order, and evaluated the performances based on two criteria: (1) an overall score on a 100-point scale and (2) six vocal attributes—vibrato, resonance, timbre, diction, intonation, and expressiveness—rated on a 7-point Likert scale (1 = very low, 7 = very high). The playback volume was standardized across all judges, and the judges did not alter the volume after this initial setup to ensure consistency throughout the evaluation process. These attributes were selected based on the previous research by Wapnick and Ekholm (1997). The judges were all professional singers; therefore, we did not provide formal definitions of the vocal attributes. However, for clarity, the six vocal attributes are described as follows: resonance refers to vocal

depth and richness, whereas timbre represents tonal qualities such as brightness and warmth. Vibrato is characterized by its regularity, rate, and extent. Diction reflects pronunciation clarity and intelligibility, whereas intonation reflects pitch accuracy and stability. Expressiveness captures the singer's ability to convey emotions, use dynamics, and shape phrases effectively.

2.3 Analysis

2.3.1 Acoustic analysis

We analyzed the acoustic features of the entire recording (including both vowels and consonants) using three parameters: SPR, HNR, and LUFS. Praat software (version 6.3.10) and MATLAB (R2024a, Audio Toolbox, MathWorks Inc.) were used for this analysis (Boersma and Weenink, 2024). To ensure the accuracy of the acoustic analysis, the recorded audio files were preprocessed to isolate the sung portions of the performances. Non-singing segments such as pauses and breaths were excluded.

The SPR was calculated from the power spectrum (expressed in decibels, dB) obtained by applying a Fast Fourier Transform (FFT) with a window size of 1,024 points and a bandwidth of 4,000 Hz. From the spectrum, we extracted the highest-amplitude harmonic peak within the low-frequency band (0–2 kHz), defined as $Power_{\mathrm{Low}}$, and the highest-amplitude harmonic peak within the high-frequency band (2–4 kHz), defined as $Power_{\mathrm{High}}$. The SPR was computed as the difference between these two peak amplitudes (Omori et al., 1996).

$$SPR(\mathrm{dB}) = Power_{\mathrm{High}} - Power_{\mathrm{Low}} \tag{1}$$

Since both $Power_{\mathrm{High}}$ and $Power_{\mathrm{Low}}$ are already expressed in dB, the subtraction directly yields the SPR without further logarithmic conversion.

HNR was calculated using the autocorrelation method implemented by Praat. This parameter quantifies the ratio of the harmonic energy to the noise energy in the voice signal (Fernandes et al., 2023). Because both the harmonic and noise components are expressed in dB, the HNR formula reflects the difference between two logarithmic magnitudes:

$$HNR(\mathrm{dB}) = Power_{\mathrm{Harmonics}} - Power_{\mathrm{Noise}} \tag{2}$$

where $Power_{\mathrm{Harmonics}}$ represents the power of the harmonic component, and $Power_{\mathrm{Noise}}$ represents the power of the noise component. The analysis was conducted using a frame-based window and the average HNR was calculated across the entire performance.

The integrated LUFS was calculated using the "integratedLoudness" function in MATLAB's Audio Toolbox based on the ITU-R BS.1770-4 standard. Rather than using LUFS values as absolute indicators of loudness, the model considered them as relative differences across singers. This is given that LUFS reflects the loudness of the audio signals, not of the singers *per se*.

2.3.2 Statistics

Given the limited number of participants, a linear mixed-effects model was used to account for inter-rater variability and model the crossed data structure in which each singer was evaluated by multiple judges (10 singers × 4 judges = 40 observations). The model was estimated using restricted maximum likelihood (REML), with judge identity included as a random intercept. Linear mixed-effects models are well-suited for small-sample designs and have been shown to produce valid statistical inferences under such conditions (Schielzeth and Forstmeier, 2009).

To analyze the effects of subjective vocal attributes and acoustic features on the overall scores, two linear mixed-effects models were constructed. To assess the normality of the residuals, Shapiro–Wilk tests were conducted for all models. The analyses were conducted using R software (version 4.4.2) with the lmerTest and lme4 packages (Bates et al., 2015; Kuznetsova et al., 2017), which facilitated linear mixed-effects modeling with p-value estimation. The marginal and conditional R-squared values were calculated using the partR2 package (Stoffel et al., 2021).

The first model examined the impact of six vocal attributes–resonance, timbre, vibrato, diction, intonation, and expressiveness–on overall scores. In this model, six vocal attributes were treated as fixed effects, and judge variability was included as a random effect. The model formula is as follows:

$$\begin{aligned} &Overall\ impression\ score \sim \\ &Resonance + Timbre + Vibrato + Diction + \\ &Intonation + Expressiveness + (1|JudgeID) \end{aligned} \tag{3}$$

The second model investigated the contribution of three acoustic features–SPR, HNR, and LUFS–to the overall scores. In this model, acoustic features were treated as fixed effects, whereas judge variability was treated as a random effect. The formula for this model is as follows:

$$Overall\ impression\ score \sim SPR + HNR + LUFS + (1|JudgeID) \tag{4}$$

For both models, the significance level α was set at 0.05. The marginal R-squared values (R^2_m) represent the explanatory power of fixed effects alone, whereas the conditional R-squared values (R^2_c) account for the explanatory power of both fixed and random effects. The confidence intervals (CI) for R^2_m and R^2_c were estimated using 100 bootstrap iterations. The variance inflation factor (VIF) was calculated using the car package (Fox and Weisberg, 2019) to assess multicollinearity among the predictor variables. The Shapiro–Wilk test was conducted on the residuals of both linear mixed-effects models to evaluate the normality assumption. The results indicated that the assumption was satisfied for both the vocal-attribute model ($W = 1.00$, $p = 0.40$) and the acoustic-feature model ($W = 0.97$, $p = 0.35$).

3 Results

As representative examples, Figures 1 and 2 present the evaluation scores and spectrograms for the three singers who received different overall scores. The top-level singer (ID: 8)

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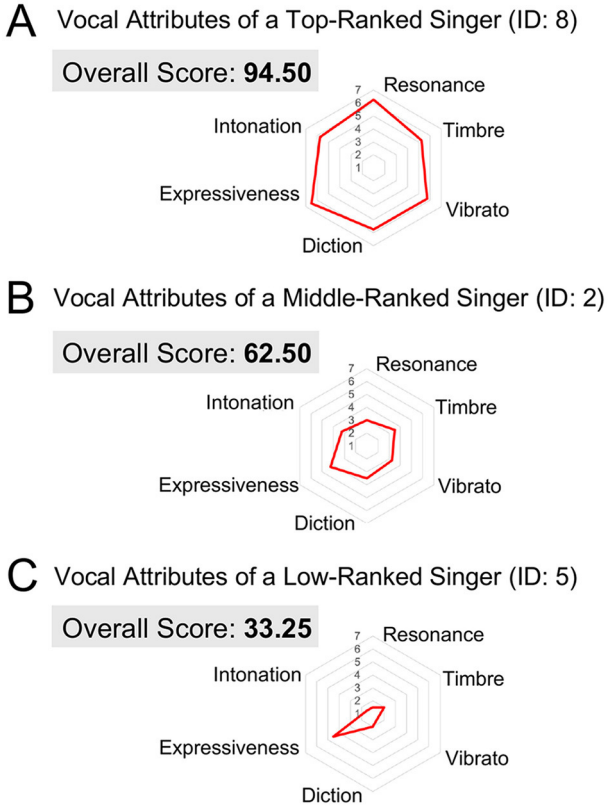

FIGURE 1
Vocal evaluation scores of three singers with different performance levels. **(A)** Vocal attributes of the top-ranked singer (ID: 8), who achieved the highest overall score. **(B)** Vocal attributes of the middle-ranked singer (ID: 2), who received a mid-range overall score. **(C)** Vocal attributes of the low-ranked singer (ID: 5), who obtained the lowest overall score.

received the highest score, the middle-level singer (ID: 2) received a mid-range score, and the low-level singer (ID: 5) received the lowest score. Spectrograms were generated from each singer's highest-pitched note (B-flat) in *Caro mio ben*. In Figures 1A–C, the radar charts display the overall scores, along with the six vocal evaluation scores for each singer. Figures 2A–C show the corresponding narrowband (left) and wideband (right) power spectrograms. Narrowband spectrograms illustrate harmonic structures and vibrato modulations, while wideband spectrograms emphasize formant clusters and spectral energy distribution.

First, the top-ranked singer (ID: 8) achieved an overall score of 94.50 (Figure 1A) and displayed consistently high ratings across all the six vocal evaluation criteria. As shown in Figure 2A, the spectrogram featured prominent energy in the 2–4 kHz range associated with the singer's formant, and the B-flat note was performed with a regular vibrato. Second, the middle-ranked singer (ID: 2) received an overall score of 62.50 (Figure 1B), exhibiting moderate ratings across the six vocal attributes. The power spectrogram (Figure 2B) shows weaker energy in the 2–4 kHz band compared with the top singer. This singer applied vibrato to the B-flat note, but with wider pitch variation, fewer oscillations, and greater irregularity than those observed in the top-ranked singer (Figure 2A). Third, the low-ranked singer (ID: 5) obtained the lowest overall score of 33.25 (Figure 1C), reflecting low ratings across all six vocal attributes. The spectrogram (Figure 2C) indicates a very weak energy in the 2–4 kHz range and the absence of vibrato in the B-flat note. Individual ratings for the overall scores and six vocal attributes are provided in Table 3, and SPR, HNR, and LUFS are shown in Table 4.

3.1 Effects of vocal attributes on overall scores

The results from the linear mixed-effects model (Equation 3) assessing the influence of vocal attributes on the overall scores are summarized in Table 5. Among the six vocal attributes, vibrato had a significant positive effect on the overall scores ($\beta = 5.02$, $p = 0.003$; Figure 3A). By contrast, resonance ($\beta = 1.97$, $p = 0.328$; Figure 3B), timbre ($\beta = 2.31$, $p = 0.192$; Figure 3C), diction ($\beta = 2.09$, $p = 0.176$; Figure 3D), intonation ($\beta = 0.38$, $p = 0.806$; Figure 3E), and expressiveness ($\beta = 2.06$, $p = 0.126$; Figure 3F) were not statistically significant. All VIFs were below 5 (range = 1.84–4.85), indicating that multicollinearity was unlikely to severely bias parameter estimates. Although a VIF above 1 reflects some shared variance, values under 5 are generally considered acceptable in previous behavioral and acoustic research (Kutner et al., 2004; O'brien, 2007).

The marginal R^2 (R^2_m) was 0.71 (95% CI: 0.55–0.86), and the conditional R^2 (R^2_c) was 0.84 (95% CI: 0.75–0.91). These results indicate that fixed effects (subjective evaluation criteria) accounted for ~71% of the variance in the overall scores (R^2_m), and the full model, including both fixed effects and judge-level random intercepts, accounted for ~84% of the variance (R^2_c). The difference between R^2_m and R^2_c suggests that a random effect—specifically, variability among judges—contributes to the overall variance in scores.

3.2 Effects of acoustic features on overall scores

The results of the linear mixed-effects model (Equation 4) assessing the influence of acoustic features on overall scores are summarized in Table 6. Among the three acoustic features, SPR had a significant positive effect on the overall impression scores ($\beta = 1.84$, $p = 0.034$; Figure 4A). In contrast, HNR ($\beta = 1.27$, $p = 0.44$; Figure 4B) and LUFS ($\beta = 1.34$, $p = 0.24$; Figure 4C) did not exhibit statistically significant effects. All VIF values were below 5.

The R^2_m was 0.20 (95% CI: 0.067–0.385), and the R^2_c was 0.20 (95% CI: 0.078–0.398). There was little difference between R^2_m and R^2_c values.

4 Discussion

This study aimed to identify the key factors influencing the overall evaluation of opera singing. To achieve this, we recorded the performances of the classical Italian song *Caro mio ben* sung by trained vocalists, collected the overall scores and ratings for

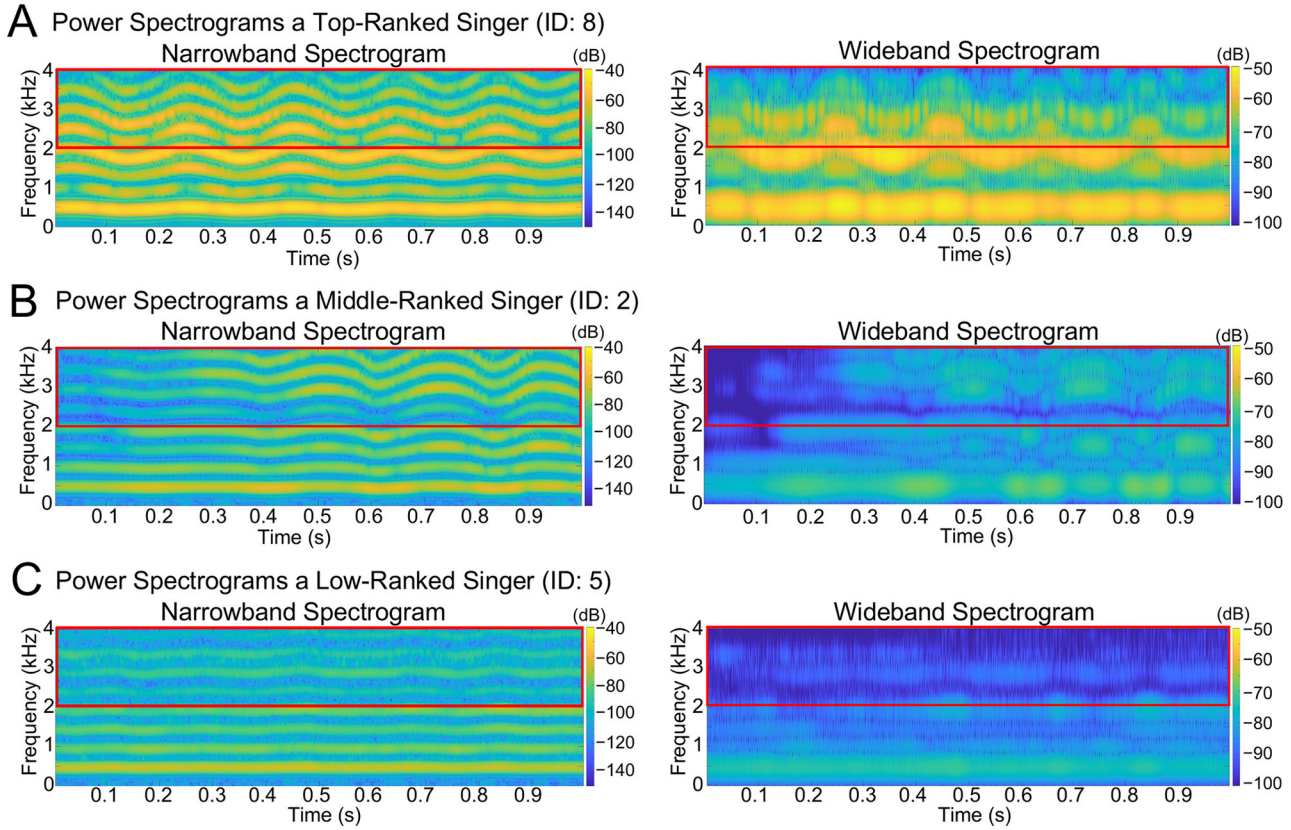

FIGURE 2
Spectrograms of three singers with different performance levels. **(A)** Power spectrograms of the singer with the highest overall score (ID: 8). **(B)** Power spectrograms of the singer with the mid-range overall score (ID: 2). **(C)** Power spectrograms of the singer with the lowest overall score (ID: 5). The left panels show narrowband spectrograms, and the right panels show wideband spectrograms, both derived from a B-flat note from the climactic phrase of *Caro mio ben*. The red horizontal box in each panel indicates the 2–4 kHz frequency range, which corresponds to the SPR band. For the narrowband spectrogram, we used a fixed window length of 2,048 samples, and for the wideband spectrogram, we used a short window length of 576 samples. Both analyses employed a Hamming window with 90% overlap and an FFT size of 4,096 points.

six vocal attributes, and analyzed the acoustic features of the recordings. Two linear mixed models were constructed: the first examined the relationship between overall scores and subjective vocal characteristics, while the second predicted overall scores based on acoustic features of SPR, HNR, and LUFS.

4.1 Effects of vocal attributes on overall scores

When we regressed the overall scores on subjective vocal characteristics, vibrato emerged as the only factor that showed a significant positive association with the overall scores (Figure 3; Table 5). This finding suggests that judges may place particular emphasis on vibrato when evaluating opera performance. By contrast, resonance, timbre, diction, intonation, and expressiveness did not show statistically significant effects.

4.1.1 Vibrato

A previous study by Wapnick and Ekholm (1997) used Pearson's correlation coefficient to examine the relationship between overall scores and other vocal performance assessments. Their findings revealed a strong correlation between overall scores and vibrato ratings as well as consistency in judges' evaluations of vibrato. Similarly, our results indicate that vibrato ratings can predict overall scores.

Calculated vibrato is widely recognized as a key feature of opera singing, contributing to both vocal expressiveness and technical proficiency (Howes et al., 2004). A previous study comparing professional opera singers with students found that vibrato quality and control—rate and extent—were closely linked to singing proficiency (Amir et al., 2006). Since many judges and vocal instructors assess vibrato quality and control as indicators of advanced vocal techniques, vibrato is expected to play a crucial role in determining the overall opera performance scores.

As our main acoustic analysis focused on overall acoustic measures, such as SPR, HNR, and LUFS, we did not initially compute the vibrato-specific acoustic parameters. This was because our primary aim was to predict the judges' overall scores based on acoustic features calculated from the entire performance, whereas vibrato analysis typically requires localized examination of sustained pitch segments. However, given that vibrato emerged as the only significant predictor among the subjective rating items in our perceptual model, we conducted an exploratory analysis to examine whether this subjective vibrato score corresponded to

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TABLE 3 Individual ratings from four judges for each vocal attribute and singer.

Judge's ID	Singer's ID	Overall score	Vibrato	Resonance	Timbre	Diction	Intonation	Expressiveness
1	1	80	5	6	6	7	7	6
	2	65	4	3	3	3	4	2
	3	60	1	4	4	7	7	4
	4	70	5	2	2	3	7	3
	5	20	1	1	1	1	7	1
	6	60	4	3	3	3	6	5
	7	100	5	6	6	6	7	6
	8	100	6	6	6	7	7	6
	9	70	6	4	4	6	6	6
	10	50	2	3	4	2	4	5
2	1	80	6	6	6	7	7	2
	2	60	3	1	1	3	5	3
	3	40	3	3	2	3	6	2
	4	40	2	5	2	4	3	3
	5	20	1	1	2	3	6	1
	6	40	1	2	2	3	2	5
	7	100	3	6	7	7	7	6
	8	100	6	7	3	7	7	6
	9	50	4	2	2	5	6	6
	10	50	3	4	4	2	3	3
3	1	80	5	6	5	5	5	4
	2	75	4	5	5	3	4	4
	3	70	3	5	5	2	4	2
	4	60	3	2	1	1	4	3
	5	58	2	2	2	1	2	2
	6	68	3	3	4	2	3	3
	7	90	5	6	5	5	5	6
	8	78	4	5	5	2	5	4
	9	85	5	6	5	4	5	6
	10	50	3	4	3	1	4	3
4	1	85	5	6	6	6	5	7
	2	50	2	3	5	5	4	3
	3	50	3	4	5	5	3	4
	4	50	4	4	5	4	5	5
	5	35	2	3	3	3	3	2
	6	60	5	4	6	3	5	5
	7	65	4	5	6	6	4	6
	8	100	7	7	7	7	7	7
	9	75	5	5	5	7	6	5
	10	25	2	3	3	1	3	2

objectively measurable features related to vibrato. Specifically, we examined whether perceived vibrato ratings could be predicted from two established acoustic parameters of vibrato: vibrato rate and vibrato extent (Sundberg, 1995) (see Supplementary methods). From each performance, a single sustained note was isolated, and both the vibrato rate and vibrato extent were calculated. The perceived vibrato rating was significantly predicted by vibrato extent but not by vibrato rate (see Supplementary results).

These findings suggest that vibrato extent plays a more prominent role than vibrato rate in expert evaluations of the vibrato quality. The positive association between vibrato extent and perceived vibrato aligns with previous research showing that greater vibrato extent conveys greater emotional expressiveness and vocal maturity (Howes et al., 2004; Prame, 1997). The absence of a vibrato rate effect is likely due to limited variability among singers within the perceptually acceptable range of 5–7 Hz (Järveläinen, 2002).

Because the judges in this study evaluated the entire performance rather than isolated notes, further research is needed to clarify how vibrato rate and vibrato extent influence expert judgments in the context of complete performance.

4.1.2 Resonance and timbre

Previous research (Wapnick and Ekholm, 1997) has found that resonance and timbre are strongly correlated with overall scores. However, in the present study, neither resonance nor timbre significantly predicted the overall scores. One possible explanation is that vibrato parameters, such as rate and extent, may influence resonance and timbre (Manfredi et al., 2015), leading to intertwined evaluations of these vocal attributes (Wooding and Nix, 2016). This overlap may have made vibrato the more dominant factor in the scoring. In Wapnick and Ekholm (1997), the correlation coefficient between vibrato, "color/warm" (a descriptor similar to timbre), and resonance was close to 0.7, and factor analysis grouped these attributes together within the same factor.

Another contributing factor may be the conceptual and perceptual overlap between resonance and timbre. In both vocal pedagogy and auditory-perceptual research, resonance is often considered a subset or acoustic correlate of the broader construct of timbre (Sundberg, 1987). Given this relationship, expert vocal instructors may have found it difficult to consistently differentiate between the two attributes during the evaluation, leading to shared variance and reduced predictive specificity.

In addition, the non-significant effects of resonance and timbre in our study may be partly due to the use of recorded audio rather than live performances. Opera is traditionally performed without microphones, allowing the audience to perceive the singer's natural resonance and timbre as their voice projects throughout the performance space. However, when evaluated through recordings, subtle variations in these qualities may not be fully captured or perceived, because the recording process and playback equipment can alter or mask them (Edwards, 2016; Zoran, 2020). As a result, evaluators may have found it difficult to distinguish between differences in resonance and timbre, leading to a lack of statistical significance in this study. This limitation could be addressed in future research by using high-fidelity, calibrated recording and playback systems designed to preserve the detailed acoustic cues of resonance and timbre.

TABLE 4 Calculated acoustic features from each singer's recorded voice.

ID	SPR (dB)	HNR (dB)	LUFS (dB)
1	−10.76	47.30	−29.01
2	−24.65	53.11	−30.89
3	−14.10	48.38	−27.12
4	−19.81	44.61	−24.54
5	−29.75	53.26	−37.18
6	−22.30	50.81	−27.72
7	−22.08	48.39	−22.72
8	−15.64	44.59	−27.49
9	−17.71	46.01	−29.20
10	−17.99	43.79	−23.34

4.1.3 Diction and intonation

Although diction is often considered crucial in opera performance assessments, it did not strongly influence judges' evaluations in this study. As *Caro mio ben* is commonly taught in Japanese high schools, the participants likely met the minimum standard of Italian pronunciation. This could explain why diction did not significantly affect the overall scores. Furthermore, previous research (Wapnick and Ekholm, 1997) has shown that diction has the lowest correlation with overall scores among various vocal

TABLE 5 Estimation of linear mixed-effects models fitted to overall score (fixed effects: vocal attributes).

Variable	β	*SE*	*df*	*t*-value	*p*-value	*VIF*
Vibrato	5.02	1.55	30.50	3.24	0.003*	2.55
Resonance	1.97	1.99	31.95	0.99	0.328	4.85
Timbre	2.31	1.73	32.10	1.33	0.192	3.30
Diction	2.09	1.51	32.40	1.38	0.176	3.62
Intonation	0.38	1.52	32.17	0.25	0.806	1.88
Expressiveness	2.06	1.31	30.20	1.57	0.126	2.14

Asterisk (*) shows statistical significance. Marginal $R^2 = 0.71$; Conditional $R^2 = 0.84$.

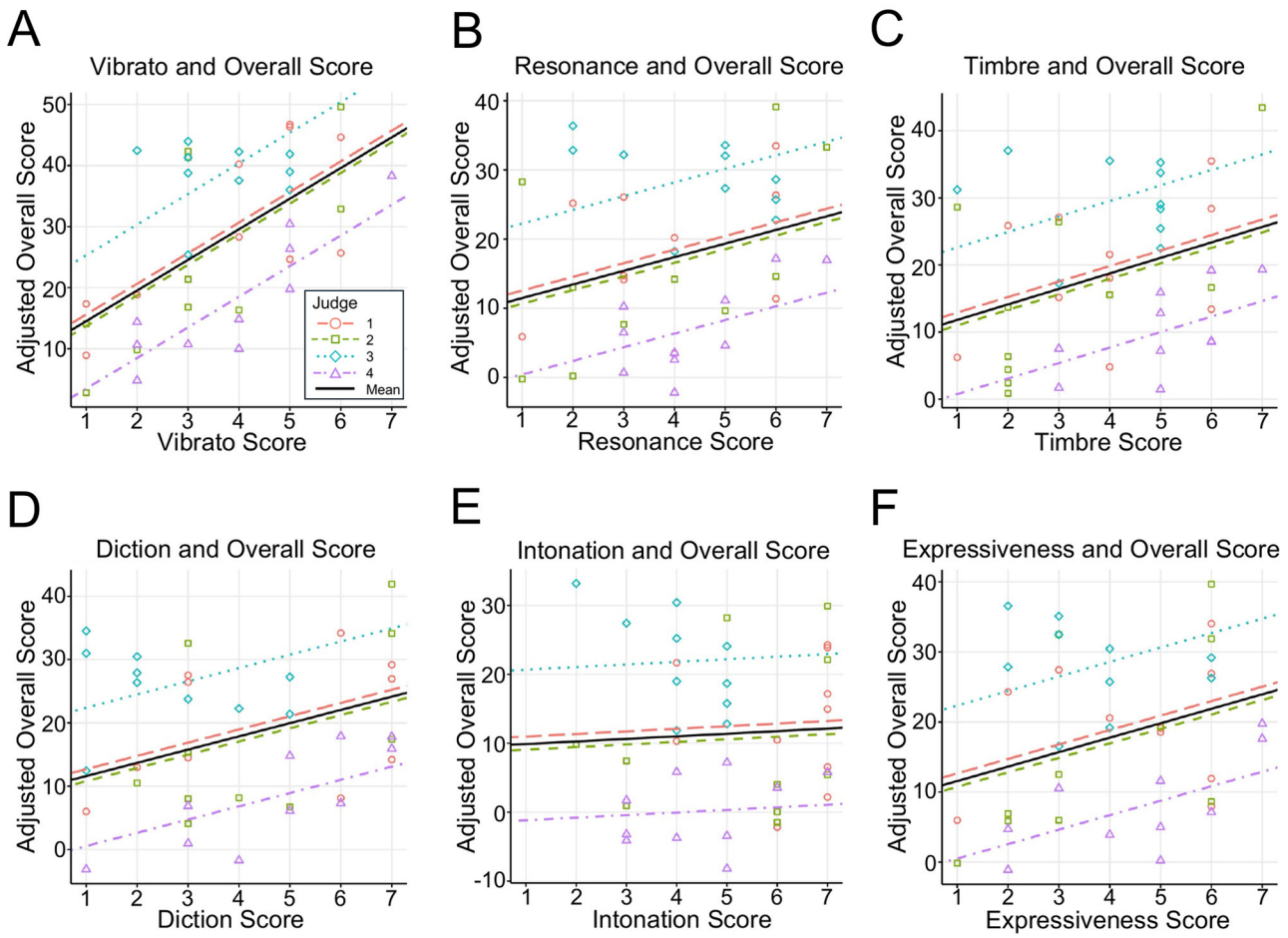

FIGURE 3
Scatter plots of vocal attributes vs. adjusted overall scores. Data were fitted using a linear mixed-effects model, where vocal attributes were treated as fixed effects and judge ID was included as a random effect. **(A)** Vibrato score plotted against the overall score. The adjusted overall score was calculated by subtracting β (resonance) × resonance score, β (timbre) × timbre score, β (diction) × diction score, β (intonation) × intonation score, and β (expressiveness) × expressiveness score from the original overall score. **(B–F)** Scatter plots of resonance, timbre, diction, intonation, and expressiveness scores were plotted against the adjusted overall score. In each case, the adjusted overall score was computed similarly by excluding the contribution of the other attributes from the original overall score.

TABLE 6 Estimation of linear mixed-effects models fitted to overall score (fixed effects: acoustic features).

Variable	β	*SE*	*df*	*t*-value	*p*-value	*VIF*
SPR	1.84	0.83	36.00	2.21	0.034*	1.83
HNR	1.27	1.63	36.00	0.78	0.44	2.75
LUFS	1.34	1.12	36.00	1.20	0.24	1.92

Asterisk (*) shows statistical significance. Marginal $R^2 = 0.20$; Conditional $R^2 = 0.20$.

attributes. However, our finding should not imply that diction is unimportant in opera singing. Rather, the non-significant result in the present study likely reflects the limited variability in diction proficiency among participants, who generally demonstrated a uniformly adequate level of pronunciation. This lack of variation may have constrained the model's ability to detect any contribution of diction to the overall evaluation.

Similarly, intonation did not significantly predict the overall scores. Professionally trained singers generally demonstrate a high pitch accuracy and reduced variability in this attribute. Moreover, vibrato, which is frequently employed in opera singing, modulates pitch over extended notes, making precise pitch assessments more challenging (D'Amario et al., 2020). In addition, the limited sample size may have reduced the power of the model to detect statistically significant effects of intonation. With a larger number of participants, subtle pitch deviations may have been more readily captured and reflected in evaluation outcomes.

One possible explanation for the absence of significant effects of diction and intonation is the selection of musical material. *Caro mio ben* was deliberately chosen for its technical simplicity and limited linguistic demands in order to isolate core vocal production skills such as vibrato and resonance. However, this choice may

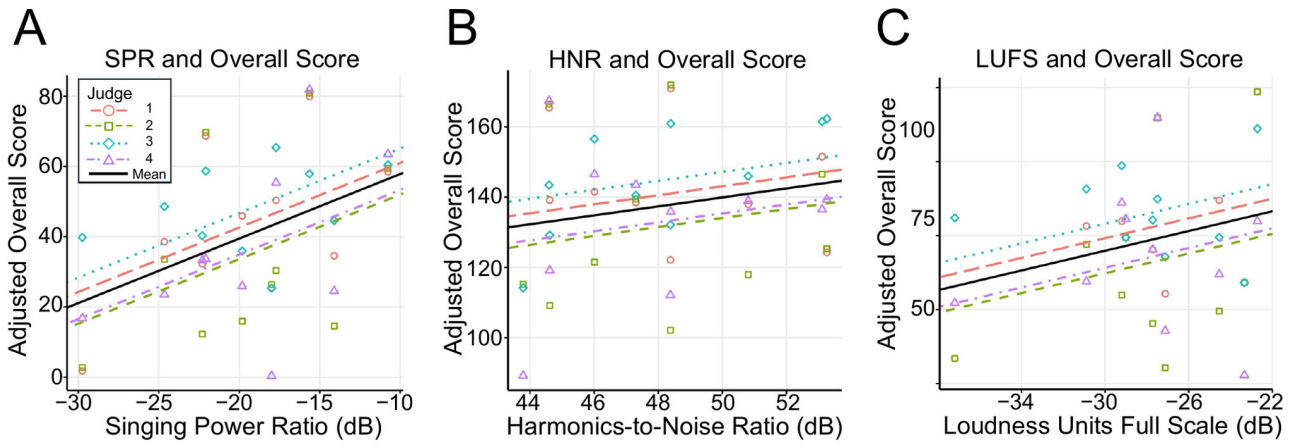

FIGURE 4
Scatter plots of acoustic features vs. adjusted overall scores. Data were fitted using a linear mixed-effects model, where acoustic features were treated as fixed effects and judge ID was included as a random effect. **(A)** Singing Power Ratio (dB) plotted against the adjusted overall score. **(B)** Harmonics to Noise Ratio (dB) plotted against the adjusted overall score. **(C)** Loudness Units Full Scale (dB) plotted against the adjusted overall score. In each case, the adjusted overall score was computed by excluding the contributions of the other acoustic features from the original overall score.

have inadvertently reduced the variability in diction and intonation performance among participants, thereby limiting the statistical power to detect effects related to these attributes.

4.1.4 Expressiveness

Expressiveness did not significantly predict overall scores, possibly because it is a broad and subjective concept and vibrato strongly influences perceived emotional content. Judges may differ in their interpretations of expressiveness, focusing on emotional delivery, phrasing, dynamic shifts, or personal styles. Consequently, these diverse standards could make it more difficult to detect a statistically significant effect once the scores are averaged. Moreover, vibrato is frequently used to convey emotions, including adjustments in rate, extent, duration, and volume (Scherer et al., 2015). Thus, when judges perceive a performance to be highly expressive, they may respond to vibrato, which makes it difficult to isolate expressiveness as a distinct predictor of overall scores.

4.2 Effects of acoustic features on overall scores

The linear mixed model regressing the overall scores on acoustic features revealed that a higher SPR was associated with higher overall scores, whereas HNR and LUFS did not show statistically significant effects (Figure 4; Table 6). This finding suggests that singers with a greater difference in power between 2–4 kHz and 0–2 kHz tend to receive higher overall scores.

4.2.1 SPR

SPR emerged as a significant predictor of overall scores, which is consistent with its known role as an indicator of formant structure and vocal projections. Previous studies have suggested that a higher SPR value corresponds to a voice that is perceived as both penetrating and rich in timbre (Watts et al., 2003). In opera, singers must be heard above an orchestra without amplification; therefore, they generally adjust their vocal tract to form singer formants between 2 and 4 kHz to enhance vocal projection (Sundberg, 1987). The higher SPR values associated with such formant tuning suggest that singers with a higher SPR may have achieved better vocal projection, which in turn contributed to their higher overall scores. Moreover, SPR has been shown to correlate with training-related improvements in vocal techniques (Usha et al., 2017), reflecting advanced control of resonance, expiratory pressure, and vocal-fold vibration, which are highly valued in operatic performance.

4.2.2 HNR

HNR is frequently used to evaluate voice quality, clarity, and the ratio of harmonic components to noise (Mouawad et al., 2013). It is also especially helpful in diagnosing voice disorders. However, trained opera singers typically exhibit very little noise in their voices (Ikuma et al., 2022). As a result, the range of HNR values for these singers was relatively small, reducing their usefulness in explaining variations in the overall score. In addition, while HNR captures the degree of "low voice noise," overall impressions in opera often hinge on factors such as voice resonance, emotional expression, and volume balance. Because HNR primarily measures noise components rather than these expressive elements, it may have had limited impact on overall evaluations. Prior work has also suggested that SPR aligns more closely with subjective evaluations than HNR (Kenny and Mitchell, 2006), further indicating that HNR may play a secondary role in judges' assessments of opera performance.

4.2.3 LUFS

Integrated LUFS is a standardized metric commonly used in audio processing for normalization purposes. It quantifies how loud a signal is on a digital level, averaged over an extended period

of time. Previous research has shown that spectral balance and resonance characteristics contribute more to the perceived vocal quality than loudness alone (Collyer et al., 2009). In particular, singer formants, which are concentrated in the 2–4 kHz range, play a critical role in determining how well a voice carries (Sundberg et al., 1993). Emphasizing these frequency components can influence subjective evaluations more strongly than the overall amplitude, which likely explains why the LUFS did not emerge as a significant predictor in the present study.

Increases in vocal intensity are typically accompanied by physiological adjustments (e.g., increased subglottal pressure and changes in vocal tract shaping) that redistribute spectral energy and affect timbre. Therefore, vocal intensity may indirectly influence the perceived vocal quality through these timbral changes. Future research should further explore the relationship between vocal intensity, timbre, and perception of vocal quality.

4.3 Insights from the two regression models

This study employed two linear mixed models to predict the overall opera-singing scores. The first model, which focused on the subjective evaluations of vocal attributes, identified vibrato as the most significant predictor (Table 5). The second model, which was based on acoustic characteristics, highlighted SPR as the most significant predictor (Table 6). These findings suggest that both dynamic vocal modulations, represented by vibrato, and spectral balance, represented by SPR, play crucial roles in the evaluation of opera singing.

Vibrato, which is characterized by fluctuations in pitch and amplitude, significantly contributes to a singer's perceived technical sophistication. It enhances the artistic quality of the voice, and listeners often assess a singer's proficiency based on vibrato's rate and extent (Muller et al., 2021). As shown in Figure 2, the top-ranked singer exhibited a stable vibrato (Figure 2A), the middle-ranked singer produced a wider, irregular vibrato (Figure 2B), and the low-ranked singer lacked vibrato entirely (Figure 2C). This is also supported by our analysis based on the acoustic characteristics of vibrato (see Supplementary Figure 1). In opera, well-controlled vibrato frequently enhances emotional depth and dramatic tension, implying that vibrato strongly shapes performance assessment.

Singers with higher SPR values, reflecting an enhanced energy in the 2–4 kHz range, tended to receive higher subjective evaluation scores. The top-ranked singer demonstrated a higher SPR with prominent energy in the 2–4 kHz range (Figure 2A), whereas the lower-ranked singers exhibited a lower SPR (Figure 2C). While this pattern suggests a potential role of SPR in differentiating performance, it should be interpreted with caution, given the limited explanatory power of the acoustic regression model ($R^2 = 0.20$).

Interestingly, although SPR significantly predicted overall impression scores, judges' explicit ratings of resonance and timbre did not. One possible explanation is that the perceptual qualities of timbre, resonance, and vibrato overlap, which leads to redundancy in the evaluation of these attributes. This interpretation is supported by the VIFs for resonance and timbre (for example VIF = 3.30 for timbre). Such an overlap may have limited the ability of individual perceptual items to emerge as significant predictors, despite their conceptual importance. Alternatively, judges may have been perceptually influenced by spectral energy cues, such as vocal projection or formant clustering, but did not consistently label these qualities as "resonance."

Taken together, these results suggest that opera-singing evaluations assessed in our dataset of ten singers by four expert listeners depend on both dynamic vocal modulations (such as vibrato) and the spectral structure captured by SPR.

4.4 Limitations and future directions

This study has several limitations. The experiment was conducted in a recording environment that did not replicate concert hall acoustics, which may have influenced the assessment of certain vocal qualities, such as resonance and timbre. Future research could explore how different singing environments and acoustic settings affect the evaluations. Moreover, the number of participating singers and judges was limited. While the use of a linear mixed-effects model allowed for valid statistical inferences based on the available data, future studies would benefit from including a larger number of expert judges and singers to improve the generalizability and robustness of the findings. Additionally, the sample was limited to female Japanese singers, which restricts the generalizability of the findings. To enhance the applicability of these results, future studies should include a more diverse participant pool, encompassing singers of various vocal types, male singers, and performers from different cultural backgrounds.

5 Conclusion

We found that vibrato had a significant impact on the overall opera performance scores. Moreover, a larger difference between the amplitude peaks in the 0–2 kHz and 2–4 kHz ranges corresponding to a higher SPR was associated with higher scores. These results suggest that vibrato, which reflects dynamic vocal modulation, and SPR, which represents spectral balance, are critical factors for the evaluation of opera singing. The insights from this study can inform vocal training and education by guiding the development of targeted exercises and feedback strategies focused on vibrato and SPR, ultimately fostering more effective improvements in both technical and artistic aspects of singing.

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 approval for the study was obtained from the Research Ethics

Committee of Keio University Shonan Fujisawa Campus (Approval Number: 441). 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

HK: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. SK: Formal analysis, Methodology, Software, Supervision, Writing – review & editing. SF: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, 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 interpreted 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.2025.1568982/full#supplementary-material

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Enhanced subjective performance achievement in wind instrument playing through positive memory recall: effects of sympathetic activation and emotional valence

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Controlling physiological and psychological states before a performance is essential for professional musicians to realize their full potential. However, the characteristics of the optimal pre-performance state remain unclear. While an increase in sympathetic nervous system activity is typically observed before performance, when associated with anxiety, it can degrade the performance quality. This study examined whether recalling positive autobiographical performance memories enhances subjective performance achievement, accompanied by increased emotional arousal, valence, and autonomic nervous system activity. Thirty-six professional wind instrument players participated in the study. Prior to performing musical pieces, participants engaged in one of three conditions: (1) recalling positive autobiographical memories, (2) recalling negative autobiographical memories, or (3) imagining routine pre-performance activities (no-memory condition). During the memory recall phase, heart rate was measured. After each performance, participants rated their subjective arousal, valence, and performance achievement. We calculated the heart rate variability indices, specifically SD1 (reflecting parasympathetic nervous system activity) and SD2/SD1 (used as a relative indicator of sympathetic predominance). The results showed that performance achievement, arousal, and valence were significantly higher in the positive than in the negative condition. Our path analysis further revealed that an increase in SD2/SD1 did not directly predict performance achievement; instead, it was associated with an increase in emotional valence, which in turn led to improved performance. These findings suggest that recalling positive performance memories activates sympathetic nervous system activity and fosters positive emotions, thereby enhancing the performance achievement of professional musicians.

KEYWORDS

musical expression, professional musicians, performance achievement, autonomic nervous system, autobiographical memories, heart rate variability

1 Introduction

For professional musicians, controlling their psychophysiological state before a performance is crucial not only for delivering high-quality performance, but also for sustaining long-term careers. However, managing this state is often challenging because of various uncontrollable factors, such as the audience, program, venue, and fellow performers, and the performer's uncertainty or limited control over these elements (Baumeister, 1984; Burin and Osório, 2017; Furuya et al., 2021; Kenny, 2011). These factors activate the sympathetic nervous system (SNS), a division of the autonomic nervous system (ANS), leading to physiological responses, such as increased heart rate, elevated respiratory rate, and sweating. These physiological responses are correlated with psychological reactions, including heightened anxiety (Abel and Larkin, 1990; Brouwer and Hogervorst, 2014; Mulcahy et al., 1990; Yoshie et al., 2009a). Such psychophysiological changes can degrade performance skills, resulting in unsatisfactory outcomes for musicians (Yoshie et al., 2009b).

Conversely, some studies indicate that SNS activation can coincide with richer emotional expressions during performance, thereby enhancing performance quality. For example, increased sympathetic activity has been observed during emotionally expressive performance (Nakahara et al., 2011). Moreover, a music competition winner demonstrated lower anxiety and superior performance despite exhibiting similar levels of sympathetic activation compared to other contestants (Yoshie et al., 2009c). These findings suggest that, even when SNS is activated, high-quality performance can be achieved by managing this activation. However, the mechanisms through which musicians regulate sympathetic activation to enhance performance quality remain unclear.

One promising approach to enhancing performance is to cultivate positive emotions during SNS activation prior to performance. Research on musical performance has shown that heart rate significantly increases, and SNS activity, closely linked to the fight-or-flight response preparing the body for action, intensifies immediately before taking the stage (Craske and Craig, 1984; Nakahara et al., 2011; Yoshie, 2008). Previous studies have demonstrated that positive emotional experiences can balance the activity of the sympathetic and parasympathetic nervous systems (PNS) (Kop et al., 2011; Kreibig, 2010; McCraty et al., 1995). The PNS is associated with rest-and-digest functions (Guyton and Hall, 2006; Saper, 2002) and can suppress SNS overactivation (Berntson et al., 1991). In contrast, negative emotional experiences are suggested to activate SNS activity, while having little effect on PNS activity (Kop et al., 2011; Kreibig, 2010; McCraty et al., 1995). Additionally, according to theories of emotion and ANS functioning, the interpretation of physiological responses leads to subjective emotional experiences (Craig, 2009; Damasio, 1996; Schachter and Singer, 1962). Therefore, even if SNS is activated, the body's response can vary depending on whether the subjective experience is positive or negative.

One way that performers manage their emotional state before taking the stage is through mental strategies such as imagery. Mental imagery has been widely studied in sports and performance psychology as a method for enhancing emotional control and performance quality under pressure (Orbach and Blumenstein, 2022). This technique often involves imagining successful past performances in vivid detail, including associated physical actions, emotional experiences, and contextual elements. Such imagery has been shown to reduce anxiety, boost confidence and self-efficacy, and improve performance outcomes (Li et al., 2024; Volgemute et al., 2024). Psychological research further indicates that recalling emotionally significant autobiographical memories can influence mood and stress responses. For instance, recalling positive experiences has been associated with the activation of brain regions involved in reward processing and emotion regulation, including areas of the prefrontal cortex (Speer and Delgado, 2017; van Schie et al., 2019). These activations are thought to contribute to reduced stress and improved emotional states. In contrast, recalling negative experiences has been linked to increased physiological arousal and heightened negative affect (MacNamara, 2018; Olsson, 2024), underscoring the role of emotional valence in shaping subsequent affective responses.

The present study aimed to examine whether recalling positive emotions enhances emotional valence even when SNS is activated and whether this leads to improved performance achievement in professional musicians. Since previous research suggests that autobiographical memories influence ANS responses (Kop et al., 2011; Strohm et al., 2021), we hypothesized that recalling a positive performance memory would activate the SNS, mitigate reductions in PNS activity, increase emotional arousal and valence, and enhance performance achievement compared with recalling negative memories. Additionally, we explored whether pre-performance ANS activity directly predicts post-performance achievement or indirectly influences emotional arousal and valence during performance, which, in turn, affects achievement. We hypothesized that ANS activity would influence emotional arousal and valence, thereby enhancing performance.

2 Materials and methods

2.1 Participants

Thirty-six active Japanese professional classical wind instrumentalists (10 males, 26 females; mean age ± SD: 37.69 ± 8.79 years, range: 24–60 years) participated in this study. All participants graduated from music universities and specialized in the instruments they played during the experiment (see Table 1). Their professional experience ranged from 3 to 38 years (mean ± SD: 15.72 ± 8.75 years). To ensure extensive performance experience and the ability to provide expert evaluations, the following inclusion criteria were established: participants had graduated from a music university or received equivalent professional training and had at least 3 years of professional experience as wind instrumentalists.

TABLE 1 Participants' instruments.

Instrument	# Participants	Instrument	# Participants
Flute	5	Baritone Saxophone	1
Oboe	2	Trumpet	4
B♭ Clarinet	6	Horn	4
Bassoon	1	Trombone	4
Alto Saxophone	6	Euphonium	3

Participants were recruited through the internet and social media platforms.

All participants reported no history of cardiovascular or mental health issues and confirmed their physical and mental well-being. Ethical approval for this study was obtained from the Research Ethics Committee of the Keio University Shonan Fujisawa Campus (Approval Number 507). The study was conducted in accordance with the Declaration of Helsinki, and written informed consent was obtained from all the participants. The experiment was conducted in soundproofed music studios located in Tokyo and Aichi Prefecture, Japan, where temperature and humidity were controlled.

2.2 Procedure and data acquisition

The experimental procedure is illustrated in Figure 1. The participants began by sitting to measure the electrocardiogram (ECG) to calculate their baseline heart rate and then transitioned to a standing position. In each condition, the participants were asked to recall autobiographical memories, perform an assigned musical piece, and evaluate their own performance. The order of the conditions was counterbalanced across participants to minimize order effects. On a separate day, the participants listened to the recordings of other participants' performances and provided objective evaluations.

ECG data were recorded wirelessly via Bluetooth on a computer (HP ZBook Firefly, HP Inc., USA) using dedicated software (OpenSignals (r)evolution, PLUX Wireless Biosignals, Portugal) at a sampling rate of 1,000 Hz. Three pre-gelled Ag/AgCl electrodes (biosignalsplux, PLUX Wireless Biosignals, Portugal) were placed on the participants' chests to ensure accurate ECG measurements.

All performances during the session were digitally recorded on a separate computer (MacBook Retina, Apple Inc., USA) using music production software (GarageBand, Apple Inc., USA) at a sampling rate of 44.1 kHz. A USB microphone (AT2020USB+, Audio-Technica, Japan) was used to capture the performed musical pieces. The microphone was positioned 1 m from the instrument at the height of the participant's mouth to ensure consistent and high-quality audio recording.

2.2.1 Preparation and baseline measurement of ECG

Participants were instructed to abstain from alcohol the day before the experiment and avoid caffeine intake on the day of the experiment. Upon arrival at the music studio, disposable electrodes were attached to the chest to measure ECG, and ECG monitoring was initiated. A brief practice session familiarized the participants with the studio acoustics and performed with the electrodes attached, during which the sound recording levels were adjusted.

The participants sat on a chair positioned in front of a music stand and were instructed to rest quietly with their eyes open for 5 min. ECG data collected during the initial resting period served as baseline data. After an additional 5 min of standing rest, the participants began the first condition. Following each condition, the participants rested in a seated position for 5 min to allow their heart rate to return to baseline before starting the next condition.

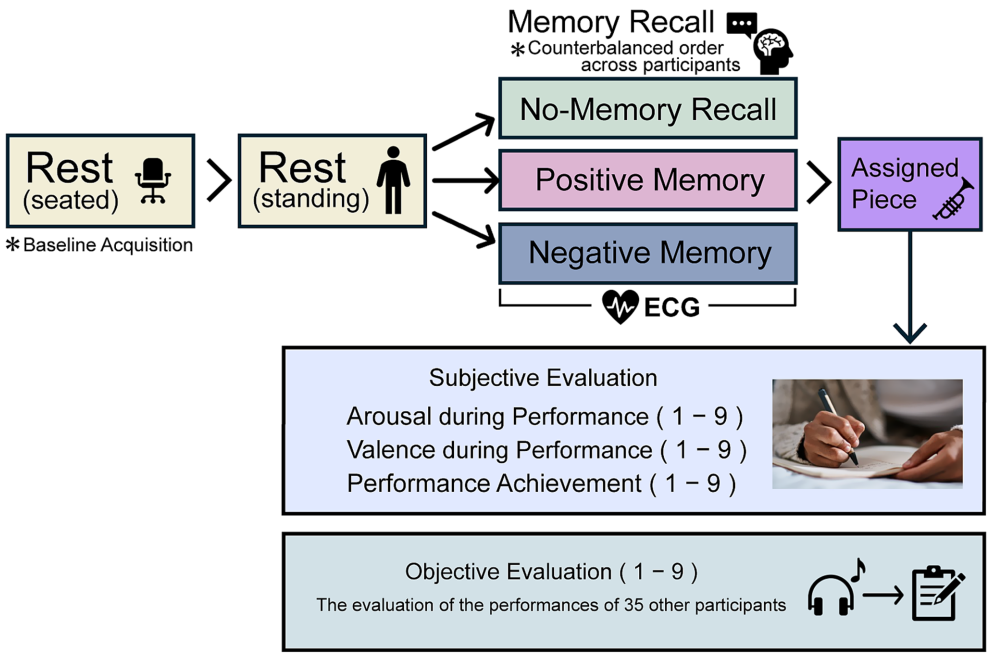

FIGURE 1
Experimental procedure. The three experimental conditions were counterbalanced across participants, and the entire procedure was repeated three times. Electrocardiogram (ECG) measurements were performed during the memory recall period. Subjective evaluations included arousal and valence, assessed retrospectively as indicators of the emotional state during the performance of the assigned piece, and performance achievement, evaluated based on the participants' sense of accomplishment after completing the piece. On a separate day, each participant objectively evaluated the performance of other participants.

2.2.2 Memory recall and ECG measurement

Participants completed three conditions in this study: (1) positive condition: participants performed the pieces after vividly recalling their most positive performance memory; (2) negative condition: participants performed the pieces after vividly recalling their most negative performance memory; and (3) no-memory condition: participants performed the assigned piece after imagining a scenario of waiting backstage, as if preparing to perform on stage, without recalling any specific memory.

To facilitate effective recall during the experiment, participants were instructed in advance to recall a specific performance during which they experienced their most positive (or negative) emotional state. They were asked to vividly remember what they experienced during the performance, including what they saw, heard, felt emotionally, and perceived in their bodies (e.g., breathing, muscle tension, or other bodily sensations). The instructions emphasized re-experiencing the subjective state of performing itself, rather than simply reflecting on the event as a whole, in order to simulate the emotional and physiological conditions associated with that moment.

The no-memory condition was designed to serve as a control that approximates a typical pre-performance state for professional musicians, without the cognitive load of recalling specific autobiographical performance memories. Since establishing a strictly emotionally neutral state is inherently difficult, participants were asked to imagine waiting backstage before the performance, a familiar and routine scenario for musicians, to minimize emotional and cognitive activation as much as possible while providing a realistic baseline.

ECG data recorded during the 5-min memory recall period for each task were used for heart rate variability (HRV) analysis. Following recommendations that ECG data collection for HRV analysis should last for at least 5 min (Electrophysiology TF of the ES, 1996), the memory recall duration for each condition was set accordingly.

2.2.3 Performed piece

In this study, an assigned musical piece was employed. Participants performed the piece using sheet music placed on a stand rather than playing from memory. The performance duration for the assigned piece was set to 5 min, and the piece was performed twice consecutively.

The assigned piece was "Ave Maria," composed by Charles Gounod in 1859. This composition combines the Latin text "Ave Maria" with a melody accompanied by J. S. Bach's Prelude No. 1 from The Well-Tempered Clavier, Book 1 (BWV 846). We selected this piece because of its accessibility to various wind instruments, manageable range, and low technical difficulty. Although it included exceptionally long phrases that required sustained and delicate breath control, as well as expressive nuance, these features likely helped wind instrument players maintain attentional focus and a moderate level of physiological arousal throughout the task.

Musical tempo and dynamics are known to influence cardiovascular and respiratory systems (Bernardi et al., 2006, 2009). To minimize physiological variability among participants owing to instrument-related differences, the piece's moderate tempo and gentle dynamics were deemed appropriate. To further ensure ease of performance, participants were allowed to select the key and were instructed to prepare the piece at a performance tempo of 72 beats per minute (bpm).

2.2.4 Subjective evaluation

At the end of each condition, participants provided subjective evaluations of their performance using a 9-point Likert scale to assess performance achievement (1 = did not perform to potential at all, 9 = performed to potential extremely well).

The Affect Grid (Russell et al., 1989; Takada and Yukawa, 2014) was employed to retrospectively evaluate emotional valence and arousal during performance. This tool allowed participants to rate their current emotional states on a 9 × 9 grid consisting of 81 cells. The horizontal axis represents the pleasure–displeasure dimension (emotional valence), where a score of 9 indicates high pleasure and 1 indicates low pleasure. The vertical axis represents the arousal dimension, where a score of 9 indicates high arousal, and 1 indicates low arousal.

2.2.5 Objective evaluation

To evaluate whether the performances conveyed the intended emotions and qualities to the audience, the participants provided objective assessments of other musicians' renditions of the assigned pieces. For this purpose, the first 20 s of each participant's recording were extracted and edited into 60-s clips. These clips were counterbalanced across the three experimental conditions to minimize the order effects. Evaluations were conducted using Google Forms, with assessment sessions scheduled at least 1 month after the experiment. Participants were instructed to use their own computers and headphones in a quiet environment.

Initially, the participants were asked to set their computer volume to 25% of the maximum level and were provided with a demo sound to facilitate accurate volume adjustment. While listening to the demo, the participants adjusted the volume to a comfortable and clear level. A headphone check test was administered to confirm proper headphone use (Woods et al., 2017). After these preparations, the participants rated each of the three performances from the other 35 participants using a 9-point scale.

2.3 Analysis

2.3.1 Preprocessing of ECG

ECG data were exported from the OpenSignals (r)evolution software and processed using the Kubios HRV Premium software, version 4.1.0 (Kubios, Finland). During preprocessing, the automatic noise detection setting was configured to "Medium," and the beat correction setting was set to "Automatic correction" to address artifacts. The R-R interval data were subsequently resampled at 4 Hz and any abnormal heart intervals were interpolated using a third-order spline, as recommended in a previous study (Tarvainen et al., 2014).

2.3.2 HRV calculation

We analyzed HRV using the Poincaré plot, a nonlinear method that displays the nth R-R interval on the x-axis and the $(n + 1)$ th interval on the y-axis, providing a visual representation of HRV (Figure 2).

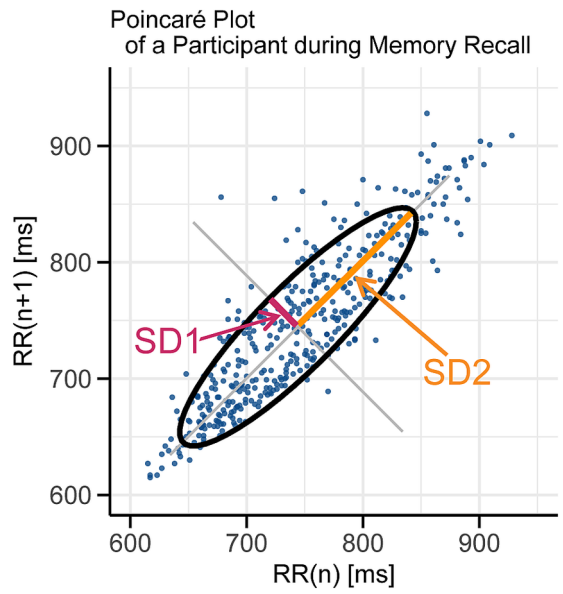

FIGURE 2
Example of Poincaré plot for a single participant. Each point represents a pair of consecutive R-R intervals: the *x*-axis shows the *n*th R-R interval and the *y*-axis shows the subsequent R-R interval. SD1 (pink line), the standard deviation along the short axis of the Poincaré plot, represents short-term fluctuations in R-R intervals and reflects parasympathetic activity. SD2 (orange line), the standard deviation along the long axis of the Poincaré plot, representing long-term variability influenced by both sympathetic and parasympathetic activities. The ellipse illustrates the overall distribution of these intervals defined by the SD1 and SD2 values.

From the Poincaré plot, we calculated SD1 (Equation 1.1) and SD2 (Equation 1.2), as follows:

$$SD1 = \sqrt{\frac{1}{2} Var\left(RR_n - RR_{n+1}\right)} \tag{1.1}$$

$$SD2 = \sqrt{2Var\left(RR_n\right) - \frac{1}{2} Var\left(RR_n - RR_{n+1}\right) + 2\mathrm{Cov}\left(RR_n, RR_{n+1}\right)} \tag{1.2}$$

where $Var\left(RR_n\right)$ represents the variance of the *n*th R-R intervals, $Var\left(RR_n - RR_{n+1}\right)$ represents the variance of the differences between the consecutive *n*th and $(n + 1)$ th R-R intervals, and $\mathrm{Cov}\left(RR_n, RR_{n+1}\right)$ represents the covariance between the consecutive *n*th and $(n + 1)$ th R-R intervals. In this study, we analyzed HRV from a 5-min duration of memory recall for each condition set prior to performance. We examined the SD2/SD1 ratio and SD1 as changes from the baseline to account for individual differences at rest.

We selected this method because the Poincaré plot is considered relatively less sensitive to minor respiratory variability than some linear spectral measures (Toichi et al., 1997; Penttilä et al., 2001; Nakagawa, 2016; Mishima, 2021). We also intentionally did not impose respiratory control to avoid interfering with participants' natural memory recall or subsequent performance.

SD1, the standard deviation along the short axis of the Poincaré plot, represents short-term fluctuations in R-R intervals and reflects parasympathetic activity. Short-term variability such as respiratory sinus arrhythmia is typically observed in the relaxed state. According to previous studies, SD1 correlates strongly with high-frequency (HF) components of HRV as well as the time-domain measure of the root mean square of successive differences (RMSSD), both reflecting parasympathetic activity. In fact, SD1 and RMSSD are mathematically related, with SD1 being equivalent to RMSSD divided by $\sqrt{2}$ (Brennan et al., 2001; Shaffer and Ginsberg, 2017).

In contrast, SD2, the standard deviation along the long axis of the Poincaré plot, represents long-term fluctuations in R-R intervals and is influenced by both sympathetic and parasympathetic activities. Long-term variability tends to increase when sympathetic activity predominates. Meanwhile, the SD2/SD1 ratio has been reported to correlate with the low-frequency to high-frequency (LF/HF) ratio, which is often used as a relative indicator of sympathetic predominance (Goit et al., 2016; Guzik et al., 2007; Hsu et al., 2012).

2.3.3 Statistics

To evaluate the effects of memory recall on performance, we analyzed whether subjective performance achievement differed among conditions using the Friedman test, followed by Dunn's test for multiple comparisons between the conditions. The same statistical tests were applied to emotional arousal and valence to determine whether these indicators varied across the conditions.

To examine whether SD2/SD1 and SD1 varied across conditions, we constructed two linear mixed-effects models: one with SD2/SD1 as the response variable, and the other with SD1. In both models, the condition was included as a fixed effect, and participant ID as a random effect. The linear mixed-effects model was run using the 'lme4' and 'lmerTest' packages in R (Bates et al., 2015; Kuznetsova et al., 2017). The model formulas (Equations 2.1, 2.2) are as follows:

$$\frac{SD2}{SD1} \sim Condition + \left(1 \mid Participant\ ID\right) \tag{2.1}$$

$$SD1 \sim Condition + \left(1 \mid Participant\ ID\right) \tag{2.2}$$

Using the positive condition as a reference, we quantitatively evaluated the deviations in the negative and no-memory conditions. Additionally, the negative condition was used as a reference to assess differences between the positive and no-memory conditions. To estimate semi-standardized effect sizes for the fixed effects, we standardized the outcome variables (SD2/SD1 and SD1 differences from baseline) using z-scores and re-fitted the linear mixed-effects models. This approach enables interpretation of the condition effects in standard deviation units while preserving the categorical nature of the predictor variable (Lorah, 2018). Additionally, to assess the contribution of between-subject variance, we calculated the intraclass correlation coefficient (ICC) for each model using the performance package in R (Lüdecke et al., 2021). Model fit was assessed by calculating the marginal R^2 (R_m^2) and conditional R^2 (R_c^2) using the 'partR2' package in R (Stoffel et al., 2021). R_m^2 represents the explanatory power of the fixed effects alone, whereas R_c^2 reflects the explanatory power of both the fixed and random effects.

To explore the relationships between SD2/SD1, SD1, arousal, valence, and performance achievement, we conducted a path analysis using structural equation modeling (SEM). In the model, performance achievement was predicted by valence and arousal; valence and arousal were in turn predicted by SD2/SD1 and SD1. Additionally, performance achievement was directly predicted by SD2/SD1 and

SD1. Data from all conditions were combined for this analysis without accounting for repeated measurements. SEM was performed using the 'lavaan' package in R (Rosseel, 2012).

Additionally, the Friedman test was used to analyze whether objective evaluations by other participants differed among the three conditions. Finally, Spearman's rank correlation coefficient was calculated to investigate the relationship between the subjective evaluations of performance in the three conditions and objective evaluations by other participants.

For all statistical tests, the significance level (α) was set at 0.05. p-values for multiple comparisons were adjusted using the Bonferroni method and are denoted as p_b in the Results section.

3 Results

3.1 Performance achievement, arousal, and valence

The mean performance achievement scores were 6.06 ± 1.59 (mean ± SD) for the positive condition, 5.03 ± 1.48 for the negative condition, and 5.81 ± 1.51 for the no-memory condition (Figure 3A). The Friedman test revealed a significant difference in the performance achievement scores among the conditions ($\chi^2(2) = 9.09$, $p = 0.011$). Post-hoc comparisons using Dunn's test indicated that the positive condition had a significantly higher

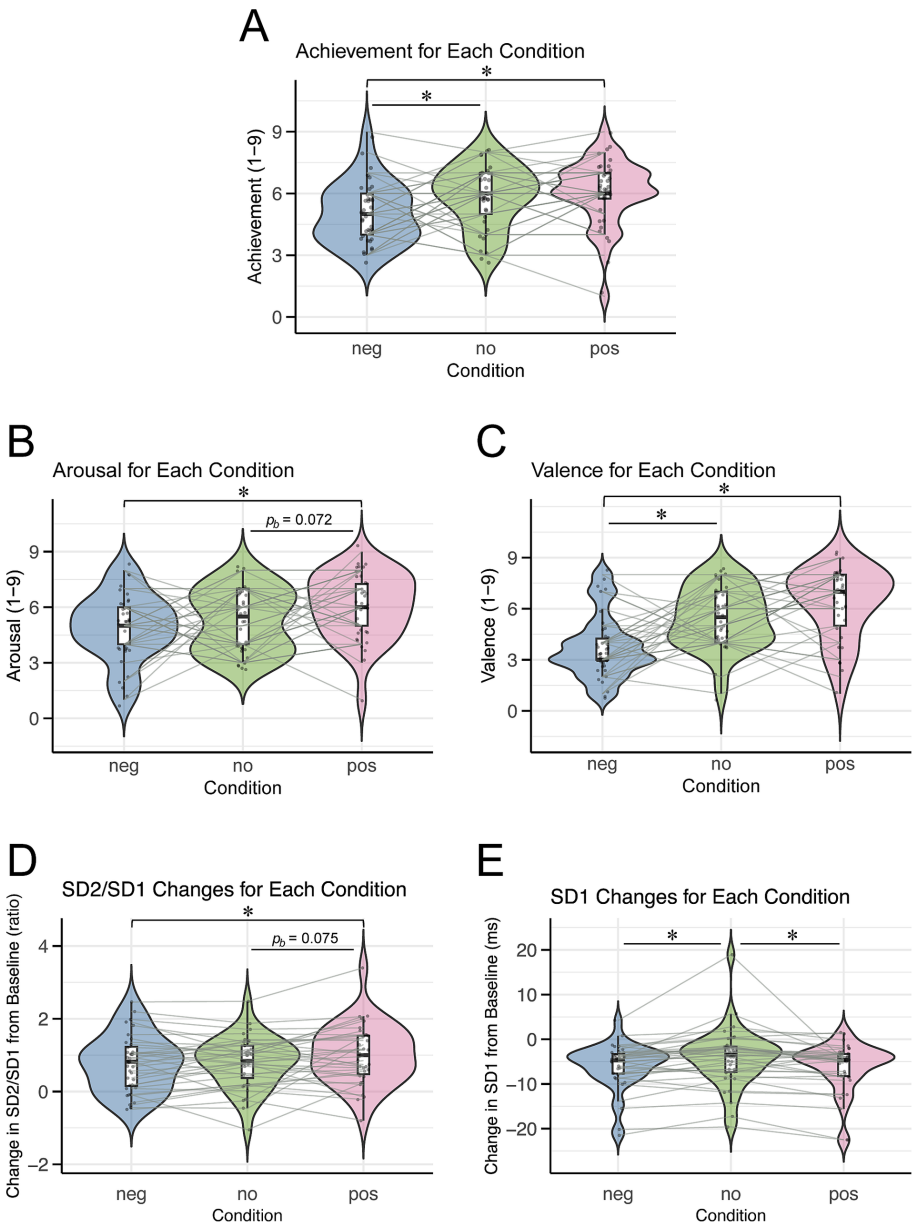

FIGURE 3
Violin plots illustrating subjective ratings and ANS indices for each condition. Each dot represents an individual participant, and asterisks ("*") indicate significant differences between conditions (*p_b < 0.05). Condition labels: "neg" = negative condition, "no" = no-memory condition, "pos" = positive condition. **(A)** Performance achievement. **(B)** Arousal. **(C)** Valence. **(D)** Changes in SD2/SD1 from the baseline. **(E)** Changes in SD1 from the baseline.

achievement score than the negative condition ($z = 3.10$, $p_b = 0.003$), and the no-memory condition also scored higher than the negative condition ($z = 2.34$, $p_b = 0.029$). However, there was no significant difference between positive and no-memory conditions ($z = 0.76$, $p_b = 0.670$).

The mean arousal scores were 6.06 ± 1.76 for the positive condition, 4.89 ± 1.83 for the negative condition, and 5.28 ± 1.68 for the no-memory condition (Figure 3B). The Friedman test showed a significant difference in arousal scores across conditions ($\chi^2(2) = 7.89$, $p = 0.019$). Dunn's *post hoc* analysis revealed a significant difference between the negative and positive conditions ($p_b = 0.012$). However, no significant differences were found between the negative and no-memory conditions ($p_b = 0.739$) or between the no-memory and positive conditions ($p_b = 0.072$).

The mean valence scores were 6.31 ± 2.10 in the positive condition, 3.78 ± 1.87 in the negative condition, and 5.47 ± 1.76 in the no-memory condition (Figure 3C). The Friedman test indicated highly significant differences in valence scores across the conditions ($\chi^2(2) = 18.38$, $p < 0.001$). Post-hoc analysis using Dunn's test identified significant differences between the negative and positive conditions ($p_b < 0.001$) and between the negative and no-memory conditions ($p_b = 0.001$). By contrast, no significant difference was observed between the no-memory and positive conditions ($p_b = 0.174$).

3.2 SD2/SD1 and SD1

The mean changes in the SD2/SD1 ratio (reflecting SNS activity) from baseline were 1.00 ± 0.82 (mean ± SD) in the positive condition, 0.77 ± 0.77 in the negative condition, and 0.80 ± 0.71 in the no-memory condition (Figure 3D). Linear mixed-effects modeling revealed that SD2/SD1 was significantly higher in the positive condition than in the negative condition, whereas no significant difference was observed between the positive and no-memory conditions (Table 2). For SD2/SD1, the estimated effect sizes (β coefficients) ranged from 0.03 (no-memory vs. negative) to 0.31 (positive vs. negative). These values reflect the magnitude of the effect in terms of standard deviations, with the outcome variable standardized. Detailed results are provided in Supplementary Table 1. The model fit was assessed with $R^2m = 0.02$ and $R^2c = 0.75$.

The mean changes in SD1 (reflecting PNS activity) from baseline were −6.25 ± 5.52 ms in the positive condition, −6.09 ± 5.20 ms in the negative condition, and −4.16 ± 6.64 ms in the no-memory condition (Figure 3E). Linear mixed-effects modeling revealed that SD1 was significantly higher in the no-memory condition than in both the positive and negative conditions, whereas no significant difference was observed between the positive and negative conditions (Table 3). For SD1, the estimated β coefficients ranged from 0.03 (negative vs. positive) to 0.36 (no-memory vs. positive), likewise reflecting the effect magnitude in terms of standard deviations. Supplementary Table 2 provides the full results. The model fit was assessed with $R^2m = 0.03$ and $R^2c = 0.83$.

3.3 Relationship between psychological and physiological indicators

We examined the relationships between psychological and physiological indicators using structural equation modeling (SEM). Data from all the conditions were combined without repeated measurements (Figure 4A). The model tested the hypothesis that performance achievement is predicted by emotional valence and arousal, valence and arousal are predicted by SD2/SD1 and SD1, and post-performance achievement is predicted by SD2/SD1 and SD1. Model fit indices indicated a good fit (Comparative Fit Index = 1.00, Tucker-Lewis Index = 1.14, Root Mean Square Error of Approximation = 0.00, and Standardized Root Mean Square Residual = 0.01).

The scatter plots for each pairwise relationship are shown in Figures 4B–F. The analysis revealed that SD2/SD1 exerted a significant positive effect on valence ($\beta = 0.19$, $p = 0.038$; Figure 4F), and valence, in turn, had a significant positive effect on performance achievement ($\beta = 0.68$, $p < 0.001$; Figure 4E). Additionally, SD1 had a significant negative effect on achievement ($\beta = -0.18$, $p = 0.012$; Figure 4C).

In contrast, neither SD2/SD1 nor arousal significantly predicted achievement ($\beta = -0.03$, $p = 0.685$, $\beta = -0.08$, $p = 0.333$, respectively; Figures 4B,D). Similarly, neither SD2/SD1 nor SD1 significantly predicted arousal ($\beta = -0.16$, $p = 0.098$ and $\beta = -0.09$, $p = 0.328$, respectively), and SD1 did not significantly predict valence ($\beta = 0.05$, $p = 0.496$). All β values were standardized.

TABLE 2 Pairwise comparisons for the conditions in SD2/SD1 using the linear-mixed regression models.

Compared conditions	β	SE	df	t-value	p_b
Negative – Positive	−0.24	0.09	70	−2.57	0.037
No-memory – Positive	−0.21	0.09	70	−2.29	0.075
No-memory – Negative	0.03	0.09	70	0.29	1.00

TABLE 3 Pairwise comparisons for the conditions in SD1 using the linear-mixed regression models.

Compared conditions	β	SE	df	t-value	p_b
Negative – Positive	0.16	0.58	70	0.28	1.00
No-memory – Positive	2.08	0.58	70	3.59	0.002
No-memory – Negative	1.92	0.58	70	3.31	0.004

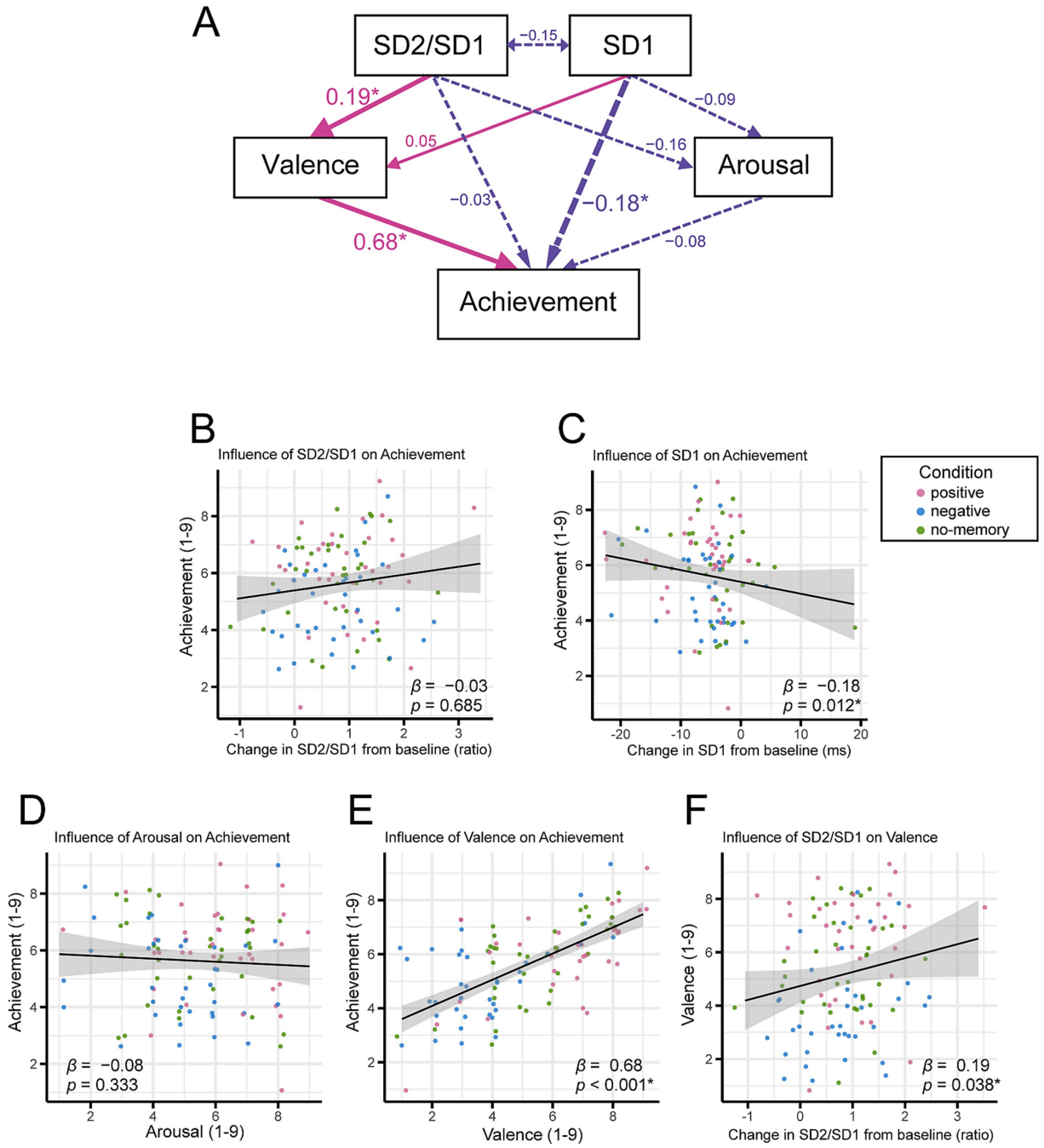

FIGURE 4
Relationship between psychological and physiological indicators. **(A)** Results of the path analysis showing how emotional valence, arousal, SD2/SD1, and SD1 influence performance achievement. Single-headed arrows represent direct predictions, whereas double-headed arrows represent correlations. Pink arrows indicate positive effects and purple (dotted) arrows indicate negative effects. The numbers next to each arrow are standardized estimates indicating the strength and direction of these effects (*$p < 0.05$). **(B–F)** Scatterplots illustrating pairwise relationships among the variables. Each dot represents an individual participant, with pink, blue, and green dots corresponding to the positive, negative, and no-memory conditions, respectively. The β coefficients and p-values shown here are consistent with those reported in the path analysis.

3.4 Correlation between subjective and objective evaluations

We additionally examined whether the performance effectively conveyed the intended emotions and quality to the audience. The Friedman test revealed no significant differences between conditions ($\chi^2(2) = 0.58$, $p = 0.75$, Figure 5A). In contrast, after combining the data for all conditions, we found a significant correlation between subjective performance achievement and objective evaluations after z-scoring for both variables (Spearman's rank correlation coefficient = 0.23, $p = 0.016$; Figure 5B). The 95% confidence interval, calculated using the bootstrap method, ranged from 0.06 to 0.40,

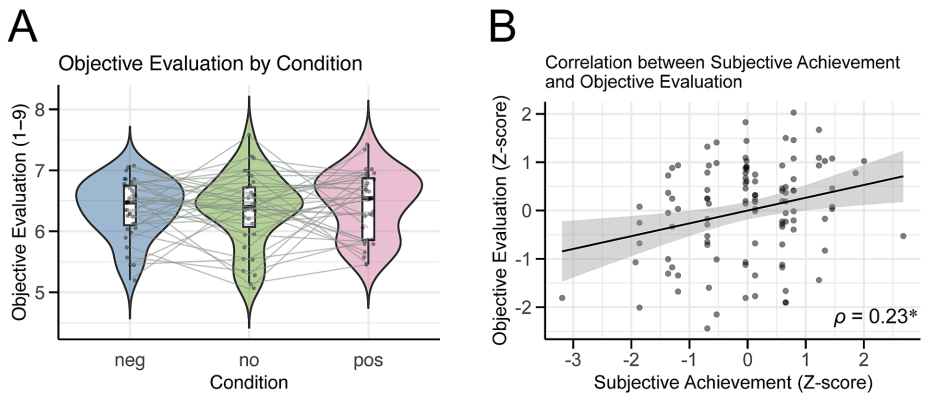

FIGURE 5
Results of the objective evaluation. **(A)** Violin plot showing the objective evaluation scores for each condition. Each dot represents the average score for each participant's performance under these conditions. **(B)** Scatter plot illustrating the relationship between subjective achievement and objective evaluation. Each dot represents a z-score evaluation value for each participant. The regression line indicates the relationship between the two variables, and the grey band represents the standard error of the regression line. ρ is Spearman's rank correlation coefficient, and a significant positive correlation was found (*$p < 0.05$).

confirming a weak positive correlation between subjective performance achievement and objective evaluations.

4 Discussion

This study investigated whether recalling a positive performance memory could activate SNS, mitigate reductions in PNS activity, increase emotional arousal and valence, and ultimately enhance performance. We also explored whether pre-performance ANS activity directly predicted post-performance achievement or indirectly influenced emotional arousal and valence during performance, thereby affecting achievement.

4.1 Effects of recalling positive compared to negative performance memories

Our results revealed that subjective performance achievement was significantly higher when participants recalled positive performance memories than when they recalled negative ones (Figure 3A). This finding suggests that recalling positive memories can facilitate higher-level performances. In addition, emotional arousal and valence were both significantly greater in the positive condition than in the negative condition (Figures 3B,C), indicating that recalling positive memories not only heightens arousal, but also enhances emotional valence during performance.

We also found that the change in the SD2/SD1 ratio from baseline was significantly higher in the positive condition than in the negative condition (Figure 3D), suggesting a stronger SNS activation when recalling positive versus negative memories. This increase in sympathetic activity aligns with previous studies showing that recalling positive emotional experiences enhances sympathetic responses (McCraty et al., 1995), and that recalling autobiographical memories can elevate ANS responses (Strohm et al., 2021). Moreover, earlier research has established that SNS activity intensifies immediately before performance (Craske and Craig, 1984; Nakahara et al., 2011; Yoshie, 2008), presumably preparing the body for optimal action.

Considering that the SD2/SD1 findings align with our observation of higher subjective performance achievement, arousal, and valence in the positive condition than in the negative condition, these results support the hypothesis that recalling positive performance memories, accompanied by SNS activation, enhances valence and increases arousal during performance, ultimately contributing to improved performance. Furthermore, our results extend the previous findings (Speer and Delgado, 2017; van Schie et al., 2019; MacNamara, 2018; Olsson, 2024) that recalling positive or imagined experiences can influence mood and emotion regulation, by demonstrating that such memory-based strategies may also contribute to enhanced performance outcomes in professional musicians.

While these benefits were evident when comparing the positive and negative conditions, it is noteworthy that there was no significant difference in performance achievement between the positive and no-memory conditions. This pattern may reflect not only a detrimental effect of negative recall, but also the fact that the no-memory condition, which was designed to simulate each musician's typical pre-performance state, may have facilitated a mental and physiological state that was more conducive to performance. Because the no-memory condition was not strictly emotionally neutral, future research should include a more carefully controlled neutral baseline to better examine the differential effects of positive and negative memory recall.

To examine whether these effects were influenced by individual differences in years of professional experience and trait-level performance anxiety, we conducted additional linear mixed-effects analyses including condition, years of experience, and trait anxiety as fixed effects, and subject as a random effect. The outcome variables were performance achievement, SD2/SD1, and SD1. The results revealed no significant effects of either experience or trait anxiety across any of the models (all $ps > 0.05$), and the direction and significance of condition effects remained consistent. These findings suggest that individual differences in professional experience and trait

anxiety did not systematically confound the main results. Full statistical results are provided in Supplementary Tables 3–8.

Previous studies have shown that positive emotions enhance activity in the prefrontal cortex and anterior cingulate cortex (ACC) (Ashby et al., 1999), and imagining musical performance has been observed to activate functional connectivity between the angular gyrus (AG) and ACC (Tanaka and Kirino, 2019). Integrating these findings, it is possible that recalling positive performance memories in this study facilitated processes such as emotion regulation, decision-making, and attentional control, which may have contributed to the improvement in performance achievement. Although we did not measure neural activity in this study, the observed benefits of recalling positive performance memories on performance achievement may be mediated by the underlying neural mechanisms. Future research should examine whether activation of the prefrontal cortex, ACC, and AG occurs when musicians recall positive autobiographical memories.

4.2 Comparisons of PNS activity between recalling positive and negative memories

We observed no significant difference in the change in SD1 between positive and negative conditions (Figure 3E). Given the antagonistic relationship between the sympathetic and parasympathetic nervous systems (Guyton and Hall, 2006; Saper, 2002), and considering our initial hypothesis that the positive condition would yield a higher SD2/SD1 ratio, we expected a more pronounced decrease in parasympathetic activity in the positive condition. However, the SD1 results did not support this prediction.

Previous studies have shown that positive emotions can simultaneously enhance sympathetic and parasympathetic activity (Kop et al., 2011; Kreibig, 2010; McCraty et al., 1995). This dual enhancement may explain why SD1 did not decline as much as anticipated in the positive condition despite the elevated SD2/SD1 values. In contrast, negative emotional experiences are reported to increase sympathetic activity, while exerting relatively little influence on parasympathetic activity (Kop et al., 2011; Kreibig, 2010; McCraty et al., 1995). Consequently, in the negative condition, SD1 may have decreased more proportionally in response to changes in SD2/SD1.

Additionally, to further validate measurement stability of SD1, we ran a supplementary analysis. We calculated RMSSD, a widely used time-domain measure of parasympathetic activity, and compared it with SD1. Across all conditions, RMSSD and SD1 demonstrated extremely high correlations (neg: $r = 0.997$, no: $r = 0.999$, pos: $r = 0.999$; all $p < 0.001$), reinforcing the validity of SD1 as a proxy for short-term parasympathetic modulation. These findings are consistent with previous reports indicating that SD1 and RMSSD reflect comparable aspects of short-term HRV (Brennan et al., 2001; Guzik et al., 2007; Ciccone et al., 2017; Shaffer and Ginsberg, 2017).

4.3 Effects of no-memory recall compared to memory-recall conditions

Interestingly, we found that performance achievement, emotional valence, and SD1 were all significantly lower in the negative memory condition than in the no-memory condition (Figures 3A,C,E). These results suggest that recalling negative performance memories decreases achievement, valence, and PNS activity, as indicated by SD1, compared with simply imagining one's routine pre-performance scenario. As SD1 reflects the rest-and-digest functions of the PNS (Guyton and Hall, 2006; Saper, 2002), its lower values in the negative condition may indicate that participants were less relaxed before performing. This reduced relaxation may have led to decreased valence during performance, ultimately contributing to a lower perceived achievement.

Another possible explanation is that the no-memory condition imposed a lower cognitive load than either memory recall condition. We also observed that SD1 was higher in the no-memory condition than in the positive condition (Figure 3E), suggesting that imagining a familiar pre-performance state allowed the participants to remain more relaxed. Additionally, we did not control individual differences in what the participants envisioned during the no-memory condition. These factors may have enabled participants to achieve a relatively more comfortable state, leading to enhanced valence and, ultimately, improved performance compared to the negative condition.

4.4 Relationship between psychological and physiological indicators

After combining data from all conditions, the path analysis revealed that valence had a significant positive effect on performance achievement, and the SD2/SD1 ratio exerted a significant positive influence on valence (Figure 4A). However, SD2/SD1 did not directly predict performance achievement. These results suggest that while activation of the sympathetic nervous system does not directly enhance performance achievement, it does increase emotional valence, which, in turn, improves musical performance. Although the standardized estimate of SD2/SD1's effect on valence was small, these findings support our hypothesis that sympathetic activity, when accompanied by positive emotions, contributes to enhanced performance achievement.

Conversely, SD1 did not significantly affect arousal or valence and negatively predicted performance achievement (Figure 4A). Rather than implying that increased parasympathetic activity is harmful, we propose that an optimal level of physiological activation, rather than excessive relaxation, may be more beneficial for performance. This perspective aligns with the idea that a certain degree of sympathetic readiness may support effective musical expression, especially under performance conditions (Robazza et al., 2004; Yoshie et al., 2008).

4.5 Correlation of subjective and objective evaluation

We found no significant differences in objective evaluations across the conditions (Figure 5A). However, there was a positive correlation between subjective performance achievement and objective evaluation (Figure 5B). Notably, the objective evaluations were based only on the first 20 s of the piece, with approximately six or seven notes. Despite this limited amount of information, the positive correlation suggests

that the enhanced quality of performances, potentially arising from recalling autobiographical performance memories, was perceptible to the listeners.

Future research should examine the criteria used in objective evaluations to determine which aspects of recorded performances are most effectively communicated. Understanding these criteria may offer insight into how positive autobiographical recall translates into perceptible improvements in musical output.

4.6 Limitations and future directions

This study had several limitations. First, because the experiment was conducted in a music studio, it remains unclear how these findings can be generalized to actual concert settings where professional musicians must avoid making mistakes. Although the performances were conducted without a live audience, all sessions were recorded, and participants were informed in advance that their performances would be evaluated by other professional musicians. This likely induced moderate performance pressure and social evaluative stress. Moreover, although the musical piece involved relatively few notes and a simple structure, it contained exceptionally long phrases that required sustained and delicate breath control, as well as expressive nuance, presenting substantial musical and physiological demands for wind instrumentalists. Importantly, our supplementary analyses indicate that the quality of performance was effectively conveyed to listeners (Figure 5B), suggesting that the findings may hold true in real concert halls as well. This raises the possibility that the present findings could generalize to more technically demanding repertoire. Future studies should further investigate how memory-induced changes influence motor performance under higher-arousal conditions and with more complex musical material.

Second, the study design involves methodological limitations in the assessment of ANS activity, specifically the exclusive reliance on HRV and the absence of respiratory monitoring. Because HRV analysis requires several minutes of data, it is challenging to capture transient dynamic changes in ANS activity (Malik, 1996; Shaffer and Ginsberg, 2017). Among the HRV-derived measures, the SD2/SD1 ratio is commonly used as a relative indicator of sympathetic dominance and has been shown to correlate with the LF/HF ratio, which itself does not directly reflect sympathetic outflow. To enhance the specificity of future studies, additional physiological indicators of sympathetic activity, such as pupil diameter (Bishop et al., 2021) and skin conductance (Brouwer and Hogervorst, 2014), should be incorporated.

In addition, we acknowledge that respiration was neither monitored nor controlled during ECG recording. SD1 and SD2/SD1 are considered relatively robust to minor respiratory fluctuations (Toichi et al., 1997; Penttilä et al., 2001; Nakagawa, 2016; Mishima, 2021), and our supplementary analyses suggested a certain degree of measurement stability in SD1. However, these indices are not entirely immune to respiratory influences. The lack of concurrent respiration monitoring is therefore a methodological limitation of this study. Future studies should incorporate respiration recordings to improve the physiological specificity of HRV analysis.

Third, the nature of the no-memory condition also presents limitations, particularly regarding differences in how participants mentally simulated the scenario. Although this condition was designed to minimize emotional activation by simulating a familiar pre-performance scenario, individual differences in participants' mental imagery may have introduced variability in emotional or cognitive responses. Establishing a strictly emotionally neutral state is inherently difficult in experimental settings, particularly in studies involving professional musicians. Future studies may consider employing more rigorously controlled baseline conditions to further isolate the effects of autobiographical memory recall on autonomic and performance-related outcomes.

Fourth, we did not collect information regarding the menstrual cycle phase of female participants. Previous research suggests that autonomic nervous system reactivity may fluctuate across the menstrual cycle, with both sympathetic and parasympathetic activities peaking during the ovulatory phase (Little and Zahn, 1974). Although the within-subject design of the present study likely mitigated some inter-individual variability, the potential confounding effect of menstrual cycle phase cannot be entirely excluded. Future studies may benefit from incorporating the menstrual cycle tracking to further refine the assessment of autonomic function in female musicians.

Nevertheless, the present findings suggest that recalling positive autobiographical performance memories can help regulate emotional and physiological states before performance, contributing to enhanced subjective achievement. This offers a conceptual basis for future studies in more ecologically valid contexts and practical guidance for musicians and other performers seeking accessible, low-risk strategies to optimize their internal state before high-stakes performance.

5 Conclusion

We found that professional musicians who recalled memories of positive performance experienced greater performance achievement. Path analysis integrating data from all conditions revealed that, although SD2/SD1 did not directly predict performance achievement, increases in SD2/SD1 were associated with higher valence, which in turn led to improved achievement. These results suggest that consciously recalling positive memories before a performance in response to rising ANS activity may help professional musicians interpret their physiological state more positively, ultimately enhancing their on-stage performance.

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 Keio University Shonan Fujisawa Campus (Approval Number 507). 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

AW: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. SK: Data curation, Formal analysis, Methodology, Supervision, Validation, Writing – review & editing. TS: Conceptualization, Methodology, Validation, Writing – review & editing. SF: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Visualization, 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 interpreted 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.2025.1544069/full#supplementary-material

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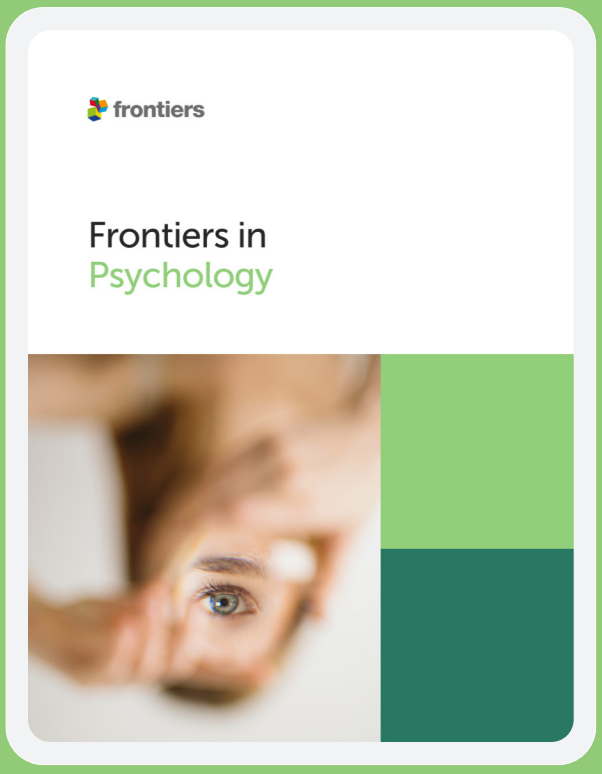

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