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Current and future directions in infant research: How can multiple measures help us learn more?

Annamaria Porru[1]*, Tamara Bastianello[1], Margaret Addabbo[2], Giulia Calignano[1], Gisella Decarli[3,4] and Jessica Gemignani[1]

[1]Department of Developmental Psychology and Socialization, University of Padova, Padova, Italy, [2]Department of Psychology, University of Bologna, Bologna, Italy, [3]Department of Human Sciences, Link Campus University, Rome, Italy, [4]Department of Psychology and Cognitive Science, University of Trento, Rovereto, Italy

EDITED BY
Catherine Sandhofer,
University of California, Los Angeles,
United States

REVIEWED BY
Elena Commodari,
University of Catania, Italy
Brianna Kaplan,
University of Texas at Austin, United States

*CORRESPONDENCE
Annamaria Porru
✉ annamaria.porru@unipd.it

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The complexity of early infancy poses relevant challenges for researchers aiming to understand developmental processes. While infants are active learners, their communication modalities remain limited and rudimentary during the first 2 years of life. Consequently, it is particularly challenging to explore their cognitive abilities and track their socio-emotional developmental trajectories. The standard model in the field has been to consider one measurement method as sufficient for detecting and quantifying developmental phenomena. However, only a multiple measures design permits verification of each measure's alignment with the underlying construct and yields less equivocal functional interpretations supported by convergent empirical signals. In this perspective paper, we emphasize the importance of adopting a multiple measures approach and provide practical recommendations and suggestions, including strategies for applying these methods. Specifically, we illustrate how integrating these methods can enable researchers to draw meaningful conclusions in infant research. Finally, we argue that the complexity arising from the critical selection of a multiple measures approach should be viewed as a unique opportunity to formulate robust developmental theories capable of predicting outcomes across different domains, rather than a limitation. However, multiple measures research is not free of challenges. Recognizing the strengths and limitations of integrating multiple measures is the first step toward developing an integrative approach that preserves ecological validity while producing robust and meaningful results. In conclusion, this paper aims to encourage developmental psychology researchers to critically embrace multiple measures research, despite the additional effort and time it may require.

KEYWORDS

infants, measurement, methodology, multimodal, multiple measures, techniques

Introduction

Studying infant development provides scientists in educational and developmental psychology with a unique opportunity to track developmental trajectories. The first two years of life, in particular, represent a period of maximum neural plasticity, during which infants acquire a range of abilities that are crucial for their future development (Fox et al., 2010). It is during this period that the foundations of many essential skills are established. However, understanding how and when infants acquire these skills has posed several challenges for developmental scientists (Davis-Kean and Ellis, 2019; LoBue et al., 2020). In fact, although infants are active learners in their environment, they cannot verbally communicate their thoughts, preferences, needs, learning strategies, or mental processes. Researchers have often discussed which strategies, measures, and techniques are most suitable for studying cognitive and socio-emotional development during the critical time window of infancy, with the aim of achieving empirical rigor, validity, and theoretical grounding.

A variety of measures and techniques have been utilized in developmental psychology research, with each method demonstrating distinct strengths and weaknesses, particularly when employed individually. Traditionally, developmental research that depends on a single method at a time risks imposing serious limitations on the overall understanding of infant development. Results from a single measure may be difficult to merge into the child's everyday experiences, as many internal and external factors influencing development are not accounted for.

For instance, naturalistic observation is considered one of the most valid and ecological methods for examining infant's behaviors in their natural environment (e.g., Karasik et al., 2011; Rodriguez and Tamis-LeMonda, 2011). Nevertheless, the process is not free of challenges, including the difficulty of achieving a useful data set from a limited sample, and the establishment of consensus among researchers regarding the operationalization and interpretation of the observed phenomena or behaviors of interest. Indeed, the interpretation of data coming from naturalistic observation relies heavily on the judgement of the research team when categorizing behaviors. This process is often limited by established team norms, subjective judgment, coder drift, and the inherent difficulty of securing strong inter-rater reliability. One technique that could help reduce those biases while concurrently boosting data collection sources in a naturalistic environment is the complementary use of the eye tracking technique, which involves monitoring eye movement and changes in pupillary response (Sirois et al., 2023). However, even such "objective" measure is also subjected to biases in data processing that require filtering, blink and artifact removal, baseline correction, luminance control, and time-sensitive modeling (Van Rij et al., 2019), increasing the risk of data loss and analytical variability across studies (Calignano et al., 2023).

Furthermore, since many cognitive and perceptual processes are invisible to the human eyes and cannot be captured by behavioral tools, developmental psychologists have employed other non-invasive physiological and neural techniques such as facial Electromyography (fEMG), ElectroEncephaloGraphy (EEG) and functional Near Infrared Spectroscopy (fNIRS) to gather data on infants' cognitive, perceptual and socio-emotional mechanisms. It must be observed that even when these techniques are employed alone, they give rise to a number of methodological trade-offs (Csibra et al., 2008; Gervain et al., 2023).

Among these methods, the fEMG has been demonstrated to detect subtle facial muscle activations in responses to affective and social cues (Addabbo et al., 2020, 2024). However, infant recordings are labor-intensive due to electrode placement challenges and motion artifacts. Moreover, even EEG, a cornerstone of developmental neuroscience, is limited by the difficulties of acquiring clean neural signals from infants. Indeed, infant EEG recordings are often particularly noisy due to movement and blinks. It is important to note that pre-processing requirements (artifact rejection, filtering, epoching, synchronization, and subsequent ERP or time-frequency analysis) have the potential to obscure the actual experimental component, thereby compromising the process of generating conclusive findings. Conversely, fNIRS, despite its enhanced tolerance for motion, yields indirect and temporally more protracted indices of neural activation. In addition, the process necessitates intricate synchronization procedures, advanced motion correction algorithms, and costly hardware components (Brigadoi et al., 2014). The high rate of attrition observed in infant samples (Baek et al., 2023) further restricts the tool's efficacy as a standalone methodological instrument.

Further, researchers have employed physiological measures in infant research. For example, electrocardiogram (ECG) based measures such as heart rate variability (HRV), heart rate (HR), and respiratory sinus arrhythmia (RSA), skin conductance (electrodermal activity, EDA), and endocrine markers such as salivary cortisol or oxytocin. However, the interpretation of these signals is complicated by their sensitivity to environmental factors, body movements, temperature, feeding status, and circadian variability. Moreover, as these measures only capture isolated components of infants' responses, they offer a partial view of the processes being investigated.

Single method approaches underscore the risk of deriving conclusions from limited and potentially biased data sets. They also highlight the need for multiple measures designs capable of compensating for the inherent weaknesses of each individual technique.

Following such a logic, in recent decades, scientists have merged innovative approaches and targeted paradigms using multiple measures to access aspects of infant development invisible to our eyes. In this perspective paper, the aim is to encourage the adoption of multiple measures approaches in infant research. The rationale behind this argument is that such approaches could enable a multifaceted and ecologically valid understanding of early socio-cognitive processes. It is anticipated that, in future developmental psychology research, multiple measures projects will become essential for assessing how infants interpret the world and how foundational skills emerge. The objective of this paper is to clarify how employing multiple measures can uncover complementary facets of the same behavior, and how this approach can be advantageous for research on infant development.

The benefits of multiple measures approach

Assessing infants' cognitive and socio-emotional abilities across multiple measures enables researchers to integrate information from neural, behavioral, and physiological domains, providing a more comprehensive characterization of the underlying developmental mechanism. From our perspective, adopting a multiple measures approach offers two key advantages for developmental psychological research. In further confirmation of this, recent empirical work that has begun to integrate multiple measures within the same experimental framework substantiates these benefits (e.g. Gemignani and Gervain, 2024; Tan and Hamlin, 2024).

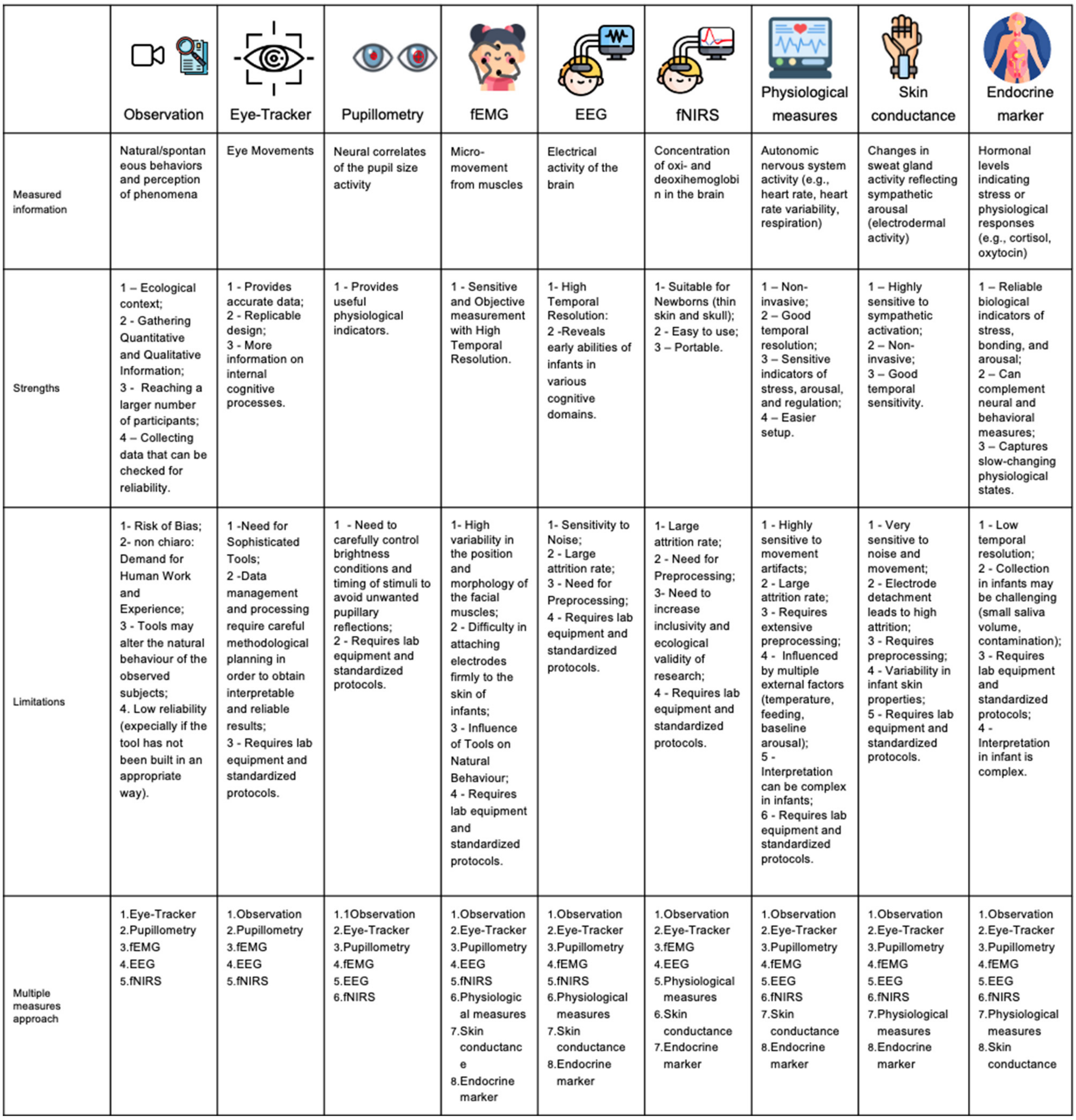
Firstly, it is important to highlight the substantial advantage concerning the enhanced validity, reliability and generalizability of findings, particularly when developmental phenomena are examined across diverse contexts, tasks or methodological approaches. For instance, a multiple measures approach has the potential to facilitate the validation of the same construct through behavioral, physiological and neural evidence. Furthermore, a multiple measures approach facilitates the conceptual replication and the further extension of findings obtained in controlled laboratory settings to more naturalistic and ecological environments (Slone et al., 2018; Soares et al., 2022; Li et al., 2025). In recent times, there has been an increasing need to corroborate prior conclusions across developmental domains through multidisciplinary and multiple measures observation (Stephen et al., 2020). In fact, in the current methodological landscape, the principal challenge for developmental scientists is not the proliferation of new measures, but the establishment of reliability and validity within the properties of those already in use (Davis-Kean and Ellis, 2019).

Merging multiple measures in developmental psychology could result in an increased reliability and accuracy in data interpretation (Flack and Skelton, 2022; Havron, 2022; LoBue et al., 2020). In studies involving infants, methodological rigor becomes critical due to small samples and the demanding, noisy nature of data collection with developmental population. Maintaining validity, reliability, and reproducibility through careful measure selection and management is thus of primary importance (Byers-Heinlein et al., 2022). In this emerging perspective, there is an increasing interest in ascertaining whether the findings obtained under controlled laboratory conditions generalize to more naturalistic and ecological contexts, closer to their real-life experience, and vice versa (see Figure 1 for a schematic representation of these techniques).

For example, contemporary technological advancements—such as audiorecording that allow for automated speech analysis (e.g., the Language ENvironemnt Analysis system, LENA Foundation, Boulder, CO, Greenwood et al., 2011; see the Italian validation, Bastianello et al., 2024), head-mounted video cameras, and head-mounted eye-tracking systems—have substantially enhanced the reliability and validity of observational research. The integration of head-mounted video-cameras or eye tracking systems has expanded our understanding of young infants's visual environments, providing new insight into cognitive development (Smith et al., 2015; Yu and Smith, 2016). Moreover, the availability of these automated measures in observational research has enabled researchers to integrate observational data with data of a different nature. Additionally, the use of LENA devices has been integrated with EEG data: researchers have explored how the amount of brain activity might be related to the amount of chaos and disorganization in the home environment with serious consequences on neurocognitive trajectories (Brito et al., 2020). Other studies that have integrated salivary and hair cortisol with observational measures of mother–infant interaction have shown that physiological stress can influence relational dynamics, even when behavioral indicators suggest stability (Laurent et al., 2017).

Secondly, employing multiple convergent measures yields a distinct empirical advantage, enabling a more integrative and fine-grained characterization of developmental processes across behavioral, cognitive, and neural domains. This, in turn, increases the precision by which we can identify developmental trajectories. Such synthesizing and integration of evidence across methodological levels, is essential for the identification of both typical and atypical developmental patterns, the prevention of long-term difficulties and the provision of more effective support to infants and young children with atypical development. It is evident that a range of methodologies are employed to capture distinct aspects associated with the domain of childhood development. The integration of these complementary sources of information enables researchers to access a more informative and useful representation of the mechanisms that give rise to early cognitive and socioemotional abilities.

In the domain of developmental psychology, there is a recognized imperative to employ diverse methodologies for measuring a specific construct (Aslin, 2007; LoBue and Adolph, 2019; Morris et al., 2006). Indeed, employing complementary measures in response to identical stimuli and environmental variations represents a compelling yet complex approach to enhancing robustness in infant research, yielding insights unattainable through single-measure methodologies. Nevertheless, integrating different methods remains difficult outside the lab, where the many factors shaping development cannot be fully controlled. In the recent period, several studies have attempted to utilize multiple measures to strengthen their findings and interpretations. Besides, recent advancement promoted by international pupil collaborative endeavors have found in the multimodal approach to data processing a powerful tool to manage the degrees of freedom in pupil data management and analysis (Sirois et al., 2023). Specifically, the multiverse philosophy behind the multimodal approach to data analysis is a promising paradigm shift to assess robustness (beyond statistical significance) and to build common knowledge in cognitive pupillometry (Calignano et al., 2023). In addition, the use of fNIRS in conjunction with fEMG has revealed the impact of emotional processing on both facial muscle and cortical activity (De Klerk et al., 2018). Similarly, it has been shown that four-month-old children exhibited mimicry skills only when observing facial actions accompanied by direct gaze. This competence was found to be associated with the activation of the posterior superior temporal sulcus (De Klerk et al., 2019). A similar complementarity emerges when combining EMG activity with eye tracking (Tan and Hamlin, 2024), where infants' affective appraisals of sociomoral scenes are observed to be simultaneously manifested in physiological arousal and overt visual attention allocation. Moreover, the combination of observation with EEG has elucidated the influence of visual attention on neural responses in numerical cognition, enabling the exploration and tracking of the developmental trajectories of early numerical abilities (Decarli et al., 2022). Convergence validity is equally essential in neural-behavioral approaches, simultaneous NIRS–EEG recordings capture both neural activity and its metabolic support, combining EEG's high temporal resolution with NIRS's spatial precision. Their complementarity makes co-registration a powerful tool in developmental cognitive neuroscience (Wallois et al., 2012), though careful experimental design is needed to accommodate their differing temporal dynamics. For example, Telkemeyer et al. (2009) presented newborns with speech-like sounds varying in temporal modulation, each reflecting different



	Observation	Eye-Tracker	Pupillometry	fEMG	EEG	fNIRS	Physiological measures	Skin conductance	Endocrine marker
Measured information	Natural/spontaneous behaviors and perception of phenomena	Eye Movements	Neural correlates of the pupil size activity	Micro-movement from muscles	Electrical activity of the brain	Concentration of oxi- and deoxihemoglobin in the brain	Autonomic nervous system activity (e.g., heart rate, heart rate variability, respiration)	Changes in sweat gland activity reflecting sympathetic arousal (electrodermal activity)	Hormonal levels indicating stress or physiological responses (e.g., cortisol, oxytocin)
Strengths	1 – Ecological context; 2 - Gathering Quantitative and Qualitative Information; 3 - Reaching a larger number of participants; 4 – Collecting data that can be checked for reliability.	1 - Provides accurate data; 2 - Replicable design; 3 - More information on internal cognitive processes.	1 - Provides useful physiological indicators.	1 - Sensitive and Objective measurement with High Temporal Resolution.	1- High Temporal Resolution: 2 -Reveals early abilities of infants in various cognitive domains.	1- Suitable for Newborns (thin skin and skull); 2 - Easy to use; 3 – Portable.	1 – Non-invasive; 2 – Good temporal resolution; 3 – Sensitive indicators of stress, arousal, and regulation; 4 – Easier setup.	1 – Highly sensitive to sympathetic activation; 2 – Non-invasive; 3 – Good temporal sensitivity.	1 – Reliable biological indicators of stress, bonding, and arousal; 2 – Can complement neural and behavioral measures; 3 – Captures slow-changing physiological states.
Limitations	1- Risk of Bias; 2- non chiaro: Demand for Human Work and Experience; 3 - Tools may alter the natural behaviour of the observed subjects; 4. Low reliability (expecially if the tool has not been built in an appropriate way).	1 -Need for Sophisticated Tools; 2 -Data management and processing require careful methodological planning in order to obtain interpretable and reliable results; 3 - Requires lab equipment and standardized protocols.	1 - Need to carefully control brightness conditions and timing of stimuli to avoid unwanted pupillary reflections; 2 - Requires lab equipment and standardized protocols.	1- High variability in the position and morphology of the facial muscles; 2 - Difficulty in attaching electrodes firmly to the skin of infants; 3 - Influence of Tools on Natural Behaviour; 4 - Requires lab equipment and standardized protocols.	1- Sensitivity to Noise; 2 - Large attrition rate; 3 - Need for Preprocessing; 4 - Requires lab equipment and standardized protocols.	1- Large attrition rate; 2 - Need for Preprocessing; 3- Need to increase inclusivity and ecological validity of research; 4 - Requires lab equipment and standardized protocols.	1 - Highly sensitive to movement artifacts; 2 - Large attrition rate; 3 - Requires extensive preprocessing; 4 - Influenced by multiple external factors (temperature, feeding, baseline arousal); 5 - Interpretation can be complex in infants; 6 - Requires lab equipment and standardized protocols.	1 - Very sensitive to noise and movement; 2 - Electrode detachment leads to high attrition; 3 - Requires preprocessing; 4 - Variability in infant skin properties; 5 - Requires lab equipment and standardized protocols.	1 - Low temporal resolution; 2 - Collection in infants may be challenging (small saliva volume, contamination); 3 - Requires lab equipment and standardized protocols; 4 - Interpretation in infant is complex.
Multiple measures approach	1.Eye-Tracker 2.Pupillometry 3.fEMG 4.EEG 5.fNIRS	1.Observation 2.Pupillometry 3.fEMG 4.EEG 5.fNIRS	1.1Observation 2.Eye-Tracker 3.Pupillometry 4.fEMG 5.EEG 6.fNIRS	1.Observation 2.Eye-Tracker 3.Pupillometry 4.EEG 5.fNIRS 6.Physiological measures 7.Skin conductance 8.Endocrine marker	1.Observation 2.Eye-Tracker 3.Pupillometry 4.fEMG 5.fNIRS 6.Physiological measures 7.Skin conductance 8.Endocrine marker	1.Observation 2.Eye-Tracker 3.fEMG 4.EEG 5.Physiological measures 6.Skin conductance 7.Endocrine marker	1.Observation 2.Eye-Tracker 3.Pupillometry 4.fEMG 5.EEG 6.fNIRS 7.Skin conductance 8.Endocrine marker	1.Observation 2.Eye-Tracker 3.Pupillometry 4.fEMG 5.EEG 6.fNIRS 7.Physiological measures 8.Endocrine marker	1.Observation 2.Eye-Tracker 3.Pupillometry 4.fEMG 5.EEG 6.fNIRS 7.Physiological measures 8.Skin conductance

FIGURE 1
A brief outline of the techniques and how they are used in combination (images reproduced with permission from Flaticon: "Hand", Hand - Free arrows icons, created by Kalashnyk; "Endocrine", Endocrine - Free healthcare and medical icons, created by Freepik; "Electrocardiogram", Electrocardiogram - Free healthcare and medical icons", created by Muhammad Ali; "Electroencephalogram", Electroencephalogram - Free icons, created by Freepik; "Girl", Girl - Free people icons", created by Freepik; "Eye", Eye - Free maps and location icons, created by Smashicons; "Eye tracking", Eye tracking - Free technology icons, created by Freepik; "Checklist", Checklist - Free files and folders icons, created by Freepik; "Cam recorder", Cam recorder - Free music and multimedia icons, created by Royyan Wijaya).

speech properties. NIRS revealed distinct cortical activation patterns, while EEG responses were more similar, highlighting the challenge of designing experiments that capture both fast and slow signals. Building on this, Cabrera and Gervain (2020) introduced an improved design combining an EEG oddball paradigm nested within long NIRS-compatible blocks. Newborns were presented with syllables differing in temporal modulation across the NIRS conditions, while EEG recorded mismatch responses to deviant consonants within each block. This design revealed both hemodynamic patterns associated with temporal modulations and the brain's ability to detect consonant changes, effectively addressing multiple research questions in a single experiment and thus enhancing the value of co-registration—an approach that has since been replicated (Gemignani and Gervain, 2024). It is noteworthy that even in the present day, there is a paucity of scientific literature reporting behavioral, physiological and neural observations in a concomitant manner. As previously mentioned, a substantial number of multiple measures studies combine only two measures. However, the findings of these studies indicate that the value of integrating measurements does not lie in the substitution or single observation; rather, it lies in the complementarity of the results obtained from all the measurements taken together. Nevertheless, the integration of co-registration and the utilization of dual techniques has the potential to facilitate the establishment of valuable parameters for comprehending typical and atypical developmental processes in infants, thereby contributing to the early identification of potential dysfunctions, even within the context of pediatric clinical practice in outpatient settings. A recent study has suggested that through the combined utilization of fNIRS and an eye-tracker, it is feasible to develop a protocol for the monitoring of cognitive functions, employing both social and non-social stimulation in a clinical pediatric setting (de Almeida et al., 2025). A recent meta-analysis has also shown that co-registering EEGs and fNIRS could be essential for diagnosing neurological disorders in premature babies from infancy (Llamas-Ramos et al., 2024).

The challenge of multiple measures approach

However, the multiple measures approach is not free of challenges and, besides offering potential advantages, it also requires informed compromises that require us to accept and deal with uncertainty and noise, especially considering the infant population, particularly in relation to data loss and quality of both measures and synchronization of stimuli. Researchers should also be mindful of the added complexity and time required for data collection and analysis when using multiple measures. On the other hand, by taking advantage of each method's strengths, researchers can address complex research questions that single methodologies might not fully capture (LoBue et al., 2020). Using multiple measures requires precise synchronization between systems, specific techniques and software, and appropriate experimental paradigms to synchronize stimulus presentation with input detection within milliseconds in order to collect and analyses data (Quintana and Heathers, 2014).

The principal challenges associated with a multiple measures approach can be categorized into three distinct categories: conceptual challenges, technical constraints, and statistical integration issues. Furthermore, concerns regarding the feasibility of the aforementioned approach, particularly in infants, have been identified as significant obstacles. From the analysis of these methodological techniques and their combined use, three critical issues emerged that we would like to draw attention to.

Firstly, adopting multiple measures designs in infancy research necessarily increases the complexity of data collection and processing (LoBue et al., 2020; Havron, 2022). Technical constraints mainly arise from data quality issues and the complex synchronization of different measurement modalities. This is because each technique relies on different temporal and signal properties, which makes constructing a unified experimental design challenging. For instance, EEG captures rapid electrophysiological responses on the millisecond scale, whereas fNIRS is limited by the much slower hemodynamic response, creating a temporal mismatch that complicates stimulus timing and task pacing (Cabrera and Gervain, 2020). Similarly, eye-tracking measures such as gaze shifts or saccades require precise, fast-changing visual stimuli, whereas pupillometry is sensitive to slower changes and is easily affected by luminance variations that may obscure cognitive effort (Hepach and Westermann, 2016). Thus, a task optimized for one modality may compromise data quality in another. These constraints multiply during preprocessing: each technique demands specialized pipelines, artifact-rejection procedures and signal-quality checks that cannot be transferred across methods.

These technical issues also often have an impact on statistical integration, which requires the ability to combine heterogeneous data with different scales, distributions and structures. Integrating these heterogeneous datasets requires advanced statistical and computational approaches that can model relationships between signals with different temporal resolutions, noise structures and underlying physiological bases (see Brigadoi et al., 2014; Di Lorenzo et al., 2019; Gemignani and Gervain, 2021, for comprehensive comparisons between pipelines and techniques to be employed on developmental data).

Secondly, concerns about feasibility are equally important, as combining multiple measures increases equipment costs and requires technical expertise and support for multimodal synchronization and data cleansing. The costs of the equipment cannot be under-estimated. Additionally, the manpower needed for reliable coding, pre-processing and multimodal synchronization increases and it represents an additional cost to projects, as it will also be necessary to employ an experienced technician who knows how to use the instrumentation and associated software. Furthermore, researchers should be aware of the strengths and limitations of each technique (see Figure 1). This awareness should guide them in addressing potential challenges and identifying the best solutions to ensure that the principles of validity and reliability are consistently respected throughout the data collection process. While the multiple measures approach offers richer insights, it entails substantial logistical and analytical demands that must be carefully planned from the outset.

Thirdly, establishing the validity and reliability of latent constructs in infancy is a particularly complex methodological challenge (Zettersten et al., 2022) because most of the constructs are inherently unmeasurable from a self-report perspective. Therefore, drawing reliable conclusions from multiple measures adds to the complexity of interpreting the results, which is not always easy or intuitive. For instance, one potential issue is that using different measures may not always produce easily interpretable results (see for example, Bastianello et al., 2025, where clear improvements in socio-emotional and cognitive outcomes following the outdoor intervention, yet salivary cortisol did not show parallel pre-post changes). This highlights the significant conceptual challenge associated with defining and aligning constructs between measures capable of capturing partially overlapping but non-identical processes. The convergence of data has been demonstrated to be a valuable tool for guiding the integration of information across multiple measures. Nevertheless, it would be erroneous to regard the divergence exclusively as a limitation. It is evident that non-convergence between measures can offer significant information from theoretical and statistical perspectives.

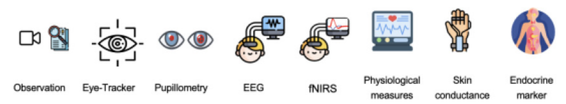
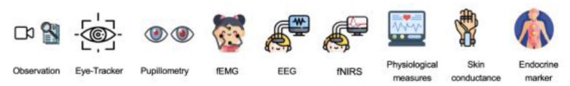
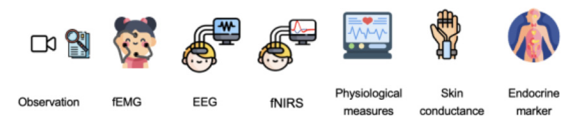
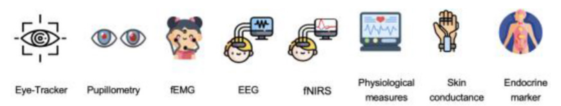
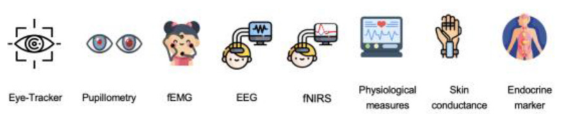
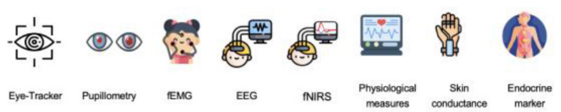
In order to address these challenges in an informed manner, we would like to propose a checklist to guide the selection of measures to be integrated into the different stages of development (see Table 1).

Conclusion

The present paper stresses the importance and benefits of critically integrating diverse methodological techniques in developmental psychology. In summary, this perspective paper highlights three key messages: (i) the added theoretical value of integrating multiple measures in infant research, (ii) the need to critically address conceptual, technical, and statistical challenges associated with multiple measures designs, and (iii) the importance of adopting a high methodological rigor in this kind of approach to guide future research. The combination of diverse techniques is both advantageous and essential for the amplification of available information, thereby facilitating a more profound comprehension of infant development. Despite the challenges and obstacles that may arise when using multiple measures, numerous studies have already indicated that implementing a multiple measures approach can lead to an integrated and informative understanding of developmental processes. Researchers in developmental psychology should increasingly consider that relying on a single measure is often insufficient to capture the complexity of growth and change over time. Although using multiple measures can be demanding, this approach encourages the construction of integrated developmental models that better account for the many facets of development that are often overlooked when assessments are limited to a single measure. The future of research in developmental psychology is clearly moving toward increasingly sophisticated, accurate and ecologically valid multiple measures designs. However, such an approach requires a high level of methodological rigor. Researchers must carefully define their research question and study design beforehand to ensure the validity of the findings and reduce the risk of interpretative errors. Although multiple measures research is often time-intensive, it offers substantial potential to advance our understanding of developmental trajectories and to inform more effective interventions.

In conclusion, the integration of naturalistic observation, eye-tracking, fEMG, EEG, NIRS, and physiological measures provides a powerful way for exploring the complexities of developmental processes. Each technique contributes a unique perspective, and their combination can allow for a more informative, useful and

TABLE 1 Checklist for selecting techniques within a multiple measures approach.

Guidelines for selecting techniques to be integrated into multi-measure research	
1. The study will involve the collection of data in an ecological setting	 Observation, Eye-Tracker, Pupillometry, EEG, fNIRS, Physiological measures, Skin conductance, Endocrine marker
2. The study will involve collecting data in a laboratory setting	 Observation, Eye-Tracker, Pupillometry, fEMG, EEG, fNIRS, Physiological measures, Skin conductance, Endocrine marker
3. The study will include participants aged < 3 months	 Observation, fEMG, EEG, fNIRS, Physiological measures, Skin conductance, Endocrine marker
4. The study will include participants aged > 3 months	 Eye-Tracker, Pupillometry, fEMG, EEG, fNIRS, Physiological measures, Skin conductance, Endocrine marker
5. Specific software knowledge is required	 Eye-Tracker, Pupillometry, fEMG, EEG, fNIRS, Physiological measures, Skin conductance, Endocrine marker
6. High-level expertise in pre-processing and data analysis is needed	 Eye-Tracker, Pupillometry, fEMG, EEG, fNIRS, Physiological measures, Skin conductance, Endocrine marker
7. Other non-psychological expertise is necessary	 EEG, fNIRS, Physiological measures, Skin conductance, Endocrine marker

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integrated understanding of infant cognition and behavior. It is evident that each of these techniques facilitates the capture of a shot from a distinct perspective. The integration of information from multiple perspectives, together with the fair sharing of data, code and materials, represents one of the most powerful ways to grasp the complexities of cognitive development and to provide developmental theories with the empirical depth they require. The existence of such synergy between theory and method is of crucial importance to the advancement of developmental science. In the future, research should continue to explore innovative and ecologically grounded ways to integrate these techniques, while also striving to enhance data interoperability and accessibility for the wide range of specialists working in developmental science. Building a solid multidisciplinary foundation will be essential to ensure their informed and responsible use.

Author contributions

AP: Writing – review & editing, Writing – original draft, Conceptualization. TB: Writing – original draft, Writing – review & editing. MA: Writing – original draft, Writing – review & editing. GC: Writing – review & editing, Writing – original draft. GD: Writing – review & editing, Writing – original draft. JG: Writing – review & editing, Writing – original draft.

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References

Addabbo, M., Licht, V., and Turati, C. (2024). Infants' facial electromyographic responses to the sight of emotional interpersonal touch. *Infancy* 29, 660–671. doi: 10.1111/infa.12600

Addabbo, M., Vacaru, S. V., Meyer, M., and Hunnius, S. (2020). 'Something in the way you move': infants are sensitive to emotions conveyed in action kinematics. *Dev. Sci.* 23:e12873. doi: 10.1111/desc.12873

Aslin, R. N. (2007). What's in a look? *Dev. Sci.* 10, 48–53. doi: 10.1111/j.1467-7687.2007.00563.x

Baek, S., Marques, S., Casey, K., Testerman, M., McGill, F., and Emberson, L. (2023). Attrition rate in infant fNIRS research: a meta-analysis. *Infancy* 28, 507–531. doi: 10.1111/infa.12521

Bastianello, T., Lorenzini, I., Nazzi, T., and Majorano, M. (2024). The Language ENvironment Analysis system (LENA): a validation study with Italian-learning children. *J. Child Lang.* 51, 1172–1192. doi: 10.1017/S0305000923000326

Bastianello, T., Silletti, F., Cassibba, R., Coppola, G., Musso, P., Rossini, V., et al. (2025). Short-term effects of an outdoor activities intervention on children's stress, socio emotional, behavioral, and cognitive regulation skills. *Early Educ. Dev.* 36, 724–743. doi: 10.1080/10409289.2024.2423387

Brigadoi, S., Ceccherini, L., Cutini, S., Scarpa, F., Scatturin, P., Selb, J., et al. (2014). Motion artifacts in functional near-infrared spectroscopy: a comparison of motion correction techniques applied to real cognitive data. *NeuroImage* 85, 181–191. doi: 10.1016/j.neuroimage.2013.04.082

Brito, N. H., Troller-Renfree, S. V., Leon-Santos, A., Isler, J. R., Fifer, W. P., and Noble, K. G. (2020). Associations among the home language environment and neural activity during infancy. *Dev. Cogn. Neurosci.* 43:100780. doi: 10.1016/j.dcn.2020.100780

Byers-Heinlein, K., Bergmann, C., and Savalei, V. (2022). Six solutions for more reliable infant research. *Infant Child Dev.* 31:e2296. doi: 10.1002/icd.2296

Cabrera, L., and Gervain, J. (2020). Speech perception at birth: the brain encodes fast and slow temporal information. *Sci. Adv.* 6:eaba7830. doi: 10.1126/sciadv.aba7830

Calignano, G., Girardi, P., and Altoè, G. (2023). *First steps into the pupillometry multiverse of developmental science. Behav. Res. Methods.* 56:3346–3365. doi: 10.3758/s13428-023-02172-8

Csibra, G., Kushnerenko, E., and Grossmann, T. (2008). "ElectrophysiologicalMethods in studying infant cognitive development," in *Handbook of Developmental Cognitive Neuroscience, 2nd Edn.* eds., C. A. Nelson, M. Luciana (Cambridge, MA: MIT Press), 247–262.

Davis-Kean, P. E., and Ellis, A. (2019). An overview of issues in infant and developmental research for the creation of robust and replicable science. *Infant Behav. Dev.* 57:101339. doi: 10.1016/j.infbeh.2019.101339

de Almeida, V. A., da Cruz, M. C. L., Morais, N. R., Rodrigues, I. V. T., Silva, C. R. F. D., Morya, E., et al. (2025). Simultaneous eye tracking and cerebral hemodynamic monitoring in infants: a guide for pediatric outpatient follow-up. *Brain Sci.* 15:469. doi: 10.3390/brainsci15050469

De Klerk, C. C. J. M., Bulgarelli, C., Hamilton, A., and Southgate, V. (2019). Selective facial mimicry of native over foreign speakers in preverbal infants. *J. Exp. Child Psychol.* 183, 33–47. doi: 10.1016/j.jecp.2019.01.015

De Klerk, C. C. J. M., Hamilton, A. F. de C., and Southgate, V. (2018). Eye contact modulates facial mimicry in 4-month-old infants: an EMG and fNIRS study. *Cortex* 106, 93–103. doi: 10.1016/j.cortex.2018.05.002

Decarli, G., Rämä, P., Granjon, L., Veggiotti, L., and De Hevia, M. D. (2022). Electrophysiological evidence for a number—action mapping in infancy. *Brain Sci.* 12:1480. doi: 10.3390/brainsci12111480

Di Lorenzo, R., Pirazzoli, L., Blasi, A., Bulgarelli, C., Hakuno, Y., Minagawa, Y., et al. (2019). Recommendations for motion correction of infant fNIRS data applicable to multiple data sets and acquisition systems. *NeuroImage* 200, 511–527. doi: 10.1016/j.neuroimage.2019.06.056

Flack, Z. M., and Skelton, A. E. (2022). When to use a cookie, and when to use a ruler: A response to BYERS-Heinlein, Bergmann and Savelei's "six solutions for more reliable infant research". *Infant Child Dev.* 31:e2337. doi: 10.1002/icd.2337

Fox, S. E., Levitt, P., and Nelson Iii, C. A. (2010). How the timing and quality of early experiences influence the development of brain architecture. *Child Dev.* 81, 28–40. doi: 10.1111/j.1467-8624.2009.01380.x

Gemignani, J., and Gervain, J. (2021). Comparing different pre-processing routines for infant fNIRS data. *Dev. Cogn. Neurosci.* 48:100943. doi: 10.1016/j.dcn.2021.100943

Gemignani, J., and Gervain, J. (2024). A within-subject multimodal NIRS-EEG classifier for infant data. *Sensors* 24:4161, doi: 10.3390/s24134161

Gervain, J., Minagawa, Y., Emberson, L., and Lloyd-Fox, S. (2023). Using functional near-infrared spectroscopy to study the early developing brain: Future directions and new challenges. *Neurophotonics* 10:023519. doi: 10.1117/1.NPh.10.2.023519

Greenwood, C. R., Thiemann-Bourque, K., Walker, D., Buzhardt, J., and Gilkerson, J. (2011). Assessing children's home language environments using automatic speech recognition technology. *Commun. Disord. Q.* 32, 83–92. doi: 10.1177/1525740110367826

Havron, N. (2022). Why not both? Using multiple measures to improve reliability in infant studies. *Infant Child Dev.* 31:e2336. doi: 10.1002/icd.2336

Hepach, R., and Westermann, G. (2016). Pupillometry in infancy research. *J. Cogn. Dev.* 17, 359–377. doi: 10.1080/15248372.2015.1135801

Karasik, L. B., Tamis-LeMonda, C. S., and Adolph, K. E. (2011). Transition from crawling to walking and infants' actions with objects and people. *Child Dev.* 82, 1199–1209. doi: 10.1111/j.1467-8624.2011.01595.x

Laurent, H. K., Duncan, L. G., Lightcap, A., and Khan, F. (2017). Mindful parenting predicts mothers' and infants' hypothalamic-pituitary-adrenal activity during a dyadic stressor. *Dev. Psychol.* 53:417. doi: 10.1037/dev0000258

Li, J., Chen, Z., Hao, X., and Liu, W. (2025). Boundaries in the eyes: measure event segmentation during naturalistic video watching using eye tracking. *Behav. Res.* 57, 255. doi: 10.3758/s13428-025-02790-4

Llamas-Ramos, R., Alvarado-Omenat, J. J., and Llamas-Ramos, I. (2024). Early EEG and NIRS measurements in preterm babies: a systematic review. *Eur. J. Pediatr*. 183, 4169–4178. doi: 10.1007/s00431-024-05712-2

LoBue, V., and Adolph, K. E. (2019). Fear in infancy: lessons from snakes, spiders, heights, and strangers. *Dev. Psychol.* 55, 1889–1907. doi: 10.1037/dev0000675

LoBue, V., Reider, L. B., Kim, E., Burris, J. L., Oleas, D. S., Buss, K. A., et al. (2020). The importance of using multiple outcome measures in infant research. *Infancy* 25, 420–437. doi: 10.1111/infa.12339

Morris, A. S., Robinson, L. R., and Eisenberg, N. (2006). "Applying a multimethod perspective to the study of developmental psychology," in *Handbook of Multimethod Measurement in Psychology,* M. Eid, E. Diener, eds., (Washington, D.C.: American Psychological Association), 371–384. doi: 10.1037/11383-025

Quintana, D. S., and Heathers, J. A. J. (2014). Considerations in the assessment of heart rate variability in biobehavioral research. *Front. Psychol.* 5:00805. doi: 10.3389/fpsyg.2014.00805

Rodriguez, E. T., and Tamis-LeMonda, C. S. (2011). Trajectories of the home learning environment across the first 5 years: associations with children's vocabulary and literacy skills at prekindergarten: trajectories of the home learning environment. *Child Dev.* 82, 1058–1075. doi: 10.1111/j.1467-8624.2011.01614.x

Sirois, S., Brisson, J., Blaser, E., Calignano, G., Donenfeld, J., Hepach, R., et al. (2023). The pupil collaboration: a multi-lab, multi-method analysis of goal attribution in infants. *Infant Behav. Dev.* 73:101890. doi: 10.1016/j.infbeh.2023.101890

Slone, L. K., Abney, D. H., Borjon, J. I., Chen, C., Franchak, J. M., Pearcy D., et al. (2018). Gaze in action: head-mounted eye tracking of children's dynamic visual attention during naturalistic behavior. *J. Vis. Exp.* 10-3791. doi: 10.3791/58496

Smith, L. B., Yu, C., Yoshida, H., and Fausey, C. M. (2015). Contributions of head-mounted cameras to studying the visual environments of infants and young children. *J. Cogn. Dev.* 16, 407–419. doi: 10.1080/15248372.2014.933430

Soares, R. da S., Oku, A. Y. A., Barreto, C. S. F., and Sato, J. R. (2022). Applying fNIRS and eye-tracking in a naturalistic educational environment. *Front. Hum. Neurosci.* 16:889806. doi: 10.3389/fnhum.2022.889806

Stephen, J. M., Solis, I., Janowich, J., Stern, M., Frenzel, M. R., Eastman, J. A., et al. (2020). The developmental chronnecto-genomics (Dev-CoG) study: a multimodal study on the developing brain. *NeuroImage* 225:117438. doi: 10.1016/j.neuroimage.2020.117438

Tan, E., and Hamlin, J. K. (2024). Toddlers' affective responses to sociomoral scenes: insights from physiological measures. *J. Exp. Child Psychol.* 237:105757. doi: 10.1016/j.jecp.2023.105757

Telkemeyer, S., Rossi, S., Koch, S. P., Nierhaus, T., Steinbrink, J., Poeppel, D., et al. (2009). Sensitivity of newborn auditory cortex to the temporal structure of sounds. *J. Neurosci.* 29, 14726–14733. doi: 10.1523/JNEUROSCI.1246-09.2009

Van Rij, J., Hendriks, P., Van Rijn, H., Baayen, R. H., and Wood, S. N. (2019). Analyzing the time course of pupillometric data. *Trends Hear.* 23:233121651983248. doi: 10.1177/2331216519832483

Wallois, F., Mahmoudzadeh, M., Patil, A., and Grebe, R. (2012). Usefulness of simultaneous EEG–NIRS recording in language studies. *Brain Lang.* 121, 110–123. doi: 10.1016/j.bandl.2011.03.010

Yu, C., and Smith, L. B. (2016). The social origins of sustained attention in one-year-old human infants. *Curr. Biol.* 26, 1235–1240. doi: 10.1016/j.cub.2016.03.026

Zettersten, M., Pomper, R., and Saffran, J. (2022). Valid points and looks: Reliability and validity go hand-in-hand when improving infant methods. *Infant Child Dev.* 31:e2326. doi: 10.1002/icd.2326