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Early Career Session

EC1 - Developmental timing and emotional context differentiate the effects of dyadic physiological synchrony on infant neural and autonomic function

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Details

Although dyadic physiological synchrony has been well characterized as a developmental phenomenon, empirical work examining its mechanistic role in infant development is still in its early stages. Theoretical accounts of physiological linkage between caregivers and infants is thought to scaffold the transition from co-regulation to self-regulation (Bornstein & Esposito, 2023; Fogel, 1993; DePasquale, 2020; Feldman, 2007). At the same time, variability in physiological synchrony may shape the extent to which maternal emotional states are transmitted to the infant. Consistent with this idea, prior work has demonstrated an amplifying role of physiological synchrony, such that it intensifies associations between parenting characteristics and children's neural and socioemotional outcomes (Brandes-Aitken et al., 2024; Lan et al., 2024; Oshri et al., 2023; Xu, Zhang, et al., 2024). Given the distinct emotional and physiological components of arousal regulation and appraisal that characterize anxiety, this maternal state may be especially important to consider in the context of physiological synchrony and its role in shaping infants' regulatory development and neural function.

The current study leverages a multimodal dataset that includes concurrent recordings of maternal and infant electrocardiography (ECG) and infant electroencephalography (EEG) collected from dyads at 3 months of age. During the 3-month assessment, dyadic ECG was recorded while infants sat on their caregivers' laps, providing a condition of physical contact without face-to-face engagement. A subset of infants also completed a 9-month laboratory visit, contributing additional ECG and EEG data. Respiratory sinus arrhythmia (RSA) served as an index of infant physiological regulation, whereas neural function was characterized using both the aperiodic power spectral density (PSD) slope and the periodic theta–beta ratio.

Using a surrogate control analysis, we first found that synchrony at 3 months was statistically significant ($t = -2.64$, $p = 0.03$). Using mixed-effect models, we found a significant interaction between time and 3-month physiological synchrony ($\beta = .21$, $p = .01$). Simple slope analyses indicated that higher physiological synchrony at 3 months predicted greater maturation in baseline infant RSA from 3 to 9 months ($t = 4.43$, $p \leq .01$). Further, we found a significant interaction between 3-month physiological synchrony and maternal anxiety on infant aperiodic EEG slope ($\beta = .28$, $p = .02$). Simple slope analyses indicated that in dyads with higher synchrony at 3 months, the negative effects of maternal anxiety on infant aperiodic slope were amplified ($t = 2.8$, $p = .01$) but in dyads with less synchrony at 3-months, the negative effects of maternal anxiety on infant aperiodic slope were buffered ($p > 0.05$).



Taken together, these findings provide some of the first direct evidence that caregiver–infant physiological synchrony not only contributes to developmental change in infants’ regulatory physiology but also buffers or sensitizes infants to the effects of maternal anxiety on neural functioning. These findings highlight the timing- and maternal context-dependent role of physiological synchrony in shaping infant neural and autonomic development.

EC2 - Early predictors of infant emotion regulation capacity: Preconception, prenatal, and early caregiving environments

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Details

It is well-documented that emotion regulation is linked to subsequent well-being, with adaptive emotion regulation predicting better cognitive and socioemotional outcomes and fewer behavior problems. Although early caregiving is known to shape individual differences in emotion regulation, less is known about how preconception and prenatal risk contribute to early infant emotion regulation capacity. Infants with higher resting respiratory sinus arrhythmia (RSA) and lower cortisol reactivity and negative affect in response to stress (i.e., early emotion regulation capacity) tend to have better emotion regulation over time. Therefore, this study aims to test the (1) cascade effect of maternal preconception risk and prenatal distress on infant emotion regulation capacity, and (2) promotive and/or protective effect of resources during prenatal (i.e., relational support) and early postnatal environments (i.e., sensitive maternal caregiving) in these associations.

This study included 299 mothers ($M = 29.7$ years, 45% non-White) and their infants (49% female). During the prenatal visit, mothers’ retrospectively reported experiences of adversity and emotionally unsupportive parenting in childhood, which were used to produce the latent maternal preconception risk factor. Maternal prenatal distress was a latent factor including mother-reported stressful life events, depressive symptoms, anxiety symptoms, household food insecurity, and neighborhood violence. Infant emotion regulation capacity reflected by cortisol reactivity and observed negative affect during standardized stressful tasks, resting/baseline RSA, and mother-reported negative affectivity. Cortisol reactivity was primarily assessed at 2 months and other components were assessed at 2 and 6 months and these measures were averaged across time. Relational support was a manifest variable calculated from the average of mother-reported perceived prenatal social support and relationship satisfaction. The 2-month maternal sensitivity was a latent variable based on behavioral ratings during free play and still-face engagement and re-engagement tasks.

Analyses were conducted via *Mplus* 8.11, with full information maximum likelihood estimation used to handle the missing data. Maternal preconception risk predicted higher infant cortisol output via increases in maternal prenatal distress (Figure 1). Relational support moderated this association; the positive association between preconception risk and prenatal distress was attenuated with high relational support (Figure 2A). Relational support predicted lower prenatal distress as a main effect. Maternal sensitivity moderated the association between prenatal distress and infant cortisol output; higher prenatal distress predicted (1) lower infant cortisol output when



maternal sensitivity was high and (2) higher cortisol output when maternal sensitivity was low (Figure 2B). Maternal sensitivity predicted lower infant cortisol output, and higher mother-reported and lower observed infant negative affect as main effects. The indirect effect of preconception risk on infant cortisol output via prenatal distress was positive when maternal sensitivity was low ($b = 1.32$, $S.E. = .19$, $95\%CI [.90, 11.21]$, $\beta = 2.21$) and negative when maternal sensitivity was high ($b = -1.06$, $S.E. = .16$, $95\%CI [-11.23, -.69]$, $\beta = -1.95$). Relational support did not moderate the indirect pathway.

Results show that both prenatal relational support and early postnatal maternal sensitivity serve as environmental resources that promote/protect the development of infant emotion regulation capacity in the presence of maternal preconception and prenatal risk.

EC3 - Everyday dynamics of infant vocalization and speech input in the United States and India

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Details

Early language environment and vocal exchanges are fundamental for language acquisition (Bergelson et al., 2023; Donnelly & Kidd, 2021). These experiences have both universal and culture-specific components. Acoustic and temporal features of caregiver's infant-directed speech (IDS; Cox et al., 2023), as well as vocal contingency (Kärtner et al., 2008), show robust cross-cultural similarities, yet speech input and vocal coordination patterns also vary across cultures. In some communities, infants are rarely directly addressed and instead receive most input from overheard speech (e.g., Shneidman & Goldin-Meadow, 2012). Indian mother-infant dyads showed more overlapping talk than U.S. dyads (Gratier, 2003). However, early vocal exchanges are often examined in constrained settings and less is known about how these processes unfold in everyday life across communities. This study compared infants' everyday vocalizations, speech input, and their temporal dynamics in U.S. and Indian families. Based on prior work, we hypothesized that Indian infants would receive more overlapping speech, and speech input in U.S. families would be organized more around infant vocalizations.

Egocentric audio–video recordings were collected at home from infants aged 1 to 15 months in Bloomington, IN, USA, and Chennai, TN, India, wearing head-mounted cameras. The present analyses used 106 hours of data from a subsample of 17 Bloomington and 18 Chennai infants ($M_{age} = 6.67$ months). Infant vocalizations and speech input type (silence, serial, overlap, IDS) were annotated in 5-second bins ($N = 76,151$). For each clip, we computed the proportion of bins containing infant vocalization, any speech input, serial speech, and IDS. Two-level models were used to test group differences in these behaviors, and separate two-level Granger causality models (Bressler & Seth, 2011; Xu et al., 2020) were fitted to quantify temporal precedence between infant vocalization and speech input in each community.

Consistent with our hypothesis, despite similar overall exposure to speech, U.S. infants heard more IDS and serial speech and vocalized more than Indian infants (see Table 1). Granger models revealed fewer predictive links in U.S. families, with infant vocalizations playing a more central role



in the network (see Figure 1). Likelihood ratio tests showed that only U.S. infants were more likely to vocalize following IDS ($p < .001$). Infants in both communities were less likely to vocalize after overlapping speech, but this inhibitory effect was stronger in India ($p = .006$). Overlapping speech was less likely to follow infant vocalizations only for Indian infants ($p < .001$); other infant-related edges did not differ ($ps > .13$).

Overall, early language environments and the temporal structure of vocal exchanges were broadly similar across U.S. and Indian families, with two main community-specific features. First, vocal communication in U.S. families was more infant-centered, characterized by more IDS and speech organized around infant vocalizations. Second, Indian infants experienced a denser language environment with more overlapping speech, in which infant vocalizations and overlapping talk tended to be temporally separated. These differences likely reflect broader household structures (smaller nuclear families vs. larger extended families) and highlight community-specific pathways by which everyday interactions can support early communicative development.

EC4 - Infants on display: caregiver presence shapes motor skill expression

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Details

All researchers agree that infants acquire new motor skills with development. However, less is known about the ebb and flow of motor skill expression—when and under which conditions infants choose to express the skills in their repertoires. Infants may consistently display postural and locomotor skills as soon as they acquire them, or they may selectively display skills depending on the surrounding context (e.g., presence of caregivers).

To test developmental change in motor skill expression, we followed 38 infants monthly from one month of age, when infants could barely lift their heads, to 18 months, when they could race across a room. During each lab session, infants played for 10 minutes with their caregiver ('social' play) and for 10 minutes on their own ('solo' play; caregivers sat nearby but were occupied with paperwork). We collected 235 sessions with social play and 188 sessions with both social and solo play.

We used a novel checklist approach—akin to a 'behavioral scavenger hunt'—to identify which motor skills infants expressed during each session. We scored 11 locomotor skills (e.g., crawling, walking), 10 postural skills (e.g., sitting, standing), and 44 postural transitions (e.g., pull-to-stand)—65 skills in total. Our approach relied on objective video observations to surmount limitations of parent report. Rather than privileging canonical skills (e.g., hands-knees crawling but not hands-feet crawling) or assuming an obligatory developmental sequence (e.g., crawling precedes cruising), our checklist oversampled the diversity of skills infants could display and allowed the sequence of motor skill expression to emerge empirically. Finally, we only identified skills that infants displayed independently (e.g., caregiver-assisted transitions were not included).



As expected, infants' skill repertoires expanded substantially across development. The average number of skills grew from $M = 0$ to $M = 13$, and the diversity of postural ($M_s = 0$ to 3), locomotor ($M_s = 0$ to 2), and transition skills ($M_s = 0$ to 7) increased with age. Preliminary analyses (pooled across sessions) suggest that caregiver presence shaped motor skill expression. Infants displayed a smaller diversity of skills while playing with their caregiver ($M = 7.41$ skills) compared to playing on their own ($M = 8.70$, $p < .001$). Expression of locomotor skills ($M_{\text{social}} = 1.29$ and $M_{\text{solo}} = 1.40$, $p = .033$) and transition skills ($M_{\text{social}} = 3.58$ and $M_{\text{solo}} = 4.73$, $p < .001$) was also reduced in the presence of caregivers. Postural skills were largely unaffected ($M_{\text{social}} = 2.55$ and $M_{\text{solo}} = 2.56$, $p = .429$), though some skills, like independent sitting, were positively impacted by caregiver presence ($M_{\text{social}} = 34\%$ of posture skills vs. $M_{\text{solo}} = 27\%$, $p < .001$). Context effects were evident at younger and older ages (median split, $Med = 10.98$), but were stronger later in development ($p_s < .01$).

In sum, motor skill expression reflects both motor skill acquisition and social context. In ongoing analyses, we are leveraging hierarchical growth modeling to examine longitudinal change for each motor skill and for each infant.

EC5 - Infants' food word meanings reflect their recent experiences

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Details

Infants experience individual referents during word-learning moments, which may vary across contexts and development. For instance, older infants may encounter sliced apples as the referent for *apple* during snack time, while younger infants may encounter applesauce. To what extent do idiosyncratic experiences with specific referents shape infants' word meanings?

Research using animal and object categories suggests that older infants extend words to novel exemplars regardless of experience, though familiar objects boost younger infants' word recognition (Garrison et al., 2020; Weaver et al., 2024). Food words may provide a stronger test of individual differences in word meanings than previously-tested categories because infants encounter foods in perceptually diverse forms (e.g., whole, mashed, or cut; Clerkin & Smith, 2022; Perry et al., 2014). Thus, in present study we examined variability in infants' referent experiences and word-referent associations for foods.

Forty-two 9- to 11-month-olds and 40 15- to 17-month-olds were tested on their comprehension of three food words (*apple*, *banana*, *cheese*) using a looking-while-listening (LWL) paradigm (Fernald et al., 2008). We included referents that were likely to be experienced by younger infants (e.g., applesauce) and older infants (e.g., apple slices), as well as the canonical form (e.g., whole apple). Caregivers reported how often their child experienced each form of food (using the images from the LWL task) in the previous week on a scale from "never" to "very frequently."

Referent experience was highly variable (Figure 1). While some referents were frequently



experienced by most infants (e.g., whole banana and peeled banana), experience with other referents varied considerably across participants (e.g., applesauce and sliced cheese).

To test whether this variability in referent experience influenced word recognition, we fit a linear mixed-effects model regressing accuracy on caregiver-reported experience in the previous week, age, and their interaction, including by-subject and by-item random slopes. Accuracy was defined as the proportion of looks to the target during a window from 300–2800ms after word onset.

Infants recognized the target words significantly above chance ($M=0.53$; $p<0.001$), but this effect was driven by the older infants ($M_{younger}=0.51$, $p=0.65$; $M_{older}=0.56$, $p<0.001$). The effect of age was significant ($p<0.001$), as was the interaction between age and experience ($p=0.02$). Notably, the effect of experience was only significant for older infants ($p=0.04$) such that 15- to 17-month-olds were more accurate at recognizing words in the presence of target images that were rated as more frequently experienced (Figure 2).

The findings suggest that 15- to 17-month-olds' experiences with food referents vary and these differences influence word comprehension. While 9- to 11-month-olds likely understand food words (Bergelson & Swingley, 2012), our task may have been too challenging for this age group as we paired images within a superordinate category (e.g., apple vs. cheese). Despite this challenging design, older infants accurately recognized words, especially when words were tested in the presence of frequently experienced referents. These results suggest that words might be more strongly associated with specific referents, demonstrating initial evidence for experience-based individual differences in early word meanings.

EC6 - Infants' multimodal emotion processing in context: associations with family expressiveness at 6–8 months

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Details

Objective: Infants typically develop in emotionally rich environments, yet little is known about how variability in family expressiveness is associated with the early development of multimodal emotion processing. While preverbal infants are known to detect and discriminate emotional signals (Flom & Bahrick, 2007; Soken & Pick, 1999), it remains unclear how effectively they integrate facial and vocal affective information, and whether this ability is linked to differences in the emotional environment of the family. The present study aimed to investigate (1) whether 6–8-month-old infants reliably match facial–vocal emotional expressions across modalities, and (2) whether individual differences in emotion-matching performance are associated with levels of family emotional expressiveness. This question concerns how early environmental variability relates to infants' emerging affective processing.



Methods:

Thirty-five infants aged 6–8 months completed an intermodal emotion matching task. During each trial, infants viewed two emotional facial expressions (happy, angry, or neutral) while simultaneously hearing a sentence with emotional prosody congruent with the emotion of one of the faces. Three facial–vocal pairings were presented: happy–angry, happy–neutral, and angry–neutral. Visual preference for the emotion-congruent face served as the index of multimodal emotion-matching sensitivity (EMS) (similarly to the preference index for named target objects in Bergelson & Swingley, 2012). Family emotional expressiveness was assessed using the Family Expressiveness Questionnaire (FEQ) (Halberstadt, 1986). We fitted a linear mixed-effects model predicting infants' EMS, including fixed effects of Emotion (happy, angry, neutral) and FEQ total score, with a random intercept for Subject. Likelihood-ratio tests and AIC supported this main-effects model as the best-fitting specification.

Results:

Infants demonstrated reliable multimodal emotion matching, looking longer at congruent happy face–voice pairs. The mixed-effects model revealed a significant main effect of Emotion on EMS. Tukey-adjusted pairwise contrasts indicated that EMS was higher in the happy than angry condition (*estimate* = 0.0508, *SE* = 0.016, $t(102) = 3.18$, $p = .010$) and in the neutral than angry condition (*estimate* = 0.0425, *SE* = 0.016, $t(102) = 2.67$, $p = .044$). As illustrated in Figure 1, FE showed a positive association with EMS ($\beta = 0.00147$, *SE* = 0.00067, $t(128) = 2.19$, $p = .029$). Overall, infants from more emotionally expressive families tended to exhibit higher multimodal matching scores across emotional conditions.

Conclusions:

These findings highlight the family as an important early emotional context within which infants' multimodal emotion processing begins to emerge. Variability in family expressiveness was consistently associated with infants' sensitivity to facial–vocal congruency across emotional conditions. Together, the results underscore the value of considering naturally occurring emotional environments when examining early socio-emotional development and suggest that interpersonal emotional dynamics within the family may be linked to individual differences in infants' multimodal emotion processing.

EC7 - Neural systems that support reinforcement learning in the infant brain

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Details

Reward is an important learning signal across development. From our earliest moments, humans respond to rewarding feedback and can learn to associate rewards with previously neutral stimuli through repeated exposure to their contingency (Rovee & Rovee, 1969; Blass et al., 1984). Although there is substantial behavioral evidence of this reinforcement learning (RL) in infancy, the neural circuitry that supports reward processing and RL early in life remains unclear. One possibility is that infants leverage the same circuits as adults during RL. In adults, the striatum and medial frontal cortex are generally considered the core of the RL system (Fouragnan et al. 2018; Bartra et



al., 2013). These regions, however, undergo significant postnatal development into adolescence, calling into question their availability to support RL early in life (Nussenbaum & Hartley, 2019). Alternatively, infants might depend on other circuits for RL. For example, the insula, amygdala, and hippocampus have been implicated in conditioning during rodent development. To address this question, we designed an infant-friendly Pavlovian reinforcement learning task that infants watched during awake fMRI (N = 24 after exclusions for motion and inattention; median age = 6.8 months). Infants were presented with two shapes, one associated with a high reward probability (80%) and the other with a low reward probability (20%). One shape was pseudorandomly selected on each trial to reveal either a rewarding stimulus (a dynamic smiley face cartoon) inside the outline of the shape or an empty outline of the shape. Trials had three phases: a cue phase where both shapes were presented, a choice phase where only the pseudorandomly selected shape remained on the screen, and a feedback phase where the reward stimulus appeared (rewarded trials) or not (non-rewarded trials). We examined gaze behavior and BOLD activity associated with reward processing during the feedback phase and reward expectation during the choice phase. Infants attended more to the location of the chosen stimulus on rewarded versus non-rewarded trials, demonstrating that they found the reward stimulus engaging. BOLD responses during feedback elicited reward-related activity in visual cortex, hippocampus, and amygdala, but not the striatum or medial frontal cortex. Moreover, infants gradually learned to expect the reward stimulus when the high versus low reward probability shape was chosen. Specifically, they looked longer at the chosen shape during the choice phase (prior to feedback) when it was the high reward probability shape versus low reward probability shape, and this effect emerged over the course of the task. Further analyses showed that during the choice phase, the amygdala and striatum were more active when the high versus low reward probability shape was chosen. This effect was not observed in other ROIs. Overall, our behavioral results show that infants can incrementally learn from reward feedback and neural results suggest that this learning may depend on primarily on the amygdala and hippocampus. Thus, these results suggests that early-developing limbic circuits might be the primary basis of RL early in life, before robust cortico-striatal circuits mature.

EC8 - The buffering effect of familism on the association between prenatal depressive symptoms and infant sleep

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Details

Background: Sleep is a critical part of infant development that has been associated with neurodevelopment (Cao et al., 2022). Limited research has examined predictors of infant sleep among Latino families such as prenatal depressive symptoms. The Mexican population is the fastest growing population in the US due to high birth rates and have reported high prenatal depressive symptoms compared to non-Latina White participants (Nam et al., 2015). Previous studies have found that prenatal depressive symptoms are associated with less sleeping duration and more sleep problems (Nevarez et al., 2010). However, limited studies have examined potential buffers that are unique among Mexican families such as familism. Familism is a cultural value that could promote resiliency and social support and has been found as a protective factor among pregnant Latinas (Campos et al., 2008). Thus, the objective of this study was to examine whether familism buffers the association between prenatal depressive symptoms and infant sleep.



Method: Pregnant women of Mexican descent ($N=72$) were recruited from local clinics in California during their first trimester and followed until their infant was 6 weeks. Familism was assessed using the Mexican American Cultural Values Scale (MACVS; Knight et al., 2010) at the first trimester. Maternal depressive symptoms were self-reported at the third trimester using the Center for Epidemiological Studies Depression (CESD; Radloff, 1977) scale. Infant sleep was assessed with parent-report using the Brief Infant Questionnaire (BISQ; Sadeh et al., 2004) when infants were 6 weeks. The BISQ provided night awakening and night sleep duration. Covariates included in the analysis were maternal age and parity. Two separate moderation analyses were conducted to test whether familism buffers the association between prenatal depressive symptoms and infant sleep.

Results: In the moderation model for night awakening, higher prenatal depressive symptoms were associated with more night awakening ($B = .03, p = .04$) but familism was not associated with night awakening ($B = .01, p = .95$). Familism moderated the association between prenatal depressive symptoms and infant sleep at 6 weeks ($B = -.08, p = .02$). The simple slopes found that in low familism and moderate familism, higher prenatal depressive symptoms were associated with more night awakening ($B = .08, p = .001$; $B = .04, p = .03$). However, in high familism, there was no association between prenatal depressive symptoms and night awakening ($B = -.02, p = .50$). In the moderation model for night sleep duration, there was no association between prenatal depressive symptoms or familism on night sleep duration ($B = -.03, p = .37$; $B = .05, p = .91$). Familism did not moderate the association between prenatal depressive symptoms and night sleep duration ($B = -.05, p = .48$).

Conclusion: These findings suggest high familism buffers the association between prenatal depressive symptoms and infant sleep among Mexican families. Latinas with high familism might have a bigger social network they could rely on that might reduce their stress. Maternal stress has been suggested as the mechanism between prenatal depression and infant sleep (O'Connor et al., 2007). These results highlight the importance on investigating familism on the well-being of infants in a Mexican population.

EC9 - The developmental roots of volatility learning: behavioral, electrophysiological, and computational evidence from 11-month-old infants

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Details

Adaptive decision-making requires tracking environmental changes (i.e. volatility) and adjusting behavior in response. The developmental roots of such volatility learning are thought to emerge as early as 9 months¹. Interestingly, in the first year of life, infants show already considerable individual differences in the ability to learn from volatility², and in adulthood, these individual differences are associated with mental health differences³. The factors that contribute to such differences, especially in early development, however, remain to be explored. Past work^{1,2} highlights the role of temperament, but given evidence that caregiver factors are critical for the development of statistical learning⁴, the early caregiving environment may likewise shape this process. By 11 months, infants possess rich experience with sensory input, but their learning systems are still



malleable, making this a key developmental period to observe how individual and environmental factors shape emerging learning mechanisms. To understand the drivers of individual differences in volatility learning in early development, we developed a combined behavioral, electrophysiological and computational approach to assess how infants learn and adapt to volatility.

Eleven-month-old infants ($N=76$; age= 335.8 ± 15.5 days; 32 girls) took part in a reinforcement learning task where a target appeared in one of two locations with a certain probability. We measured infants' gaze, EEG and temperament (Infant Behavior Questionnaire-R Very Short) as well as caregivers' behavior toward their infants (Comprehensive Early Childhood Parenting Questionnaire). First, we related infants' accurate anticipatory looks toward the more likely target side to their temperament and the caregivers' behavior. Additionally, we used a computational model that describes how people learn and adapt when learning in volatile environments^{5,6}. We applied this model to the infants' anticipatory gaze data to understand how they integrate volatility information to update their expectations over time.

The preliminary results include the behavioral and computational data of 63 infants, with next steps involving the analysis of the neural data. The computational model successfully captured individual and group-level trends, demonstrating that infants utilize volatility and adapt to it in a similar fashion as children and adults (Fig1). Bayesian Structural Equation Models revealed infants with higher IBQ Effortful Control showed a more adaptive learning profile overall. They made more accurate anticipatory gazes ($b=0.37$, 95% CI [0.13 to 0.62]), were more sensitive to changes in the environment ($b=0.35$, 95% CI [0.10 to 0.59]), and had a more flexible and exploratory learning style ($b=-0.35$, 95% CI [-0.60 to -0.11]) (Fig2). Moreover, positive parental discipline was correlated with greater Effortful Control ($r=0.26$, 95% CI [0.04 to 0.47]), highlighting a potential pathway through which parenting may contribute to early regulatory capacities.

These results provide the first evidence that 11-month-old infants can use and adapt to changes in environmental volatility in a way that is well captured by the same computational framework typically applied to adults. They also emphasize that early experiences and emerging self-regulation are tightly interlinked with adaptive learning and adaptation to change during early development.

Oral Session 1 - Memory, Executive Function, and Representational Learning

01.1 - Teaching 21-month-olds to form precise representations of sets of four items

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Details

Prior work suggests that early numerical cognition depends on two systems: an object-tracking system (OTS) that can precisely represent sets of 1-3 items, and an approximate-number system (ANS) that can approximately represent sets of 4 items or more. Part of the evidence for these conclusions comes from tasks showing that infants can compare discrete quantities within a system, but not across systems. One such task is the cracker-choice task (Feigenson et al., 2002). After watching an experimenter lower different numbers of crackers or other food items into two containers, infants preferentially approach the container with more items only if both numbers can be represented by the same system. Thus, infants succeed with 1-vs-2 or 2-vs-3 items (OTS), or with 4-vs-8 or 6-vs-9 items (ANS), but choose randomly with 2-vs-4 or 3-vs-6 items, which implicate



both systems. We asked whether a brief computer-animated training intended to teach infants to precisely represent sets of 4 items would help them succeed with 2-vs-4 items.

Experiments 1 and 2 were conducted in the lab. Experiment 1 served as a baseline for the 2-vs-4 cracker-choice task: Infants sat at a table and watched an experimenter lower 2 crackers into one container and 4 into another, one cracker at a time. Infants were then encouraged to choose a container. 24-month-olds ($N=24$) preferentially reached for the container with 4 crackers (75%, $p=.003$), but 21-month-olds ($N=31$) did not (42%, $p=.763$).

In Experiment 2, a new group of 21-month-olds received 10 computer-animated training trials involving 3-vs-4 and 4-vs-5 contrasts. Each trial started with two identical sets of 3 or 4 objects (e.g., ducks); one object was then added to one set to create a set of 4 or a set of 5. Next, infants heard, “Four! Where’s four?” followed by a pause. At the end of this pause, the set with 4 objects was highlighted, and infants heard, “Four, four!” Following training, infants received the 2-vs-4 cracker-choice task. Infants who made a choice ($N=58$) preferentially reached for the container with 4 crackers (69%, $p=.005$), showing transfer of learning.

Experiments 3 and 4 were conducted online and sought to confirm Experiments 1 and 2; data collection is nearly completed. Experiment 3 served as a baseline for the online 2-vs-4 cracker-choice task. Infants saw 2-vs-4 cookies being distributed into two containers, one cookie at a time, and then they heard “Which bowl do you want?”. 24-month-olds ($N=22$) preferentially looked at the container with 4 cookies (74%, $p=.003$), but 22-month-olds ($N=21$) did not (48%, $p=.647$). In Experiment 4, a new group of 21-month-olds received the same training trials as Experiment 2 followed by the online 2-vs-4 cracker-choice task. Infants ($N=46$) preferentially looked at the container with 4 cookies (72%, $p<.001$), replicating transfer of learning in the online format.

Our experiments demonstrate that with training, infants can rapidly learn to form precise representations of sets of 4 items, making possible successful 2-vs-4 comparisons in the cracker-choice task. Our results raise many exciting questions for future research. How exactly is our training altering infants’ representations? Which aspects of our training are critical for doing so? How well would our training generalize to other discrete quantities? We believe our results are paving the way for exciting new developments in research on early numerical cognition.

O1.2 - Early false-belief understanding in infancy: evidence from a dual-identity task with 16- to 34-month-old children

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Details

Understanding others’ mental states—particularly their false beliefs—is a foundational milestone in social-cognitive development. While classical explicit false-belief (FB) tasks estimate this ability to emerge around age four, research using implicit, nonverbal paradigms suggests earlier competencies in infancy. However, the theoretical nature of these early abilities remains debated, especially regarding whether infants rely on low-level registration processes or genuinely represent



others' beliefs propositionally. The present study contributes to this discussion by examining whether children aged 16–34 months demonstrate sensitivity to others' false beliefs in an interactive Dual-Identity Task, which requires attributing beliefs about object identity rather than object location. Identity-based FB paradigms are theoretically informative because they cannot be solved solely by tracking where an agent last encountered an object; instead, they require understanding that appearances can be misleading and that another person may form a belief inconsistent with reality.

A total of 120 children ($M_{age} = 22.40$ months) participated and were randomly assigned to a False-Belief (FB) or True-Belief (TB) condition. Across three trials, children interacted with an experimenter who either had or lacked knowledge about the true identity of a reversible puppet. Upon return, the experimenter searched a set of boxes while expressing uncertainty. Children's communicative behaviors—passing the puppet to someone, pointing toward it, or touching it—served as indicators of whether they attempted to correct the experimenter's mistaken belief. Responses were coded on four hierarchical levels, from direct object transfer to a combination of pointing and tactile interactions. Reaction times from the experimenter's re-entry to the first communicative action were recorded to assess cognitive processing demands.

Generalized estimating equation analyses revealed that children in the FB condition initiated significantly more communicative behaviors than those in the TB condition, particularly on broader communication levels involving pointing or touching. This suggests that children selectively adjusted their communicative efforts when the experimenter held a false belief—consistent with early mental state attribution. No differences emerged for direct object transfers alone, indicating that more complex or multimodal behaviors may be more sensitive indicators of early ToM processes. Exploratory analyses further showed that FB-congruent responding increased across trials, suggesting growing task familiarity or emerging recognition of the task's epistemic structure. Age effects indicated more frequent communicative behaviors among older children, yet no interaction with condition, suggesting that sensitivity to false beliefs was present across the examined age span.

Reaction-times analyses revealed no significant effects between conditions. Further, no condition differences were observed in children's interactions with the irrelevant boxes, indicating that effects were specific to the epistemically relevant object.

Overall, these findings provide new evidence that infants between 16 and 34 months demonstrate sensitivity to identity-based false beliefs in an interactive, ecologically valid task. The results contribute to ongoing debates about the continuity between implicit and explicit Theory of Mind and highlight the value of identity-based paradigms for capturing early mentalistic reasoning beyond simple registration-based mechanisms. Implications for theoretical models of early ToM and methodological recommendations for future research are discussed.



O1.3 - The ADAM task: A novel method for measuring early phonological working memory in infancy

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Details

Working memory (WM) supports early learning by enabling the temporary storage and manipulation of information (Baddeley et al., 1998; Kane et al., 2004). While visual WM has been extensively studied in infancy, much less is known about phonological WM (pWM), despite its relevance for speech processing and language acquisition (Baddeley, 2000; Gathercole & Pickering, 2000). Existing pWM tasks typically begin around 3-4 years and rely on explicit verbal repetition or recall (Baddeley et al., 1975; Gathercole & Baddeley, 1989), making them unsuitable for infants. Yet infants can retain and compare speech information in real time to support statistical learning, rule extraction, and word mapping (Saffran et al., 1996; Marcus et al., 1999; Kabdebon & Dehaene-Lambertz, 2019), suggesting the presence of early phonological retention mechanisms.

The present study introduces a new infant-paced paradigm, the ADaptive Auditory Memory (ADAM) task, designed to measure pWM from 5 to 12 months of age. ADAM uses a two-alternative looking procedure consisting of rapid learning blocks that evaluated infants' ability to remember target sequences and to predict upcoming events, while distracting stimuli are intermixed. Seventy-six infants completed three rapid learning blocks, each composed of six familiarization and two test trials. Each block presented three repetitions of a target syllable sequence interleaved with three distractors, requiring infants to encode relevant auditory information amidst competing input. Target-distractor pairs changed across blocks, reducing long-term memory involvement and emphasizing WM retention. Consistent with definitions of WM (Cowan et al., 2020), ADAM requires infants to encode and maintain syllable sequences over short delays while anticipating visual outcomes. Because test trials provide no reinforcement, successful anticipatory looking reflects active maintenance and comparison of syllabic representations. To estimate individual pWM span, all infants started with trisyllabic sequences; performance determined whether subsequent blocks used bisyllabic or quadrisyllabic sequences. First-look accuracy and latency to the correct side served as dependent measures of pWM.

Results revealed robust age-related gains in processing efficiency: older infants oriented more rapidly (first-look latency: $\chi^2(2)=11.29$, $p=.004$) and required less time to reach the correct side ($\chi^2(2)=7.58$, $p=.023$). In contrast, memory span showed no age-related changes with infants across ages displaying a capacity of approximately 2-3 syllables.

Moreover, to evaluate cross-method robustness and the feasibility of remote testing, we compared 31 infants tested online using Labvanced's webcam-based eye-tracker with 31 tested with Tobii in-lab. Since gaze measures can vary depending on the recording setup and coding procedure, we compared the distribution of each metric across online and in-lab pipelines using the overlapping index (η ; 0 = no overlap, 1 = complete overlap). Accuracy-based outcomes showed high overlap



($\eta^2=.94-.99$), while latencies measures showed moderate-high similarity ($\eta^2=.80-.92$), demonstrating stable results across settings.

Taken together, these findings provide evidence that ADAM is a robust and scalable paradigm for measuring phonological working memory in infancy. It functions reliably across recording systems and can be implemented both in-lab and online, allowing ADAM to be used from as early as 5 months of age and to reach families from diverse backgrounds that can be often underrepresented in laboratory research.

O1.4 - Iconic and beat gestures support ordinal memory in toddlerhood

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Details

Although gesture plays a central role in everyday communication, the extent to which gesture supports memory in toddlers is understudied. Representational gestures, such as iconic gestures, enhance memory by providing semantically rich visual cues in children as young as 3 years of age (Aussems & Kita, 2019). Less is known about how beat gestures support their cognition; these gestures lack semantic content but highlight prosodic and structural aspects of speech (So et al., 2011). The present study addressed this gap by examining how toddlers' recall of a spatial narrative is influenced by the different sorts of gestures they routinely encounter.

41 3 y.o. children ($M_{age} = 3.57$ yrs, 20 F) were tested in children's museums. Participants were told: *"This is my friend, Minnie. You're going to watch a video of Minnie on her day off. Try to remember where she goes and what she does in each place"*. They were instructed to pay attention to the order of the character's movements and the actions performed at each location. The character appeared in the dollhouse, moving around to 6 different rooms, pausing at each room for 3 seconds, where an audio clip stated the room that character was in and the action the character performed (e.g. Minnie went to *the bathroom to brush her teeth*). The statements were paired with iconic gestures (IG), beat gestures (BG), or no gestures (NG; just a smiling silent experimenter). (Fig 1). Condition was randomly assigned, and the location/action order was counterbalanced across participants. After the video ended, a still of the dollhouse was shown, and the experimenter prompted the child to recall the rooms the characters went to in the order they were presented: *"Can you point on the screen where you first saw Minnie?"*. The child pointed to a room, and the experimenter then asked: *"What was she doing in there?"*. This prompt sequence was repeated for each room the child recalled: *"Where did she go next?"*, *"And what was she doing there?"*.

The children received two types of scores: % recall of the *order* of locations/actions, and % recall of the *type* of locations/actions. Accuracy was analyzed using generalized linear mixed-effects models to assess the effects of the gesture condition. Children in the IG and BG conditions recalled the order of the locations and actions in the narrative more readily than children in the NG condition. For the locations and actions type recall scores, there were no significant effects of condition (see Fig 2 for values). These results indicate that toddlers are able to use both subtle,



non-semantic gesture and representational gesture to support their encoding of the *order* of events, but the encoding of the *content* of the events does not benefit to the same extent. This is in line with theories that highlight a privileged link between spatial representations and ordinal representations (Dijck et al., 2013), possibly due to hippocampal involvement in both domains (Schiller et al., 2015).

O1.5 - The effect of bilingual environments on symbolic play in the second year

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Details

Introduction: Symbolic play emerges around 13 to 15 months and has been linked to developments in infants' language and nonverbal cognitive skills, including visual perception, visual attention, and memory generalization. Most symbolic play studies have focused on children from monolingual households, despite growing interest in how contextual influences – including bilingual environments – shape infants' cognitive development. Recent research suggests that bilingual learners differ from monolingual learners in how they explore and learn from their environments, possibly through adaptive differences in attentional efficiency (Bialystok, 2024). These differences may stem from how infants' cognitive systems adapt to variable learning environments. For instance, bilingual environments have been hypothesized to support greater representational flexibility in infants (Hayne & Barr, 2022). If this is the case, bilingual learners may demonstrate more advanced symbolic play in the second year of life. To test this hypothesis, and better understand developmental differences between young children raised in monolingual and bilingual environments, we compared 15- to 19-month-old bilingual and monolingual learners on their symbolic play.

Methods: Data were collected remotely between 2021 and 2024 from mother-child dyads ($n = 100$). Children ($M = 16.9$ months, $SD = 0.9$) were categorized into a bilingual or monolingual group based on maternal report of language exposure. Symbolic play was observed during dyadic free-play interactions with a standardized set of objects and coded in 10-second intervals using a five-level coding scheme (see Figure/Table). These levels were then collapsed into two categories: Early-Emerging Symbolic Play (inter-rater reliability $\alpha = 0.89$) and Later-Emerging Symbolic Play ($\alpha = 0.81$).

Results: The odds of engaging in Early-Emerging Symbolic Play within a 10-second interval did not differ significantly between language groups ($OR \approx 1.28$, 95% CI [0.87, 1.87], $p = 0.22$). On average, bilingual learners engaged in Early-Emerging Symbolic Play on 20.5% of intervals ($SD = 20.2\%$, $Median = 16.3\%$, $Range = 0 - 66.7\%$) and monolingual learners did so on 20.1% of intervals ($SD = 17.5\%$, $Median = 16.2\%$, $Range = 0 - 67.6\%$). However, bilingual learners were significantly more likely to engage in Later-Emerging Symbolic Play than monolingual learners ($OR \approx 1.71$, 95% CI [1.07, 2.74], $p = .03$). On average, bilingual learners engaged in Later-Emerging Symbolic Play on 6.7% of intervals ($SD = 7.0\%$, $Median = 4.8\%$, $Range = 0 - 26.3\%$), while monolingual learners did so on 4.0% of intervals ($SD = 6.6\%$, $Median = 2.4\%$, $Range = 0 - 40.6\%$); see Figure 1.



Conclusion: Although children in both language groups showed similar levels of engagement at lower levels of symbolic play, differences emerged at higher levels. During the observation, bilingual learners were more likely to engage in more abstract and decontextualized levels of symbolic play than their monolingual peers. Taken together, the results suggest that bilingual learners demonstrate advanced representational abilities through their play during the second year of life. These findings further support the hypothesis that bilingual exposure leads to cognitive adaptations with diverse behavioral manifestations, and shed light on contextual influences on cognitive development.

01.6 - Development of inhibitory control, working memory and cognitive flexibility on the transition between infancy and toddlerhood

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Details

Executive functions (EFs) are key cognitive skills that we use every day to adapt, problem-solve, and achieve our goals. In childhood, these skills also play an essential role in learning and social adjustment (Mulder et al., 2014). EFs are traditionally conceptualised as three interdependent domains – inhibitory control, working memory and cognitive flexibility (Miyake et al., 2000). Progress in the field of early EFs has been limited by a lack of age-appropriate tasks for children under 2 years, especially tasks that can be easily adapted to measure EF skills longitudinally without fundamentally changing the task design (Holmboe et al., 2021). Consequently, our knowledge of the development of EF skills on the transition from infancy to toddlerhood is currently limited.

To address this, we recently developed a new task battery to assess the three core EF domains of inhibitory control, working memory and cognitive flexibility from 10-30 months. Here, we present data from three of these tasks, collected longitudinally at 10 and 16 months in a large sample (N = 75-156, depending on task and age). The Early Childhood Inhibitory Touchscreen Task (ECITT) is a measure of inhibitory control suitable from 9 months of age (Hendry et al., 2021). The Magic Box task is a novel task developed to measure object-based working memory in infancy and toddlerhood. It is inspired by existing manual search tasks (Feigenson & Carey, 2003; Van De Walle et al., 2000) but has been adapted to be more suitable for measuring individual differences. The Shapes task is a novel manual task that involves infants placing blocks in a shape-sorter box across increasingly difficult levels (see Fig. 1). Infants are always presented with the simplest problem first – the blocks being positioned right in front of their correct locations. This is then followed by a series of switch trials (the box is turned 180 degrees before a response can be made), which require cognitive flexibility.

Using these three tasks as our indicators, we find that there is no improvement in inhibitory control and no longitudinal stability between 10 and 16 months. In contrast, working memory performance improves significantly between 10 and 16 months. 16-month-olds retrieve more hidden objects from inside a box, and they search longer for an object that has ‘magically’ disappeared (Fig. 2). However, individual differences in working memory performance are not stable between 10 and 16 months. Finally, infants improve significantly in their cognitive flexibility between 10 and 16



months, and performance differences are moderately stable across this period ($r = .29$, $p < .01$). Against our expectations, individual differences in cognitive flexibility (at either age) could not be explained by inhibitory control (correlation between ECITT and Shapes: $r < .1$, N.S.).

We conclude that the transition between infancy and toddlerhood is a period of substantial development in emerging EF skills. Inhibitory control seems to develop at a slower rate, with young toddlers (16 months) still struggling to inhibit a prepotent motor response. Individual differences in EF skills are generally not stable at this young age (Hendry et al., 2021, and findings reported here). However, cognitive flexibility shows earlier stability than other EF domains – a novel finding that highlights the importance of cognitive flexibility even in infancy.

O1.7 - Embedding executive function into play activities

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Details

This session will examine components of executive function (EF) in young children's naturally occurring play behaviors. EFs include inhibition, working memory, cognitive flexibility, plan and organization, and emotional control. Two researchers observed 10-minute video recordings of five children from the Developmental Play Assessment for Practitioners (DPA-P) focused on play behaviors and coded for EFs. Children with autism, Down syndrome, developmental delays, and without delays were included development of the DPA-P. Interrater reliability will be shared and implications for policy and practice will be discussed.

Traditionally, EFs are assessed using elicited behaviors based on established tests (e.g., the Behavior Rating Inventory of Executive Function (BRIEF-P). Although the BRIEF-P starts at 24 months, there are no multidimensional assessments of EFs for children under 24 months. Authentic assessment, in contrast, emphasizes natural contexts, which are more appropriate for very young children. Developing a method to identify and assess EFs based on naturally occurring play behaviors would be an advance over the use of traditional assessments.

A pilot study of play observations of young children (ages 8, 18, and 36 months) playing in their homes with a caregiver were coded at 5-minute interval for 30 minutes of play. The coders examined the videos for evidence of EF components during play. Interrater reliability was 88.8% across the two coders. These play observations are part of a large database of 492 children, developing with and without disabilities, from ages 8 to 60 months, which formed the basis of the (DPA-P. The five play observations were coded by the researchers for indicators of EFs including inhibition, working memory, cognitive flexibility, plan and organization, and emotional control. For example, episodes of planning and organization were identified in activities in which the children linked activities together into a play sequence (e.g., the child sees the baby doll, looks for a spoon, stirs the spoon in a cup, and then feeds the baby doll. That example also provides evidence of working memory. The children's DPA-P play profiles will be compared to the evaluation of their EF skills.



There are no standardized multidimensional assessments of young children with and without developmental delays that include EFs within the assessment procedures particularly under the age of 2 years. This presentation aims to understand how naturally occurring play activities could be evaluated for EFs, without the use of computer or iPad technologies or reliance on elicited behaviors. EFs are an important part of early brain development. EFs have been studied in infants and toddlers in laboratory settings with typically only one category of EF typically examined. By observing children in more ecologically valid settings, we can gain deeper insights into their EF skills, paving the way for more targeted interventions and support in their growth and development. In this session, we will engage the audience through video presentations of EFs as observed in play situations. We will also discuss the implications for policy and practice.

O1.8 - Building early memory networks: Associative inference and ontogenetic changes in associative transfer

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Details

Infants acquire substantial information incidentally from their surround, yet early learning is often highly stimulus-specific. Domain-general associative processes, however, can provide a mechanism for more flexible memory expression. Prior sensory preconditioning (SPC) work has demonstrated that infants can form associations between stimuli they simply observe together—without reinforcement—allowing learning about one item to transfer to another (Barr, Marrott, & Rovee-Collier, 2003; Cuevas & Giles, 2016). Across two complementary research programs, we examined (a) the minimal conditions under which 6- and 9-month-olds form and retain associative links, and (b) whether 6-month-olds integrate overlapping associations into mnemonic networks that support associative inference.

The first line of investigation assessed how brief exposure can be and still support reliable associative transfer. Using SPC combined with deferred imitation (i.e., puppet task; Barr, Dowden, & Hayne, 1996), infants encountered paired puppets during naturalistic snack or play periods. Six-month-olds exhibited robust learning transfer after only a single 1.87-min simultaneous exposure and retained this association for 48 hr. Briefer exposure did not support learning transfer (Fig. 1, left). Nine-month-olds, in contrast, required substantially longer exposure (15 min) involving movement to form and retain associations (Fig. 1, right). These findings reveal clear developmental differences in the minimal learning input needed to support associative learning transfer and suggest age-related shifts in attention, encoding efficiency, and/or the functional relevance of co-occurring events.

The second research program asked whether 6-month-olds integrate multiple overlapping associations into organized memory networks that support associative inference by bridging two related, but previously independent, literatures—SPC and associative inference (e.g., Preston et al., 2004; Schlichting et al., 2017). Infants viewed two-item puppet pairs (AB, BC; and in extended designs, CD and DE) across several days during incidental exposure. They subsequently transferred learning between stimuli that had never been experienced together (A–C), and this



transfer was bidirectional (Fig. 2). When exposed to four- or five-pair structures, infants again inferred relations among indirectly linked items (A–E, A–D, B–D). Network organization exhibited principled constraints: infants did not generalize to unrelated puppets, extinction selectively weakened links (Fig. 2), and integrated associations persisted for 2 days but not 5. These patterns indicate that both encoding-based integration and retrieval-based mediation contribute to early associative network formation.

Taken together, these two lines of work show that 6-month-olds rapidly form and integrate associative memories under minimal conditions, providing the earliest evidence to date of associative inference in infancy. In contrast, 9-month-olds require more extensive or dynamic exposure to achieve comparable learning, highlighting ontogenetic changes in the thresholds and mechanisms supporting associative transfer. These findings challenge accounts positing maturation-based, inflexible early memory systems and instead demonstrate that experience-dependent associative processes form a foundational scaffold for the emergence of relational memory. By revealing that young infants can combine overlapping experiences to infer indirect relations, this work advances understanding of how early memory networks are constructed. What remains to be explored is how these mnemonic networks emerge developmentally, including the mechanisms driving their growth.

O1.9 - Following eye gaze through time: assessing visual short-term memory in 14- and 20-month-old infants

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Details

Visual short-term memory (VSTM) is a limited-capacity memory system that is important for visually guided behavior and is associated with IQ and other measures of cognitive abilities in adults (Luck & Vogel, 2013). Research with infants has revealed age-related changes in VSTM performance using *change detection* tasks (e.g., Oakes et al., 2013; Ross-Sheehy et al., 2003). In these tasks, infants view one or more items during an initial sample array followed by a short delay and then a test array in which one or more items may have changed. Previous studies have asked whether infants *can* store information in VSTM, but more recent research has shifted to examine *how* infants store information in VSTM. For example, young infants' detection of changes in VSTM tasks depends on their actually looking to the to-be-changed item prior to the change onset (Beckner et al., 2020; Cantrell et al., 2019; Eschman & Ross-Sheehy, 2023; Ross-Sheehy & Eschman, 2019).

In the present study, we assessed VSTM in 14-month-old (N=33) and 20-month-old (N=38) infants using an eye-tracking change detection task. Infants were presented with a series of change detection trials that had the following sequence: a 1000-ms sample array of three or four colored circles (i.e., set sizes), followed by a 500-ms delay with a blank screen, and finally a 2000-ms test array in which one randomly selected circle has changed color. We refer to the sample and delay



arrays as the *prechange period*, and the test array as the *postchange period*. Infants completed up to 26 trials at each set size.

We calculated *change localization* scores during the period of each trial after the change occurred by dividing the duration of infants' looking at the changed item by their total looking at all items combined (3 or 4 items depending on set size). At both ages, infants' change localization scores were significantly above chance for both set sizes (0.33 and 0.25 for set size 4), $ps < .01$ (see Figure 1). Thus, both 14- and 20-month-old infants successfully stored information from 3- and 4-item arrays in VSTM.

Next, we examined infants' moment-to-moment changes in looking to determine how infants' attention varied as a function of what they had attended to during the prechange period, *Target* trials if they looked longest at the item that would later change color and *Distractor* trials if they looked longest at one of the items that did not change. Infants maintained their looking to the item they preferred during the prechange period longer than expected by chance regardless of whether that item changed (see Figure 2). However, this effect was more pronounced for the target item than distractor items, indicating that infants sustained their looking to the preferred item longer when that item subsequently changed and had a stronger preference during the postchange period when the preferred item was the target. These results suggest that overt gaze during learning is important for forming VSTM representations even during the second year of life.

Oral Session 2 – Visual and Face Processing

O2.2 - Emotion word comprehension from faces and bodies: Evidence from a looking-while-listening task

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Details

Understanding when children acquire emotion words is fundamental to theories of emotional and linguistic development. Research using traditional tasks (e.g., labeling, sorting) has suggested gradual acquisition of emotion words from ages 3-5, with inconsistent findings for 2-year-olds (e.g., Russell & Widen, 2002; Widen & Russell, 2008; Price et al., 2022; Wu et al., 2023). However, these tasks may underestimate young children's abilities due to their high demands. Using a more sensitive looking-while-listening paradigm adapted from infancy research (Fernald et al., 2008), we conducted two preregistered experiments examining emotion word comprehension in 18- to 36-month-olds.

In Experiment 1, toddlers (18–36 months; $N = 96$) viewed two facial expressions (e.g., happy and sad) presented side by side on a screen while hearing an audio prompt (e.g., “Who is happy?”). We measured children's preferential looking toward the target expression from 367 to 2000 ms following the onset of the target word (e.g., Bergelson & Swingley, 2013; Swingley & Fernald, 2002). Four emotion words were tested: “happy,” “sad,” “angry,” and “scared.” Children's performance was analyzed separately for trials involving cross-valence facial expression contrasts (e.g., happy vs. sad) and within-valence facial expression contrasts (e.g., sad vs. angry). To validate the



effectiveness of the paradigm, we also included two control trials featuring common nouns (“apple,” “flower”). While all children performed above chance on control trials ($p < .001$), their performance on emotion trials differed by age. Children aged 18-24 months performed at chance in both cross-valence ($M=0.54$, $t(31)=1.13$, $p=.267$) and within-valence ($M=0.49$, $t(31)=-0.39$, $p=.698$) trials. By 24-30 months, children succeeded on cross-valence ($M=0.58$, $t(31)=2.05$, $p=.049$) but not within-valence trials ($M=0.53$, $t(31)=1.49$, $p=.146$). By 30-36 months, performance extended to both trial types (cross-valence: $M=0.68$, $t(31)=6.44$, $p < .001$; within-valence ($M=0.59$, $t(31)=3.42$, $p=.002$). These findings show that emotion word comprehension emerges during age two.

Experiment 2 ($N=100$, ages 18–30 months) extended this work by testing whether adding body postures to facial expressions would support emotion word comprehension. Again, while all children performed above chance on non-emotion, control trials ($p < .001$), their performance on emotion trials differed by age. Children aged 18-24 months performed at chance in both cross-valence ($M=0.54$, $t(49)=1.91$, $p=.062$) and within-valence ($M=0.48$, $t(48)=-0.54$, $p=.590$) trials. However, 24–30-month-olds reliably mapped emotion words to expressions across *both* cross-valence ($M=0.56$, $t(49)=2.59$, $p=.012$) and within-valence ($M=0.59$, $t(49)=3.85$, $p < .001$) trials.

Together, by applying the looking-while-listening paradigm to emotion words for the first time, we provide the most detailed developmental timeline to date. Experiment 1 shows that emotion word comprehension emerges around 24 months with facial expressions alone, progressing from cross-valence (24-30 months) to within-valence distinctions (30-36 months). Experiment 2 demonstrates that 24- to 30-month-olds can successfully map emotion words when both facial and bodily cues are available, suggesting potential benefits of multimodal emotional displays for early word comprehension. These findings highlight the importance of considering both task sensitivity and stimulus modality when assessing young children's emotion word knowledge.

O2.3 - The impact of audiovisual synchrony on neural correlates of infant face recognition

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Details

Background: Infants typically engage in social interactions in multimodal settings, where they both see and hear other people. These interactions are characterized by intersensory redundancy (IR), which attracts infant attention and enhances processing of information that is not specific to a sensory modality (Bahrick & Lickliter, 2000). Event-related potentials (ERPs) can be valuable to understand how IR influences infants’ attention and face processing. The Nc is an ERP component that reflects attention allocation and stimulus salience (Guy et al., 2016), while the N290 and P400 are associated with face processing (Conte et al., 2020).

Objective: This study investigates face processing and recognition in 12-month-olds in multimodal contexts using ERP measures.

Method: Twenty-four 12-month-old infants have been recruited for this ongoing study. Participants completed a familiarization phase where they viewed serial presentations of two videos of actors reciting children’s stories. One video was presented synchronously with the soundtrack, while the other was presented asynchronously. After familiarization, ERPs were measured in response to photographs of the familiar-synchronous face, familiar-asynchronous face, and a novel face, using



a Magstim-EGI 128-channel EEG system. Preliminary analyses reported here include data from 12 participants.

Data Analysis: ERPs were segmented from 100 ms before stimulus onset through 1000 ms following onset. N290 and P400 peak amplitudes and Nc mean amplitude were analyzed using methods from past studies (Conte et al., 2020). Analyses included stimulus type (familiar-synchronous, familiar-asynchronous, novel) and electrode location as repeated measures. One-way ANOVAs and paired-sample t-tests were run for significance analyses. Simple effects were examined through the calculation of least square means with Bonferroni corrections for multiple comparisons.

Hypotheses: Infants were expected to be more attentive to the synchronous than the asynchronous face during familiarization, as synchrony was expected to attract attention. However, IR was expected to direct attention to information presented across both audio and visual sense modalities, inhibiting face processing. Therefore, infants were expected to more thoroughly process and recognize the familiar-asynchronous face, but not the familiar-synchronous face. Reduced Nc amplitude to the familiar-asynchronous face, compared to synchronous and novel faces, was expected and may indicate recognition. We predicted that N290 and P400 responses would be observed to face stimuli, however, may not vary based stimulus familiarity, as past studies have shown conflicting results (de Haan et al., 2002; Halit et al., 2004).

Results: Analyses of N290 and P400 amplitude showed no significant differences based on stimulus type. For the Nc, no significant effects of stimulus type were found, though trends suggested greater Nc amplitude in response to familiar-synchronous faces.

Conclusion: The study found no significant differences in neural responses to familiar-synchronous or familiar-asynchronous faces versus novel faces. The null effects may result from insufficient familiarization time or stimulus complexity, limiting infants' ability to recognize faces. The Nc component did not show a clear novelty preference, indicating no significant face discrimination. These findings highlight the complexities of studying audiovisual face processing in infants. Inclusion of additional participants may increase our power in detecting significant effects and data collection is ongoing.

O2.4 - Innate face preference in the human newborn: empirical fact or mostly myth? A systematic review

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Details

Faces are among the most salient and important stimuli in human development. Human expertise in face perception has motivated suggestions that faces are innately 'special' perceptual objects processed by dedicated neural mechanisms. Indeed, human newborns have been reported to exhibit an attentional preference for face-like patterns, and this 'newborn face preference' is widely cited as evidence for an innate face detection mechanism. The influential CONSPEC theory posits an evolutionarily ancient neural module that directs newborn attention to faces, thereby canalising



the development of expertise in face perception. Despite its theoretical influence, the primary literature has not previously been systematically reviewed. Here, we report results of a systematic review and meta-analysis of experimental studies comparing newborns' attention to face-like versus non-face-like stimuli. Across 15 publications reporting 22 experiments, only five studies tested face-naïve newborns (≤ 1 hr postnatal). Replicable preference was observed for one schematic face stimulus, whilst another face-like stimulus did not elicit a preference. Seventeen studies testing face-experienced newborns (2–7 days postnatal) demonstrated moderate-to-large face preference effects, but these results are more parsimoniously and plausibly attributable to postnatal learning. Substantial heterogeneity was observed in the 11 experiments amenable to meta-analysis. Theoretical analysis indicated that conclusions supporting an innate face detector rest heavily on interpretative assumptions which discount the relevance of postnatal learning. These assumptions are primarily based upon a flawed re-interpretation of a key result, which was originally reported as solidly negative (no preference for a three-blob face-like configuration) but is now treated and cited as a foundational positive finding. This misleading narrative has come to dominate the secondary literature in a self-perpetuating manner. Hundreds of mis-citations of the original study (Johnson, Dziurawiec, Ellis, Morton 1991) have created the myth of a solid, consistent evidence base which does not exist. Overall, the empirical evidence provides limited support for a robust, general inborn face preference and does not substantiate claims of a dedicated innate face detection module. We highlight the need for more precise theoretical models and rigorous tests of innateness in early face perception, and for re-evaluation of arguments based upon the presumed existence of inborn face preference and/or a dedicated innate face detector.

O2.5 - Influence of surgical masks on spontaneous face preference in full-term newborns and infants born premature

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Details

Introduction. Full-term newborns already orient their attention to faces over non-faces stimuli within minutes of birth (Frantz, 1936; Morton & Johnson, 1991). This early preference is sensitive to orientation and spatial configuration, as neonates prefer upright faces to inverted ones (Simion et al., 2002). This skill is considered to be essential for later cognitive and social development (Pascalis et al., 2020). Since the COVID-19 pandemic, mask wearing, has partially occluded facial features, altering key configuration cues. This raises the question of whether early exposure to masked faces in maternity wards during the COVID-19 outbreak affected the emergence of such face-processing skills. The issue may be even more critical for infants born preterm, who are exposed to masked faces for extended periods during hospitalization. This study therefore aims to assess and compare the impact of mask wearing on visual face preferences in full-term newborns and preterm infants with the same gestational age.



Methods. A total of 48 healthy full-term newborns (#age in days: 1.6 days) and 37 preterm infants reaching the same maturational age (#corrected age in days: 3 days) were recruited from the Grenoble University Hospital maternity ward. Two faces were presented side by side on a screen at ~30cm from the participant's face under two conditions: (1) one masked vs. one unmasked face (full-term: $n = 19$; preterm: $n = 17$), and (2) two masked faces, one upright vs. one inverted (full-term: $n = 19$; preterm: $n = 20$). Each condition contained two 10-s trials of cumulative looking time. The side of each face was counterbalanced between trials. Gaze behavior was video-recorded, and visual preference quantified as the Proportion of Looking Time (PTLT) via frame-by-frame manual coding, blind to stimulus position.

Results. In the first condition (masked vs. unmasked), both full-term and preterm neonates showed no significant visual preference for either face ($p = 0.66$; $p = 0.21$, respectively). In the second condition (masked upright vs. masked inverted), full-term neonates showed a significant visual preference for the masked upright face ($p < .01$), whereas preterm neonates showed no significant preference between the two ($p = 0.20$).

Conclusion. These findings suggest that while full-term newborns are already sensitive to the upright configuration of masked faces, preterm newborns do not yet show such orientation preferences. This difference may reflect a developmental delay in face processing in preterm infants when exposed to altered facial configurations such as mask-wearing. Continued data collection will help clarify whether these early differences persist with larger samples. Further studies should test how mask wearing influences the developmental trajectory of face processing in premature infants.

O2.6 - Does gender incongruency influence face recognition?

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Details

Gender is one of the earliest social categories processed by infants, and a central focus of research on early social cognition. In our study, we examined gender face-voice representation in infants under two years of age.

Infants' ability to process gender cues emerges very early. For faces, Quinn et al. (2002) show a bias toward female faces and better recognition of them as early as 3–4 months. Parallel work in psychoacoustics demonstrates that infants begin to differentiate male and female voices by 6 months of age (Miller, 1983;). In terms of multimodal representation, studies based on a visual-preference design, in which infants see a male and a female face side by side while hearing either a male or a female voice, have shown a longer gaze at the congruent face only when it is a female face from 12 months of age for Poulin-Dubois et al. (1994, 1998), and from 9 months of age for Hillairet de Boisferon et al. (2015), This pattern may reflect the development of integration, but also infants' well-documented spontaneous preference toward female faces. In order to avoid this bias, we designed a paradigm based on a familiarization–visual paired comparison method. If infants have a face-voice representation of gender, incongruency should interfere with their recognition



ability. During a familiarization period, infants are shown a female face while listening to a nursery rhyme sung either by a woman (control condition) or by a man (experimental condition). In the test phase, the familiar face is paired with a novel female face. Significant longer gaze toward the new face indicates successful recognition of the familiar one. We hypothesized that voice congruency would modulate learning and recognition. When seeing a female face associated with a male voice, infants should fail to recognize it, which would indicate that they are integrating gender cues across modalities.

In a first condition, we tested 12 (n=40), 18 (n=40) and 24 (n=40) month-olds infants with a video of a singing woman during familiarization and static pictures on test. All age groups failed to recognize it. We supposed that a dynamic face was the problem as in Hillairet et al. (2015).

In a second condition we presented a photo of a woman for the familiarization phase while an audio (congruent or not) was played. We tested 40 24-month-olds, who present a significant novelty preference in the congruent condition but not in the incongruent condition. So we demonstrated that infants at that age have integrated the two modalities into a representation of gender. We have tested half of our sample at 18-months of age and full results will be presented at ICIS.

O2.7 - Infant sensitivity to the coffer visual illusion across early development

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Details

Visual perception develops through interactions between our visual system and the structure of the surrounding environment. Studies with adults indicate that environmental context influences interpretations of visual illusions. One example is the Coffin Illusion, a pattern composed of a horizontal luminance gradient with sixteen circular elements arranged in a four-by-four grid. The luminance gradients within the circles support alternating percepts in which observers report either a configuration of circles or a configuration of rectangles. Adults in urban environments tend to report rectangular interpretations more often than adults in rural environments, suggesting that experience shapes perceptual organization (Kroupin et al., 2025). Little is known about the developmental origins of such differences, and it is unclear when infants first extract global structure from ambiguous stimuli of this kind. The present study examined whether infants between three and eight months show systematic changes in shape preference after exposure to the Coffin Illusion.

The procedure consisted of three phases: a pre test, a habituation phase, and a post test. In the pre and post tests, infants viewed either a circle array or a rectangle array arranged in a four-by-four grid. Each array was presented on the left or right side of a monitor inside a white rectangular frame. Infants' gaze was monitored by an experimenter, and each trial began only after infants fixated at the attention getter. During the habituation phase, infants viewed a Coffin Illusion stimulus repeatedly (10 sec for 4 times). Stimuli were presented using PsychoPy, and infants sat on a parent's lap while a pinhole camera recorded gaze behavior throughout the entire session.



Forty infants' data were included in the analysis. Nine infants were 3-to-4-months of age, eleven infants were 5-to-6-months of age, and twenty infants were 7-to-8-months of age. Ten additional infants were tested but excluded due to fussiness, inattention, or crying. Gaze direction was coded frame by frame with MIGE software. Coders labeled gaze toward predefined areas of interest, producing a continuous sequence of fixation states for each trial. Circle preference was calculated as the proportion of total fixation time directed to the circle stimulus relative to combined fixation to both circle and rectangle stimuli. Infants who did not reach the habituation criterion were excluded prior to analysis.

Paired t-tests compared circle preference between pre and post tests within each age group. Infants in the 5-to-6-month group showed a significant increase in novelty preference for circles, after habituation. This means that these infants perceived a configuration of rectangles in the Coffer Illusion. Infants in the 3-to-4-month and 7-to-8-month groups did not show significant changes in preference. Although infants aged 3-to-4-months showed a similar pattern, with relatively high novelty preference for circles in the post test. In contrast, 7-to-8-months infants demonstrated an opposing pattern, beginning with a higher initial circle preference that subsequently decreased. Findings suggest that sensitivity to the Coffer Illusion begins to emerge around five to six months of age. The developmental pattern indicates that infants' interpretations of ambiguous visual structure vary across early infancy.

[O2.8 - The effects of background, face direction, and animal running postures on implied motion adaptation in infants](#)

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Details

Implied motion is a static image depicting a running animal, for example the photograph of a horse running at the racetrack. This image depicts the bent legs, flowing hair, a drifting landscape and so on. This implied motion involves these factors such as a blurred background, a running animal posture, and face direction. However, it is unclear whether human extract and process motion from static information such as factors of background blur, running animal posture, and face direction. The aim of this study was separating these factors of implied motion perception in infants.

By using motion adaptation paradigm, we can investigate the generalization of motion perceived from static image to physical motion. In our previous study (Umekawa et al., 2024) we examined infants' implied motion adaptation by measuring eye movements, and found that only 7-8 months can perceive motion from static images and generalize it to physical motion.

We examined effects of background on implied motion adaptation in infants using implied motion without background. In the experiment, leftward or rightward RDKs were presented 10 trials for 2000ms each. After that 10 leftward or rightward running animal static images without background were shown for 600ms per image followed by the RDK for 2000ms. We judged infants' eye movement directions to RDKs and calculated matches of eye movement direction as "match ratio." We compared match ratios before and after viewing animal images. Results showed 7-8 months



adapted to implied motion without background. This means background motion is not the important factor of implied motion. Next, we examined the effects of the face direction and running animal posture on implied motion adaptation by using standing animal and inverted implied motion. The experimental procedures were identical to the no background experiment except for stimuli. If the face direction would be an important factor, infants would adapt to standing animal direction. The current results showed that 7-8 months did not adapt to the standing animal's face direction. This means that the face direction is not the important factor of implied motion. If the animal running posture would be an important factor of implied motion perception, 7-8 months would not adapt to inverted implied motion (Yin, 1969). The results showed that 7-8 months adapted to the inverted implied motion. Implied motion adaptation occurred even when inverted. This means that the inversion is not effective on implied motion adaptation.

The current study showed that none of background, face direction, and running animal postures were critical factors of implied motion perception in infants. The results showed that infants adapted to implied motion without a background but not to standing animals. This means that infants could adapt to the running animal posture but not to the background. Findings suggest that infants might extract motion from the running animal postures in implied motion. The inverted experiment result was controversial. The results showed that infants adapted to the inverted running animal posture. This means that infants can perceive the running animal posture even in inverted.

O2.9 - ManyBabies 5 Meta: A systematic review and meta-analysis of infant looking time preferences for novel vs. familiar visual stimuli

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Details

An influential account of infant looking time preferences stems from Hunter and Ames (1988), which suggests that three key dimensions play a major role in whether infants will prefer a novel stimulus over a familiar stimulus: age, familiarization time (the amount of time infants have been exposed to a given stimulus), *task difficulty* (features of the task and stimulus that make it easier or harder to process the stimuli, e.g., stimulus complexity). While frequently used to explain infant novelty and familiarity preferences, this model has proven difficult to evaluate because any single study is limited in terms of the extent to which all key dimensions can be tested systematically. An alternative approach is to leverage the collective literature on infant looking preferences by aggregating information across many studies - to what extent is the infant literature consistent with the model articulated by Hunter and Ames?

We conducted a preregistered meta-analysis of all infant studies (<24 months) measuring infants' attention to novel vs. familiar stimuli after a familiarization phase using a visual-paired comparison paradigm. After screening articles from our literature search (total records screened: N=5,040), we identified 132 papers for inclusion and coded both the magnitude of the novelty/ familiarity preference as well as participant features (e.g., infant age), aspects of the experiment design (e.g., the total familiarization time), and aspects of the stimulus (e.g., reported complexity). Overall, we recorded 884 distinct effect sizes across the 132 included papers. We had two main research



goals. The first was to characterize the magnitude and distribution of novelty and familiarity effects. The second was to assess the reliability of effects of infant age, familiarization time, and task difficulty on novelty and familiarity preferences.

Overall, the meta-analysis found strong evidence of a novelty preference across the literature, but little evidence of familiarity preferences. The overall meta-analytic effect size was Hedges' $g = 0.44$, 95% CI [0.40, 0.48] (novelty preferences were coded as positive). The distribution of effect sizes showed no evidence of bimodality (Figure 1); familiarity preferences (16.7% of effects) were far rarer than novelty preferences and seldom large (e.g., only 3.5% of effects were familiarity preferences with a medium effect size or larger, i.e., Hedges' $g < -0.5$). Aggregating across studies, there was no effect of familiarization time ($b = -0.02$, $z = -1.21$, $p = .23$) or age ($b = 0.02$, $z = 0.87$, $p = .39$) on the magnitude of the looking preference. Stimulus characteristics were rarely reported (only two papers explicitly reported a complexity manipulation). Intriguingly, there was preliminary evidence of an interaction between age and familiarization time ($b = -0.05$, $z = -2.03$, $p < .05$), indicating that longer familiarization times were associated with weaker effects in older infants.

Overall, our meta-analysis found robust evidence of novelty preferences across the literature, but little evidence for familiarity preferences or for robust effects of predictors (age, familiarization time) thought to guide the transition from familiarity to novelty preferences. These results are consistent with an emerging literature suggesting that familiarity preferences, at least in visual processing paradigms, may be harder to elicit than traditional models proposed. In our presentation, we will discuss benefits and limitations of taking a meta-analytic approach and what gaps in the literature future research can target to strengthen our theories of infant visual attention.

Oral Session 3 – Attention, Learning, and Regulatory State

O3.1 - Closing the loop on early learning: using infant neurofeedback to reveal causal neural mechanisms

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Details

Regularity learning, infants' ability to detect structure and predict upcoming events, is a core component of early cognition and supports later language and cognitive development. Neural signatures of prediction in infancy typically manifest as heightened cortical activation to unpredictable events and increased functional connectivity, particularly between frontal and posterior regions, when events are predictable. However, whether these activation patterns are causally related, and how they differ from other emerging abilities such as sensorimotor processing, remains unknown.

Infancy is marked by heightened neural plasticity and sensitivity to environmental structure, creating a period in which neural systems may be especially amenable to externally guided modulation. Neurofeedback offers a promising framework for probing causal mechanisms in brain development through non-invasive, targeted modulation of neural activity, yet it has not been



applied with infants. Could neurofeedback reveal causal mechanisms underlying early learning? If so, what forms of input best harness infant plasticity? To address these questions, a novel fNIRS-based neurofeedback paradigm for infants was developed to test whether guided modulation of functional connectivity can alter neural responses associated with predictive processing.

Across three studies, we iteratively validated the paradigm and demonstrated its potential for probing causal mechanisms in early neural development. Study 1 established the foundations of an infant-friendly training paradigm by characterizing spontaneous visual preferences suitable for contingent feedback. Across three split-screen experiments ($N=20$ each; age 5-13 months), we assessed infants' preferences for variations in motion speed, color saturation, and their combination. Infants robustly preferred faster, more saturated, and combined-feature videos, providing a reliable and engaging feedback signal for subsequent neurofeedback training.

Study 2 reproduced canonical neural patterns associated with prediction across two comparable task versions, ensuring that the neurofeedback signal targeted a functionally meaningful network. Consistent with prior work, unpredictable sequences evoked greater cortical activation, whereas predictable sequences elicited increased frontal-temporal connectivity ($N=10$ each; age 5-9 months). To establish the specificity of these effects, we also introduced a sensorimotor control task ($N=10$; age 5-9 months). This task produced distinct neural signatures, demonstrating that prediction-related activation and connectivity patterns were not attributable to general sensory or motor processes.

Study 3 ($N=60$, age 5-9 months; Figure 1a) implemented the full neurofeedback protocol, using the preferences identified in Study 1 as the basis for real-time feedback on frontal-temporal coupling. Preliminary results indicate that neurofeedback-driven modulation is indeed possible in infancy: infants trained to increase connectivity in the prediction network subsequently showed enhanced neural discrimination between predictable and unpredictable sequences (Figure 1b). Crucially, this effect was localized to prediction-related regions and did not extend to those associated with the sensorimotor control task.

Together, these studies provide the first evidence that targeted neurofeedback can induce functionally specific modulation of infant neural networks. By leveraging early plasticity and its interaction with foundational cognitive processes, this work introduces a novel methodological framework for testing causal mechanisms in early learning. More broadly, it demonstrates how emerging cognitive capacities both shape, and are shaped by, the developing brain.

O3.2 - Investigating the influence of infant-directed speech on attention and visual processing using ERPs and gamma activity

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Details

Evidence suggests that infant attention for and learning of speech stimuli is enhanced by infant-directed speech (IDS), characterized by a higher mean pitch and higher variability in prosody. Far less is known about whether IDS has broader, domain-general effects on infant cognition. In



particular, it is unclear whether IDS shapes attention and learning during the encoding and processing of visual or multimodal information. A substantial body of literature describes the processing of unimodal stimuli in social contexts (for a review on speech prosody see Spinelli et al., 2017; review on gaze Çetinçelik et al., 2021). However, comparatively little is known about intermodal attention-guiding effects of IDS in cueing situations that more closely resemble everyday caregiver–infant interactions.

The aim of the present study is to test whether IDS functions as an attention-relevant cue that modulates visual processing in 4-month-old infants using EEG. We employed an auditory–visual cueing paradigm modeled after established two-phase designs used to investigate the effects of ostensive gaze on object processing (e.g., Wahl et al., 2013). During the cueing phase, infants viewed an object while simultaneously hearing either IDS or adult-directed speech (ADS). This was followed by a visual target phase in which the object was presented visually without concurrent speech, enabling us to assess whether the preceding speech style affects neural indices of attention and learning during later visual processing.

Our preregistered hypotheses focus on oscillatory and event-related markers linked to attention allocation and learning. First, given evidence that IDS supports infants’ attention and learning, and that gamma-band synchronization has been associated with attentional and learning-related mechanisms, we predict stronger frontal gamma synchronization during cueing when objects are paired with IDS compared to ADS. Second, because IDS may facilitate processing of cued stimuli and thereby reduce attentional costs, we predict reduced Nc amplitude during the target phase for objects previously cued by IDS relative to ADS. In addition, we will explore whether IDS versus ADS modulates theta-band activity during cueing and post-target slow wave activity (PSW), indices that have been linked to aspects of attentional control and memory updating.

This study is a Stage-1 accepted Registered Report, approved prior to data collection. Data collection for the full sample is complete (N = 60). Planned analyses will be finalized by March 2026. Overall, this study aims to clarify whether IDS operates as a broadly effective social cue that shapes infants’ neural processing beyond speech itself, advancing mechanistic accounts of early multisensory attention and learning.

O3.3 - The role of infant visual attention in the development of frontal EEG alpha power in early childhood

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Details

Early markers of attentional behavior are driven by neurodevelopmental changes in the frontal lobe (Bell, 1998). Baseline electroencephalography (EEG) is an efficient, noninvasive method for assessing neurodevelopmental changes, providing a window into the organization of the brain, and reflecting individual differences in behavior (Perone & Gartstein, 2018). Individual differences in infant behavior attention are theorized to reflect the speed of information processing (Colombo et al., 2010) and predict later performance on cognitive tasks (Cuevas & Bell, 2014). Systematic research has revealed that infants who demonstrate brief visual fixations (i.e., short lookers [SL]),



during stimulus exposure process information more efficiently than infants who demonstrate long visual fixations (i.e., long lookers [LL]; Colombo, 1995). An important goal in developmental neuroscience is to disentangle the complex link between the emergence of infant attention behavior and the underlying maturational changes in key neural regions in early childhood. The present study examined whether early individual differences in infant looking behavior at 5-months are related to differences in the maturation of frontal EEG power in early childhood.

Data are from 390 children at 5-, 10-, 24-, and 36-months. At 5-months, attention was measured using looking data (i.e., peak look; Colombo et al., 1991) during a glove task (Cuevas & Bell, 2014). A median split was conducted on peak look duration (Median = 8.32 s) to classify infants as SL (i.e., < 8.32 s) or LL (i.e., > 8.32 s). At 10-, 24-, and 36-months, baseline EEG alpha power (6–9 Hz) of frontal sites (i.e., Fp1, Fp2, F3, F4, F7, F8) was measured while the infant watched a video.

Analyses were conducted in R (R Core Team, 2025) using linear mixed-effects growth modeling to examine developmental trajectories in frontal EEG power across ages (centered at 24-months), looking group (SL vs. LL), and maternal education (centered). A random-intercept and random-slope model with a linear age term provided the best fit, $\chi^2(1) = 5.92$, $p = .015$. Higher maternal education was associated with higher frontal EEG power ($b = 0.04$, $SE = 0.02$, $p = .043$), controlling for age and looking group. LL had a significantly steeper positive frontal EEG power trajectory relative to SL, $b = 0.09$, $SE = 0.04$, $t(290) = 2.44$, $p = .016$. Estimated marginal means (EMM) showed that significant differences between looking groups only emerged at 36-months, $b = 0.15$, $SE = 0.07$, $t(285) = 2.086$, $p = .038$. Specifically, LL (EMM = 3.12, $SE = 0.05$) had higher frontal EEG alpha power at 36-months compared to SL (EMM = 2.97, $SE = 0.05$).

Results suggest that early individual differences in infant visual attention 5-months predict distinct trajectories of frontal neurodevelopment across early childhood. Therefore, infant attention may serve as an early behavioral marker of neural functioning, with LL potentially reflecting increased effort or compensatory mechanisms in attention processing compared to SL. Gaining further insight into the relations between infant attention behaviors and neural patterns in early childhood may help identify early risk profiles and inform interventions that specifically target cognitive development.

O3.4 - Another participant excluded? The impact of tiredness on infants' task performance

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Details

Infant research depends on brief windows of attention and cooperation, yet we know surprisingly little about how fluctuations in infants' internal states affect the data we collect (Seehagen et al., 2019). In any research context, either laboratory, home-based, or naturalistic, fatigue may alter infants' engagement, behavior, and performance in ways that remain largely undocumented (Forbes et al., 2025; Konrad et al., 2016). Yet, understanding these effects is essential for interpreting experimental results with accuracy and confidence. This study investigates how tiredness affects infants' performance in two tasks: an experimental task evaluating phonological



working memory (pWM) and a standardized assessment of developmental progress (i.e., the Bayley Scales). We tested 149 infants and toddlers aged 5-to-30 months, controlling for the time elapsed since their more recent sleep period and the beginning of the testing. Parental reports were used to analyze prior sleep. We measured pWM using an eye-tracking paradigm lasting 5-10-min. The task adapted to each child's performance by presenting sequences of syllables of various lengths, either two-, three-, or four-syllable pseudowords, with each level including three familiarization phases followed by a test phase. A memory span score (MS), defined as the maximum number of syllables successfully retained, was calculated for each participant and used as dependent variable. Afterward, participants completed the Bayley Scales (Bayley, 2019), a 20–30-min. assessment that provides standardized measures of cognitive, language, and motor development. Considering the pWM test, a general linear model showed a significant difference in memory span between children awake for less than 1 hour and those awake for more than 2 hours, independent of age ($F(3,129)=3.20$, $p=.026$, $\eta^2p=.07$). Infants awake for more than 2:01 hours performed worse ($M=1.86$) than those awake for less than 00:59 minutes ($M=2.41$; $b=-0.49$, $t(126)=-2.09$, $p=.038$). This suggests that fatigue has a measurable, negative impact on infants' memory performance. In contrast, tiredness did not affect performance on the Bayley cognitive, language, or motor scales, with all models showing *n.s.* effects. We further examined a subgroup of infants tested early in the morning, after a night sleep ($n=27$). A regression model ($F(2,25)=4.13$, $p=.017$, $R^2=.336$) indicated that shorter periods of night-time wakefulness the night before ($t=-2.28$, $p=.031$) and longer total night sleep ($t=2.40$, $p=.024$) predicted higher MS, whereas the number of awakenings did not influenced performance ($t=-0.08$, $p=.932$). This pattern did not emerge in the group of infants tested later in morning, after a nap ($n=24$), for whom neither nap duration ($p=.490$) nor night sleep characteristics ($p=.692$) affected MS. Likewise, nap duration did not influence MS in the group of children tested in the afternoon ($n=69$, $p=.424$). The same models run on Bayley scores also produced *n.s.* results. Taken together, these results underscore the importance of considering infants' internal states and daily rhythms when interpreting cognitive outcomes. Notably, in this study these factors exerted a significant influence on memory performance specifically, aligning with evidence that sleep plays a crucial role in learning and memory consolidation (Mason et al., 2022; Spencer et al., 2017). This line of work can also offer practical insights for designing infant studies, such as better controlling or accounting for contextual factors that influence tiredness. Optimizing testing schedules around infants' alertness may also improve data quality and lead to more reliable assessments of early cognition.

O3.5 - Caregiver predictability and infant looking relationships are associated with nucleus accumbens and hippocampus volumes early in life

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Details

Early in life, children learn to understand and navigate their environments largely through interactions with their caregivers. These exchanges are inherently dynamic, shaped by the moment-to-moment behaviors of both infant and caregiver. Prior research shows that the predictability of the sensory signals caregivers provide is linked to infants' visual orienting behaviors (Forest et al., 2025; Kidd et al., 2012). The present study shifts focus from examining



caregiver behavior or infant visual responses in isolation to investigating how their interaction may influence the developing brain. Here, we examine how infants visually respond to their caregivers' patterns of behavioral predictability, and how this joint behavioral dynamic may relate to structural differences in brain regions implicated in learning systems in a cohort in Cape Town, South Africa. Specifically, the brain regions examined in this study were the accumbens, hippocampus, caudate, and amygdala. Behavioral data were collected during two sessions; the first was when infants were 2 to 5 months ($N = 224$; $M = 3.81$, $SD = 0.86$) and the second was when infants were 6 to 11 months ($N = 228$; $M = 8.89$, $SD = 1.57$). We operationalized behavioral caregiver-infant relationships as a curvature metric derived from a Bayesian model fit to examine the associations between caregiver predictability and infant visual responses. In this work, negative curvature signaled a more “optimal” fit for learning, suggesting that infants adapt their visual orientation to look at caregiver more when they are providing more learnable information. Low-field MRI data were collected during three visits when infants were 5 to 12 months ($n = 143$), 12 to 18 months ($n = 98$), and 19 to 27 months ($n = 58$) during natural sleep. Using these data, we tested the following hypothesis: the relationship between caregiver predictability and infant visual responses (i.e., curvature) will be associated with the structural development of the accumbens, an area known to be involved in prediction error processing in humans (Davidow et al., 2016; Rodriguez et al., 2006). Results revealed that overall, infants looked at their caregiver less as their behaviors became less predictable during both sessions. More critically, behavioral caregiver-infant dynamics 6 to 11 months postpartum with more positive curvature fits (less optimal) were associated with smaller right accumbens ($\beta = -18.43$, $SE = 6.81$, $t(138) = -2.71$, $p = .008$) and smaller right hippocampal volumes ($\beta = -60.58$, $SE = 27.75$, $t(138) = -2.18$, $p = .031$) measured during the same visit, even after adjusting for age, sex, and total intracranial volume. Additionally, the same positive curvature dynamics measured from 6 to 11 months of age were also predictive of larger left accumbens volume ($\beta = 19.06$, $SE = 8.71$, $t(53) = 2.19$, $p = .033$) in the third MRI visit (19 to 27 months). This work further supports the argument that early caregiver-infant dynamics are foundational to cognitive function and overall brain development and advances our understanding of the mechanisms through which infants begin to “learn to learn” from their earliest, most influential environment, the caregiver.

O3.6 - Cognitive and social drivers of infant attention: information gain and caregiver behavior for 9-month-olds' sustained attention

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Details

According to the learning progress hypothesis, infants' attention is guided by seeking information to learn from: Infants are more likely to look away when little information is to be gained from a stimulus and continue to attend if information gain is high (Poli et al., 2020). Yet, the role of social interaction in combination with information gain remains unclear. That is particularly surprising given that a separate line of research has shown social interactions to play an important role in infants' attention (Yu & Smith, 2016). Amongst others, previous findings suggest that infants sustain their attention for longer when being engaged in a social context (Wass et al., 2020; Yu & Smith, 2016).



To better understand what shapes infants' attention, we investigated the role of the caregiver in conjunction with the role of information gain as potential drivers of infants' sustained visual attention. For this purpose, we combined testing 9-month-old infants and their caregivers in a behavioral experiment with a computational modeling approach. This study was pre-registered (<https://osf.io/gd6cb>).

Nine-month-old infants and their caregivers (N=80) were sitting at a table watching toys being revealed in a learnable pattern in three boxes in front of them (fig. 1). Dyads were divided into two different conditions: half of the caregivers were instructed not to interfere during the experiment (restricted social condition), while the other half was encouraged to interact with their infants as they would do at home (free social condition).

The information gain provided by the learnable pattern, the caregivers' behavior, and measures of infants' attention were used in a computational model to answer the following questions:

1. Is infants' visual attention guided by information gain in a semi-naturalistic setting?
2. What is the impact of caregivers' behavior and information gain provided by the environment for infants' visual attention?

We used a computational model to analyze infants' behavior, specifically, predicting the conditional probability of them looking away from the setup. For a more comprehensive analysis, we performed Bayesian Model Averaging. We found that information gain, the social interaction condition and the time that passed in the experiment influenced the conditional probability of infants' lookaway, including the two-way interactions between them.

As expected, higher information gain was lowering the conditional probability of looking away, while the time children were engaged in the experiment increased it. Late in the experiment the caregivers' interactive behaviors kept the conditional probability of looking away low irrespective of how much information could still be gained from the stimuli (fig.2). When caregivers were not involved, infants' looking behavior was largely dependent on the information to be gained in the stimuli and how long the experiment had already lasted.

We conclude that infants' attention, in the absence of caregivers' interactive behaviors, is driven by information gain even in a more naturalistic setting. Notably, when the caregiver is allowed to interact with their infant, the effect of information gain on their attention is weaker. Implications for early social learning and attention development will be discussed.

O3.7 - Longitudinal development of top-down attention from 6 to 18 months: Brain, temperament, and caregiving influences

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Details

Attention can be guided by external stimulation (bottom-up attention) or internally controlled through experience-based expectations (top-down attention). Top-down attention emerges



during the first months of life and develops rapidly throughout early childhood. Crucially, it supports the later development of self-regulation and the voluntary control of thoughts and actions (Rueda, 2024).

A common way to assess top-down attention in preverbal infants is to measure anticipatory eye movements toward regularly appearing stimuli using eye-tracking. In the switching task, an attractive stimulus is repeatedly presented in one of two possible locations, with a blank interval between trials (Block 1). If infants begin to anticipate the correct location before stimulus onset for several consecutive trials, the stimulus then switches to the opposite location (Block 2). This task yields several indicators of top-down attention: the number of trials needed to reach the criterion of three anticipatory looks in Block 1, the proportion of anticipatory looks in Block 1, and the proportion of perseverative looks toward the previous location in Block 2.

Our study investigated brain, temperament, and caregiving factors that contribute to the early development of top-down attention. We administered the switching task in a longitudinal cohort (initial $n = 142$) of infants assessed at 6 months and followed at 9 months ($n = 122$) and 18 months ($n = 91$). Additionally, we recorded resting-state EEG for several minutes and collected parent-report measures of child temperament and family socioeconomic status.

Results showed that the proportion of correct anticipations in Block 1 was above .60 at 6 months and increased significantly from 9 to 18 months. The proportion of perseverative looks in Block 2 was also above .60 at 6 and 9 months but decreased significantly by 18 months, indicating improved cognitive flexibility. Hierarchical regression analyses revealed that both earlier task performance and family socioeconomic status predicted how quickly infants learned to anticipate the correct location in Block 1 at 18 months. Finally, EEG analyses indicated that theta (3–5 Hz) relative and oscillatory power in central channels was negatively associated, whereas alpha (6–9 Hz) power was positively associated, with the proportion of correct anticipations at 18 months (see Fig 1).

These findings advance our understanding of the neural and environmental contributors to the development of top-down attention in infancy. Such knowledge is essential for the early identification of atypical attentional development and for designing interventions that support optimal cognitive outcomes.

O3.8 - Multidimensional physiological states of infant visual attention

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Details

Infants who exhibit longer durations of sustained visual attention (SVA) show better self-control (Lansink and Richards, 1997), attentional abilities (Grossman and Taylor, 2007), and language development (Welsh et al., 2010). SVA has traditionally been operationalized using gaze duration (Yu & Smith, 2016) and video-coded behavioral markers (Ruff and Rothbart, 1996). However, attention is a biological process that unfolds within the context of the infant's body and their ongoing physiological state. Although prior work has identified changes in heart rate with SVA observed during screen-based tasks (Richards and Casey, 1991), physiological responses to



behavioral and cognitive states are dynamic, coordinated across systems, and extend beyond heart rate alone (Pasquini et al., 2023). Consequently, little is known about how attention is organized in relation to other bodily processes including respiration and body movement during naturalistic interaction. Here, we used k-means clustering to identify naturally occurring physiological states defined by heart rate, respiration, and body acceleration, and examined how these states relate to gaze velocity, a proxy for visual attention.

Infant caregiver dyads (N = 7) with infants aged 9 to 24 months participated in a 15-minute session of naturalistic tabletop play. Caregivers were instructed to play with their child as they would at home using a set of six toys. Infants wore a head mounted eye tracker (Pupil Neon) and a wireless cardiac sensor (Movisens EcgMove4) that recorded ECG and torso acceleration. ECG (1024 Hz) was cleaned and processed using TonaFlow (<https://github.com/borjonlab/tonaflow>) to extract heart rate. ECG-derived respiration was estimated using NeuroKit2 (Makowski et al., 2021). Gaze velocity (200 Hz) was computed as the Euclidean distance between successive gaze coordinates divided by the corresponding time interval. Body acceleration (64 Hz) was calculated using the same approach. Heart rate, respiration rate, and body acceleration were standardized and submitted to k means clustering. Silhouette analysis indicated a three-cluster solution.

Three distinct physiological clusters emerged. Cluster 1 featured lower heart rate, reduced movement, and lower respiration. Cluster 2 showed higher heart rate and body movement but lower respiration. Finally, cluster 3 showed higher heart rate and elevated respiration (Figure 1a). Mean gaze velocity was lower in clusters 1 and 2 relative to cluster 3 (Figure 1b).

Findings suggest that infant SVA is supported by multiple, physiologically distinct states. One cluster reflected a profile associated with faster gaze movements and potential disengagement, potentially indicating higher arousal. Two low gaze velocity clusters emerged with reduced respiration but differing cardiac and movement profiles. These states indicate that sustained attention may be regulated through different autonomic configurations. Identifying early physiological signatures of attentional regulation provides a foundation for examining how individual differences in infants' prevailing autonomic states relate to later self-regulation, attention, and learning. Future work will extend this approach to a larger sample and examine developmental change in the coordination between physiology and object directed attention.

03.9 - Predictors of gaze shifting and attention in young deaf signing children

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Details

Deaf infants learning American Sign Language (ASL) perceive both linguistic and non-linguistic information in the visual modality. Therefore, in order to connect language input to the world, deaf children need to learn to alternate gaze. Deaf infants acquiring sign language from birth learn early on how to allocate their attention to receive maximal linguistic input from their caregivers. For example, deaf infants direct their visual attention to their parents more often than hearing infants (Koester, 1995; Spencer, 2000), and are more adept at following adult gaze (Brooks et al., 2020). In naturalistic play, young deaf children shift their gaze frequently and purposefully (Lieberman et al., 2014) and perceive a majority of caregiver signs in their entirety (Gappmayr et al., 2025).



Furthermore, deaf children's attention is often scaffolded by parents to encourage gaze shifting (Swisher, 2000; Holzrichter & Meier, 2000; Gale & Schick, 2008), although comparatively less is known about the specific types of behaviors that parents use to direct their children's attention and whether these behaviors change with development.

We conducted two experiments to explore gaze patterns in deaf children. First, we replicate and extend findings from a prior study on deaf children's gaze shift behaviors during naturalistic interaction (Authors) with a larger and more diverse participant sample. We investigate whether children's gaze shifts are spontaneous (i.e. child-led) or prompted by caregiver cues, and whether the proportion of child-led shifts increases with age. Second, we used an eye-tracking paradigm to investigate how deaf children manage their visual attention when viewing signs and objects independently.

In study 1, we analyzed naturalistic play sessions between deaf children ($n = 24$; ages 9 to 60 months; mean age 38 months) and their deaf or hearing caregivers interacting in ASL. Parent signs and attention-getters were annotated by deaf signing coders. We also annotated all child gaze shifts both towards and away from the parent, and coded the two-second window before each gaze shift to determine whether it was spontaneous or prompted by a parent behavior (i.e. a sign, attention-getter, or point). We found that frequency of gaze shifts was significantly predicted by child age ($t = 2.39, p < 0.05$) as well as the number of signs produced by the parent ($t = 3.35, p < 0.01$); older children and children whose parents produced more signs shifted gaze more often. Overall, 24% of gaze shifts were child-led. Among the remaining 76% of shifts that were prompted by parents, the most frequent prompt was an ASL sign, comprising 43% of all prompted shifts.

To determine whether gaze behaviors with a caregiver are related to deaf children's deployment of visual attentional strategies, a subset of participants ($n = 16$) also participated in the eye-tracking task. Children viewed images of familiar objects followed by videos of a signer who labeled the object in ASL. We found a positive correlation between frequency of children's gaze shifts during naturalistic play with a caregiver and children's gaze to the signer during the eyetracking task ($r(16) = .59, p = .016$). This result suggests that deaf children's ability to efficiently shift their visual attention during interaction may generalize to an independent task.

Together, our findings provide evidence that deaf children's visual attention behaviors in early childhood are impacted by language input. Frequent gaze shifting may therefore be an early-acquired strategy that deaf children apply across contexts to maximize perception of linguistic input.

O3.10 - The receptive behaviors of Joint Attention: beyond western knowledge

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Details

Introduction: Joint Attention (JA) refers to the human ability to share interests and attention by adopting a common point of reference with a social partner (Mundy, 2018). It encompasses a range of receptive (Responding to JA - RJA) and expressive behaviors (Initiating JA - IJA) (Seibert et al., 1982). Although RJA (i.e., following the partner's head, gaze, vocalization, and/or pointing) is



considered an experience-expectant universal mechanism (Tomasello et al., 2005), its manifestation may be modulated by socioeconomic (Reilly et al., 2021) and cultural contexts (Little et al., 2016).

Aims and Hypothesis: This study investigated the effect of cultural and socioeconomic influences on early RJA in Brazilian and Italian infants. We hypothesized that RJA capacity would be observed in both groups, but with possible differences in their performance due to the different socioeconomic and cultural contexts between Italy and Brazil.

Methods: A Brazilian cohort of infants ($n=28$; mean age = 16.64 months) from low-SES families and an Italian cohort of infants ($n=30$; mean age = 20.77 months) from middle- to high-SES families were recruited. Data were collected in both cohorts using the same webcam-based eye-tracking Labvanced platform (Finger et al., 2017). The procedure commenced with a calibration phase, followed by two blocks of ten trials each (i.e. 20 trials). In each trial, a central face and two peripheral pinwheels were presented. Initially, the face gave a verbal prompt in the participant's native language (Phase 1), then turned the head and gaze to one pinwheel (Phase 2) and, if the infant fixated on the cued pinwheel, it animated after a variable delay time (ranging 200–1000 ms) (Phase 3).

Three dependent variables, recorded by the same eye-tracker software, were analyzed with Mixed-Effects Models: Dwell time across phases (DTAP) to face and each pinwheel; Accuracy (percentage of fixations to the cued pinwheel during Phase 3), and Stimuli Dwell Time along Delays (SDTD).

Results: Similar trends of DTAP were observed for both groups of participants. Moreover, higher fixations to the cued compared to the uncued pinwheel were observed during Phase 3 ($p < .001$), confirming the occurrence of RJA in both groups. Significant group differences were also observed: Italian infants showed a higher overall number of fixations compared to the Brazilian cohort ($p < .001$), across all phases and stimuli. Furthermore, the Italian group exhibited significantly greater attentional accuracy (57%) than the Brazilian group (17%) ($p < .001$). Regarding SDTD, fixations to the face and target varied along delays: at 200 ms both stimuli were fixated equally, whereas at 400 ms the cued-pinwheel was significantly preferred to face for both groups. As the delay increased, Brazilian infants showed increased attention to the face, a pattern not observed in the Italian group, indicating a different pattern of attention along delays. Finally, both groups consistently showed low dwell time to the uncued object along all delays.

Discussion: These findings highlight the importance of considering socioeconomic and cultural factors in the study of RJA. Further research is needed to fully understand the impact of these factors on infants' capacity to respond to social cues in non- WEIRD populations.

Oral Session 4 – Caregiver–Infant Engagement and Social Coordination

O4.1 - Investigating the effects of other adults on mother-toddler neural synchrony in collaborative play

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Details

Children's lives do not take place in isolation. We can learn more about child development by investigating children's interactions than by studying children alone. Similarly, measuring the interaction of children's brains with others during social tasks has the potential to greatly increase our knowledge of neurodevelopment. Hyperscanning techniques (simultaneously measuring brain activation in two or more people (Hakim et al., 2023)) allow for deeper investigations into neural synchrony during mother-child interactions. Interpersonal neural synchrony has been linked to successful cooperative interactions in school-age child-parent pairs (Nguyen et al., 2020; St Clair et al., 2025), with greater synchrony shown when working together. However, it is unknown whether the same patterns of neural synchrony are shown in toddlers, who are developing their ability to work with others. This presentation will discuss the results of two studies investigating neural synchrony in collaborating mother-toddler pairs.

In both studies, mother-child dyads with children aged 24-36 months completed a Lego Duplo building task. During the task, their brain activation was measured using wireless functional near-infrared spectroscopy across the bilateral prefrontal cortex and temporoparietal junction. For study 1, 20 mother-child dyads (mean age 30.15 months) completed a Maternal Collaboration condition, where the mother and child built a Lego structure together, interacting as they would at home, and an Individual condition, where they built structures independently while separated by a curtain. Neural synchrony was calculated using wavelet transform coherence analysis and analysed using linear mixed-effect models.

Study 1 found that the mother's temporoparietal junction and the child's prefrontal cortex exhibited different patterns of neural synchrony depending on whether they completed the task together or separately (Figure 1). Unexpectedly, dyads varied greatly on whether neural synchrony was greater in the Maternal Collaboration or Individual condition, which could only be significantly predicted by the presence of a second tester in the session (Figure 2). When another adult was involved in the testing session, the dyads were more likely to show greater neural synchrony in the Individual condition; however, when only the primary tester was present, dyads showed greater synchrony in Collaboration.

Study 2 investigated further the effects of other adults in the room on mother-toddler neural synchrony by introducing a third 'Stranger Collaboration' condition, where the child built a structure with a previously unknown adult, while the mother watched. Twenty-one mother-child dyads (mean age 30.85 months) completed these 3 conditions while brain activation was measured using the same method as Study 1. Study 2 revealed that across the whole brain, neural synchrony was significantly greater in the Maternal Collaboration condition, and there was no significant difference in synchrony between the Individual and Stranger Collaboration conditions.

These results suggest that even though their collaborative skills are developing, toddlers show similar patterns of neural synchrony with their mothers during collaboration as older children and between adults. They also suggest that neural synchrony is not solely modulated by the presence of other adults in the room, but by the mother's distractedness and concern over predicting her child's actions.



O4.2 - Temporal dynamics of social bidding reveal early biobehavioral regulation

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Details

Social bidding, defined as infants' attempts to elicit caregiver attention through gaze, smiles, or vocalizations, reflects a core aspect of early social engagement and regulation. These behaviors help infants sustain connection and manage arousal during daily interactions and structured stressors such as the Still-Face Paradigm. Infants show considerable variability in how they attempt to re-engage caregivers: some persist throughout the Still-Face episode, others make only brief attempts, and some do not bid at all. This variability highlights meaningful individual differences in how infants regulate emotion and attempt to restore social interaction when caregivers become unresponsive. Although most research has focused on the overall frequency of social bidding, far less is known about its temporal dynamics, including when infants initiate bidding and how long they maintain these efforts, and how these dimensions relate to biobehavioral regulation. From a Polyvagal Theory perspective, infants' physiological capacity for flexible regulation, indexed by respiratory sinus arrhythmia (RSA), may help explain both the timing and persistence of social engagement efforts under stress. The present study examined two temporal dimensions of social bidding in 4–6-month-old infants ($N = 130$) to clarify how infants initiate and maintain engagement during maternal unresponsiveness. Time to first bid indexed how quickly infants mobilized a re-engagement attempt following the onset of the Still-Face episode, whereas persistence captured sustained activation of social engagement efforts once initiated. We tested whether infants' baseline RSA and mother–infant RSA synchrony during Social Play predicted these temporal dynamics, and whether earlier mobilization and greater sustained activation supported distinct components of affective and physiological recovery during Reunion. Cox proportional hazards regressions identified predictors of bid timing. Infants with higher baseline RSA ($HR = 1.23$, $p = .05$) and more positive RSA synchrony ($HR = 1.24$, $p = .03$) mobilized re-engagement attempts more quickly, indicating greater physiological readiness to initiate regulatory strategies under social stress. Infants were also more likely to persist if they had higher baseline RSA ($HR = 0.77$, $p = .03$) and more positive synchrony ($HR = 0.72$, $p = .02$), reflecting stronger physiological support for maintaining regulatory behavior. Finally, temporal dynamics were differentially associated with components of recovery. Earlier mobilization significantly predicted greater reductions in negative affect during Reunion, whereas greater sustained activation significantly predicted larger RSA increases, suggesting that these two temporal dimensions of bidding are differentially related to affective versus physiological recovery. By linking the temporal organization of social bidding to physiological and affective regulatory processes, this study advances understanding of early biobehavioral coordination and aligns with Polyvagal Theory's view that flexible social engagement is connected to adaptive parasympathetic functioning. Infants who mobilized re-engagement quickly and maintained these efforts over time showed stronger emotional and physiological recovery following maternal unresponsiveness. The temporal dynamics of social behavior thus provide a sensitive index of emerging regulatory competence and may help identify foundational individual differences in early social–emotional development.



04.3 - An infant massage to improve mother-infant synchrony: A NIH-funded randomized controlled trial of Massage+

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Details

Background

Mother-infant synchrony is a coordinated, reciprocal and temporal communication pattern between mother and infant and exerts a critical influence on children's development. Adverse outcomes of poor parent-infant synchrony include behavioral and developmental problems, low empathy, attachment insecurity, poor social adaptation, cognitive deficits, and psychopathologies¹. Few parenting interventions promote early mother-infant synchrony, though they may be important for mothers with a history of childhood adversity.

Purpose

Study purpose was to evaluate how a behavioral intervention, Massage+, that incorporates talking to the infant, touch (via infant massage), eye-to-eye contact, and rocking influenced mother-infant synchrony.

Methods

In a NIH funded RCT, we enrolled nulliparous, adult, pregnant women (with Adverse Childhood Experience scores of ≥ 2) expecting a full-term healthy infant. At birth, we randomized 213 dyads to a Massage+ group (daily infant massage contingent upon infant cues) or an attention control group (learning safe infant care). After three months of daily Massage+, mother-infant synchrony was micro-coded from video-recorded free-play sessions, analyzing mutual gaze, affect, touch, and speech (see table). We compared group differences on the amount of co-occurring synchrony, sequential synchrony, and time-to-first initiation of synchrony using two-sample tests. Adjusted models of co-occurring synchrony included ACE scores at screening; GAD-7, PHQ-8, and general PTSD scores at baseline; and infant sex. Multiple imputation along with additional tipping-point analyses were used to address missingness. Among 162 dyads with video recordings at three months after birth, Massage+ dyads demonstrated significantly more co-occurring and sequential synchrony, and/or faster time-to-first initiation of synchrony, compared to controls in the following areas:

A) SHARED POSITIVE AFFECT: Massage+ co-occurring mean (*M*) (97.5% *CI*) = 27.08 (21.28, 32.87), Control *M* (97.5% *CI*) = 15.99 (11.47, 20.51); Massage+ sequential *M* (95% *CI*) = 28.19 (23.08, 33.29), Control *M* (95% *CI*) = 16.02 (11.89, 20.15); time-to-initiation of first synchrony Massage+ median (95% *CI*) = 8 (4, 20), Control median (95% *CI*) = 30.5 (17, 45)

B) SHARED GAZE WITH MATERNAL TOUCH: Massage+ co-occurring *M* (95% *CI*) = 89.80 (79.14, 100.47), Control *M* (95% *CI*) = 71.00 (62.69, 79.31); Massage+ sequential *M* (95% *CI*) = 88.71 (78.18, 99.25), Control *M* (95% *CI*) = 70.27 (61.82, 78.71)



C) MATERNAL ENGAGEMENT WITH HIGH INFANT AROUSAL: Massage+ co-occurring M (95% CI) = 20.58 (16.43, 24.74), Control M (95% CI) = 12.13 (8.77, 15.48); Massage+ sequential M (95% CI) = 20.79 (16.42, 25.17), Control M (95% CI) = 11.73 (8.20, 15.26); time-to-initiation of first synchrony Massage+ *median* (95% CI) = 13.5 (6, 24), Control *median* (95% CI) = 34 (10, 58)

Adjusted analyses of co-occurring synchrony showed similar results. Tipping-point analyses showed that results are robust to deviations from missing-at-random assumptions.

Conclusion

Massage+ promotes synchronous interaction during early brain development, teaching infants that shared positive social moments are rewarding. When infants expressed positive arousal, Massage+ dyads were better able to increase and coordinate synchrony, and to more quickly settle into synchrony. This intervention may be well-suited to improve synchrony in mothers with childhood adversity and other at-risk groups. Future research should test its effectiveness in clinical settings.

O4.4 - Infants use helping to infer the existence and strength of caring relationships

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Details

An act of kindness can reflect different social motives: someone may be motivated to be generally nice to others or to help their friends. In three preregistered experiments, we used a violation of expectation paradigm to assess the motives infants infer from observations of helping and hindering: Do 14- and 15-month-old infants (N=156; 52 per experiment) believe past helpers are motivated by a general disposition to act kindly or specific relationships to support their close social partners?

In Experiments 1 & 2, we familiarized infants to one agent who helped, and one who hindered, a common target's goal of reaching the top of a hill. In the test trials, the same target (Exp1), or a new target (Exp2), needed help bypassing a large wall. In both experiments, infants saw alternating test trials in which the original helper (expected trials) or the original hinderer (unexpected trials) helped by moving the wall out of the target's path. If infants use helping and hindering to infer dispositions then they should expect the original helper to be more likely, compared to the hinderer, to help both the original and the new target. Alternatively, if inferring specific relationships, infants should only possess strong expectations that the helper would help their original target, but not a novel target, in the future.

Data from Experiment 1 (Original Target), revealed infants looked longer to unexpected events, in which the original hinderer helped, than to expected events, in which the original helper helped, $X^2 = 11.95$, $p < .001$, $d = .45$. In Experiment 2 (Novel Target), infants' looking time did not differ significantly between test trials, $X^2 = 0.01$, $p = .89$, $d = .001$. There was also a significant interaction between trial type and experiment, $X^2 = 4.77$, $p < .05$, $\eta^2 = .11$, indicating that the target's identity (original vs. novel target) affected relative looking to trials in which the original helper or hinderer helped. These results suggest that infants used helping and hindering to infer the original helper's



relationship-based motivation to help and did not use the original actions of the two agents to infer prosocial dispositions.

In Experiment 3, infants were first shown familiarization events in which one helper selectively helped one of three targets obtain an out-of-reach ball: The helper helped each target an equal number of times, but appeared to value the welfare of one “high-value” target the most, and another “low-value” target the least, based on who they chose to help when a subset of targets appeared together. At test, we found that infants looked significantly longer when the helper chose to help the low-value target, compared to when they helped the high-value target, $X^2=5.58$, $p < .05$, $d=.37$, despite never seeing this target pairing during familiarization. These results suggest that infants made a transitive inference whereby they expected the helper to favor the target with whom they seemed most strongly affiliated, based on their previous choices of who to help.

Overall, infants appear to use acts of helping to infer the existence and strength of positive relationships. Infants expected a helper, compared to a hinderer, to help their original target but not a novel target in the future. Infants also used a character’s choice of who to help to determine how much they valued the welfare of different social targets and predicted the helper would prioritize the goals of those they previously appeared to value the most.

O4.5 - Bodily access and developmental pathways: infant experience through co-presence in Nso households of Cameroon

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Details

Research on infant development has been dominated by interaction-centered models that prioritize face-to-face engagement, joint attention, and turn-taking as primary developmental engines. While influential within developmental psychology, these approaches often overlook how infants are embedded in everyday caregiving ecologies, particularly in cultural settings where care is interwoven with subsistence and domestic work. Ethnographic and sociocultural perspectives suggest that infants acquire knowledge not only through direct interaction but also through sustained observational access, and exposure to routine activity. Drawing on Gibson’s concept of environmental affordances and Rogoff’s account of guided participation, this study situates early development within culturally organized home environments in which infants learn through being positioned, transported, and included in ongoing action.

The study investigates how bodily access and spatial exposure structure infants’ everyday experiences in Nso families of Cameroon, and how these exposure conditions provide developmental pathways through which infants encounter caregiving practices, material culture, and social coordination.

Ethnographic data were collected from 51 households in the Nso region of Cameroon, involving 43 mothers and 8 fathers (M age = 34 years) and their infants and toddlers (M age = 8.2 months; range = 0–26 months). One-hour naturalistic focal video observations were conducted in domestic



settings, documenting caregivers' routine activities—including cooking, laundry, farming preparation, and household coordination—alongside infant care practices such as feeding, bathing, and diapering. These care activities were typically embedded within ongoing routines and transitions, as infants were tagged along.

Video data were systematically coded for infants' spatial exposure (e.g., kitchen, living area, compound), bodily positioning relative to caregivers and ongoing actions and activities (e.g., back-carrying, lap-holding, ground placement), modes of bodily stimulation, caregiver handoffs, and the perceptual availability of people, objects, and vocalization. Analyses focused on exposure conditions and affordances as well as interactional events.

Preliminary findings show that infants' developmental experience was organized through continuous bodily co-presence within everyday work. Across ages, infants were almost always present—either as direct recipients of care or as peripheral observers—gaining sustained auditory, visual, and tactile access to social and material worlds. In early infancy, back-carrying during household and farming activities provided ongoing sensory input and regulation, while brief rhythmic handling emerged during task transitions. From early on infants' exposure diversified through repositioning by caregivers, siblings, and grandmothers, producing multiple acquisition vantage points across household spaces. Face-to-face interaction and joint attention occurred intermittently, embedded within routine activity rather than structured as dedicated play.

By foregrounding bodily access and environmental affordances, this study demonstrates how infants in Nso households participate in social life through presence as much as through interaction. Integrating ethnographic detail with developmental theory, the findings highlight co-presence as a foundational pathway through which infants encounter culturally patterned caregiving, material environments, and emerging social cognition.

O4.6 - What makes a prosocial infant? An exploration of parental beliefs that predict infant sharing behavior

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Details

Previous research has shown that infants vary in their degree of prosociality and that socio-cultural experiences influence infant prosociality (Cortes Barragan & Meltzoff, 2025). Yet, one area that remains understudied is the possible connection between parents' humanistic values and infants' prosocial behavior. We examined the role of parents' "identification with all humanity" in predicting infants' sharing behavior in an experimental laboratory task. The "identification with all humanity" is a social-psychology construct measured by a valid scale in adults (McFarland et al., 2012). Identification with all humanity has been contrasted with identification with less encompassing groups, such as identification with one's nation (patriotism) or specific community. In adults, identification with all humanity strongly predicts a person's degree of altruism and prosociality towards strangers, but it is not known whether parents' identification with all humanity relates to prosocial behavior in their infants.



We tested $N=24$ (50% girls) 19-month-olds ($M=19.59$, $SD=0.26$) in a laboratory experiment. Infants were presented with 2 sharing trials involving their own personal items, e.g., teddy bear or other favorite toy. Trials were presented in a counterbalanced order and videorecorded for subsequent scoring by independent coders blind to the hypothesis. Infants received a dichotomous score of whether they shared either of their objects. Parents completed the Identification With All Humanity Scale (5-point Likert scale) as well as control scales measuring identification with one's nation or identification only with one's own close-in community instead of "all humanity." We hypothesized that parental identification with all humanity—embracing all others as being like themselves—would predict prosociality in their infants but that the control measures would not. To analyze the data, we constructed a median split for each of the 3 parental measures, and following previous research, used a median split to categorize parents as high vs. low in their identification scores on each of the 3 identification measures.

As predicted, the level of parental identification with all humanity significantly predicted infants' level of sharing their personal objects with a stranger. 7 of 12 infants whose parents scored above the median on identification with all humanity showed sharing behavior in contrast to only 1 in 12 infants whose parents scored below the median, Fisher's exact test $p=0.027$ (Figure 1). The other two identifications were not associated with infant sharing behavior, Fisher's exact test $ps > .60$. We also examined the data with a binomial logistic model that included infant gender as a covariate and found the same results.

Parents' humanistic value of identification with all humanity was associated with infants' sharing behavior with a stranger. This work is in line with other emerging work showing the effect of socio-cultural experiences in supporting the emergence of infant prosociality. Parents who self-report high levels of humanistic values may treat non-family members with high levels of prosociality, and infants may observe and learn from such events, leading them to engage prosocially toward non-kin. Such opportunities for learning may not only undergird individual differences in infant sharing, but also point to a pathway for designing interventions to nurture prosocial development in infant populations. Discussion will focus on the mechanism(s) of intergenerational transfer from parents to infants, and the interesting specificity of the effect, while recognizing that replications and extensions beyond this $N=24$ are warranted.

O4.7 - "Use your word": Infants express a variety of meanings with single words

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Details

The pragmatics of language—how infants flexibly use words across contexts—is foundational to early communication. Despite a history of case studies that richly documented infants' spontaneous word use in natural contexts most research relies on brief laboratory tasks or automated analyses of flat-file transcripts—methods unlikely to capture the everyday activities of infants' communicative acts. To address this gap, we human-annotated videos of a relatively large sample of 60 infants ($M = 16.1$ months) and their mothers from English- and Spanish-speaking homes during 1–2 hours of everyday activities. We classified 4,000+ single-word utterances into six pragmatic categories and 22 subcategories (Table 1), using contextual cues from videos (e.g., gaze,



gesture, prosody, and activity context) to guide interpretation (inter-rater Kappa = 0.93); we also classified each utterance as spontaneous or imitated (i.e., repeated within 3 secs of mother's use of the target word).

Infants were prolific and purposeful communicators, averaging 379 non-distress vocalizations across the visit ($SD = 293$; $range = 21-1556$). Most vocalizations were non-words (83%), but when infants produced words, they were overwhelmingly single-word utterances (94% of worded-utterances). Infants' single-word utterances served a variety of functions. Although infants used words referentially (to label/describe; 25%), the majority of their words (75%) were used to request (35%), object (13%), affirm (8%), exclaim (12%), and participate in social routines (7%). Similarly, exploratory analyses of word classes (e.g., nouns, verbs, adjectives, interjections, etc.) indicated that although nouns were common, half of infants' words fell into other classes (e.g., adjectives, imperatives), underscoring the importance of considering both the *function* of infants' early words (i.e., pragmatics) and their linguistic *form* (i.e., *word class*). Patterns of word functions and forms were similar in infants from English- and Spanish-speaking homes.

Strikingly, 87% of infants' single-word utterances were spontaneous rather than imitated. Spontaneous words were most often used to request people, object, or exclaim—suggesting that infants' earliest pragmatic expressions reflect self-generated communicative goals. In contrast, imitations were more often referential, frequently observed during structured moments such as book sharing where labelling is common.

Finally, we tested associations between word variety (i.e., word types produced) and pragmatic diversity. Notably, half of infants who produced fewer than five distinct word types already used their single words to express the six pragmatic categories. Nonetheless, a deep dive into the nuanced use of words across all sub-categories indicated a clear developmental progression of pragmatic functions: Infants who used few word types tended to exclaim and request people, and, as word variety increased, infants expressed a broader range of functions (Figure 1A-B).

Methodologically, video-based, ecologically-grounded observations reveal the full range of infants' everyday pragmatic functions, which may be obscured by flat-file transcripts or constrained activities (e.g., predominance of nouns observed during book reading). Even single words serve as powerful social tools, extending insights from studies on the pragmatics of preverbal communication (e.g., proto-imperatives and declaratives). As such, assessments of infants' communicative development should consider *how* infants use their words—or perhaps, 'a word'—to effectively communicate their needs.

O4.8 - Language input in the Amazonian indigenous context: examining Panāra language environments across infant age

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Details

Infants acquire language by interacting with people around them; however, the social contexts in which language acquisition unfolds vary drastically across cultures^{1,2}. Cross-cultural differences in



family structure may impact both total amount of language input as well as relative proportion by speaker type^{3,4,5,6}. Most research on infant language input considers child-centered societies—where social situations are adapted to include children—with daylong recordings collected in the context of nuclear families^{7,8}. The present study utilizes recent advances in automatic speech processing to examine daylong recordings collected from infants (age range: 1-36 months) raised in the Panãra Indigenous community (Mato Grosso, Brazil). Panãra society is not child-centered, and children are raised in multigenerational households with shared caregiving responsibilities⁹. We ask the following questions: (1) How often do Panãra infants encounter language input from others? (2) Who are their most common interlocutors? (3) Does amount of language input change with infant age? (4) Does language input correlate with infant vocalizations?

Daylong audio recordings (38 recordings; 22 infants; mean duration: 15 hours 12 minutes) were collected between July 2023-2025. We utilize VTC-ALICE, a recently developed open-source alternative to LENA trained on audio input from multiple languages including rural and urban settings^{10,11}. Because Panãra words are highly morphologically complex, our analyses of speech input consider “duration of speech” rather than word counts¹¹.

Results indicate that Panãra infants are exposed to linguistic input from multiple speaker types throughout their day, averaging to 13.5 minutes of speech per hour (Range: 3.3-19; SD=3.96). Most input comes from female adults (FEM; Fig1), followed by other children (CHI), with input from male speakers (MAL) consistently low. Panãra infants vocalized an average of 5.8 minutes/hour (SD = 2.6), with older infants vocalizing more than younger infants ($r(38) = .398, p = .013$). Finally, key child vocalizations correlate most strongly with other child speech (CHI; $r(38) = .737, p < .001$; Fig1), marginally significantly with adult female speech (FEM; $r(38) = .312, p = .057$; Fig1), and not significantly with adult male speech (MAL; $p > .1$; Fig1).

These results align with existing literature on language input in other non-Western rural societies; we find that Panãra children hear more verbal input than children in Vanuatu (11min/hr⁶) and slightly less verbal input than children in Timor Leste (15 min/hr¹²). Likewise, our findings are consistent with studies of input in smaller scale societies that report other child input as an important predictor of target child vocalizations^{3,4,6}, and may be a result of children spending the majority of time together, often exhibiting alloparental care for Panãra infants^{3,4,5,6}.

Follow-up work will perform manual annotations to consider (1) Social contexts (dyadic vs group interactions) and (2) Directionality of input – ethnographic observations suggest child-directed speech is rare. Our study emphasizes the importance of studying diverse language contexts, particularly in societies where overheard speech and peer interactions may primarily drive acquisition^{13,14}.

O4.9 - Unpacking dyadic reciprocity: infant and maternal contributions across contexts

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Details

Social adaptability and cognitive flexibility begin in early parent–infant interactions. These exchanges provide opportunities for engagement, regulation, and learning, and their quality



predicts socio-emotional and cognitive outcomes. High-quality interactions may even buffer risk in vulnerable populations.

Although coordinated exchanges are recognized as foundational, the mechanisms driving dyadic reciprocity—the dynamic, back-and-forth coordination between partners—remain unclear. Caregivers differ in sensitivity and responsiveness, and infants vary in social engagement. Understanding how these characteristics jointly shape reciprocity is essential for explaining how interactions become more organized and flexible over time.

Context also matters. Most research focuses on free play, yet reciprocity patterns shift with task demands, dyadic expectations, and partner capacities. This variability underscores the need to examine dyadic processes across multiple contexts to capture the dynamic nature of early social development.

The present study addresses these gaps by investigating (1) unique maternal and infant contributions to dyadic reciprocity and (2) how reciprocity and interactional qualities vary across contexts. Findings aim to clarify mechanisms underlying adaptive social development and inform strategies to support early relational health.

Design

Forty-five mother–infant dyads (infants aged 12–24 months) participated in three 4-minute play situations: (a) free play (natural interaction), (b) goal-directed play (shape sorter task), and (c) instructed synchrony (mother asked to synchronize with her infant in any way she chose). Interactions were coded using the Coding Interactive Behavior (CIB) scale (Feldman, 1998) for parental sensitivity and intrusiveness, child involvement and withdrawal, and dyadic reciprocity.

Results

1. Dyadic synchrony did not vary significantly by task (free play $M = 3.85$, $SE = 0.12$, goal-directed $M = 3.83$, $SE = 0.11$, instructed synchrony $M = 4.07$, $SE = 0.11$), nor did maternal qualities (Table 1).
2. Infant qualities did vary by task. Infants showed significantly less involvement during the goal-directed task than the free play or instructed synchrony task (Table 2). Infants also showed significantly less withdrawal during instructed synchrony task than the other two tasks.
3. When the two maternal and two infant qualities were regressed onto dyadic reciprocity for each task, maternal sensitivity consistently explained variance across contexts. However, the other qualities contributed in distinct combinations. Notably, infant withdrawal but not involvement contributed significantly to dyadic reciprocity in free play; the reverse pattern was seen in instructed synchrony play.

Conclusion

These findings highlight that while maternal sensitivity provides a stable foundation for reciprocity, infant engagement is highly context-dependent. The absence of task effects on maternal behavior suggests that caregivers maintain consistent interactional styles, whereas infants adapt their involvement and withdrawal to situational demands. Understanding these nuanced contributions advances our knowledge of how dyadic reciprocity develops and underscores the importance of studying interactions across varied contexts. Such insights can inform interventions aimed at



promoting adaptive social development and strengthening early relational health, particularly in populations at risk.

04.10 - “The laboratory must be like life.” Infant behavior during naturalistic free play in the lab versus natural activity at home

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Details

Ecological validity—the extent to which laboratory research reflects real life—is critical to understand behavioral development. As Gibson (1979) put it, “the laboratory *must* be like life.” But is it? Here we asked which features of infant behavior are preserved and which are lost when the observational context shifts from a naturalistic lab environment to the natural home environment. To test the stability of individual differences across contexts, we observed the same babies in both settings. We used infant walking as a model system to compare behavior across contexts because walking is a foundational, directly observable behavior that can occur in any context.

We observed 14- to 15-month-old walking infants ($N = 52$) and their caregivers during 15 min of free play in a lab playroom filled with toys and elevations (Figure 1A). Then, we visited the same infant-caregiver dyads at home (*Median* = 5 days later) and observed them during 60 min of everyday activity (Figure 1B). From video, we annotated how much infants walked (e.g., % time walking), key characteristics of walking (e.g., path shape), and the functions of walking (e.g., visiting destinations). We predicted (1) infants would walk more in the lab than at home because many everyday home activities (e.g., cuddling, book reading) compete with walking; and (2) the essential characteristics of walking would be preserved across contexts because they are not tied to quantity of walking; but we were agnostic about (3) whether functions of walking would differ across contexts.

Preliminary results from 22 infants largely support our predictions. (1) Infants walked more in the lab than they did at home. In the lab, infants spent twice as much time walking, initiated twice as many bouts, took twice as many steps, and fell twice as frequently (Figure 2A). (2) The key characteristics of walking, however, were preserved across contexts—percentages of short bouts, curved bouts, and bouts with only forward steps were similar in lab and home, and infants’ longest walking bouts in lab mirrored their longest bouts at home (Figure 2B). (3) The functions of walking yielded mixed results. Infants visited more destinations and traveled greater distances per bout in the lab than at home, but they carried and pushed objects similarly often across contexts (Figure 2C).

Findings suggest that the “lab is like life” for some features of infant walking but not others. Estimates of how much infants walk must be obtained from home observations during everyday activity. However, insights into characteristic features of walking can be obtained wherever infants walk. Some functions of walking are dependent on context, and others are not. Thus, we highlight the critical importance of observational context when studying infant behavior and drawing ecologically-valid inferences about development. Ongoing analyses of the full sample will test the stability of individual differences across contexts and compare infant behavior across repeated lab



free play sessions to determine whether increased walking in lab is driven by novelty or by differences in context.

Oral Session 5 – Speech Perception and Multilingual Word Learning

O5.1 - Rhythmicity and audiovisual cues guide attention to child-directed communication in autistic and nonautistic toddlers

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Details

Background: Autistic toddlers extract different information from complex social scenes than nonautistic peers (Jones & Klin, 2009), exhibiting more idiosyncratic attentional patterns when viewing scenes of others interacting (Avni et al., 2020). Such idiosyncrasies contribute to challenges developing social skills (Klin et al., 2015). However, these patterns may be impacted by social contexts and characteristics. Child-directed (CD) song is a highly motivating dyadic activity for autistic toddlers (Lense & Camarata, 2020). CD-Song contains predictable temporal structure and patterns of audio and visual cueing that dynamically scaffolds visual attention in nonautistic infants (Alviar et al., 2023; Lense et al., 2022).

Objective: We investigated how consistency of visual attention varies across social communication contexts of child-directed song (CD-Song) and child-directed speech (CD-Speech) in autistic and nonautistic toddlers. We also explored how characteristics of CD-Song (i.e., temporal predictability, visual motion, and audio volume) affected consistency of visual attention.

Methods: Autistic (n=50, 41 male) and nonautistic (n=47, 24 male) toddlers between 14 and 36 months old were eye-tracked while watching videos of caregivers speaking to them (CD-Speech) and singing to them (CD-Song), along with versions of the CD-Song videos manipulated to remove predictable temporal structure. We computed spatial inter-subject correlations (ISCs) for each participant's eye position and every other participant with the same diagnosis and predicted overall video ISC by stimulus type and diagnosis. Within CD-Song, we compared ISCs between manipulated and unmanipulated stimuli to assess how rhythmic predictability influences visual attention. To examine moment-to-moment viewing dynamics within CD-Song, we computed variability in participants' eye position (dispersion) at each frame within diagnostic group, and predicted dispersion by frame-to-frame visual motion and audio volume change.

Results: Diagnosis and stimuli type both impacted ISCs. Nonautistic toddlers had higher ISCs than their autistic peers, and unjittered song had higher ISCs than other stimuli (Figure 1). The diagnostic difference varied across stimulus types: ISCs did not differ by diagnosis for unjittered song ($\beta=0.01$, $p=NS$), but nonautistic toddlers exhibited more consistent attention patterns than autistic toddlers across mildly jittered song ($\beta=0.03$, $p<0.05$), moderately jittered song ($\beta=0.05$, $p<0.001$) and CD-speech ($\beta=0.05$, $p<0.001$). Frame-by-frame similarity in eye location within diagnostic groups was enhanced by more motion ($\beta=-0.02$, $p<0.001$; negative coefficient means less dispersion) and reduced by larger changes in sound volume ($\beta=0.01$, $p<0.001$); however, such effects were stronger for nonautistic toddlers ($p's<0.001$).



Conclusions: Consistency in visual attention is driven by social context and time-varying stimulus characteristics including movement and sound intensity. CD-Song is highly effective at consistently scaffolding attention in autistic and nonautistic toddlers. This consistency is driven by a combination of temporal predictability and audio and visual cues. Autistic toddlers are particularly sensitive to temporal predictability, implying they may be relying on rhythm-based mechanisms to parse child-directed signals. Nonautistic toddlers' sensitivity to auditory and visual cues may reflect their roles as meaningful social communication signals in the song context. Results inform how different communicative contexts may support social engagement in autistic toddlers.

O5.2 - Early word form recognition and sensitivity to phonological changes in Akan-learning multilingual infants in Ghana (Africa)

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Details

Infants' sensitivity to phonological properties distinguishing word meanings in their native language, including consonants and vowels in all languages and lexical tones in tone languages, is a requirement for lexical acquisition. It has been proposed that consonantal information plays a more important role than vocalic information in lexical acquisition/processing, an asymmetry called consonant bias (C-bias) (Nespor et al., 2003). However, developmental evidence across different language families shows variation (see Nazzi, 2025): a C-bias emerges early in development in Romance languages (e.g., French), later in development in Germanic languages (e.g., English), while a vowel bias (V-bias) is found in Sinitic languages (e.g., Cantonese, Chen et al., 2020). This V-bias in Sinitic languages has been linked to the presence of lexical tones – mainly carried by vowels – which may increase vowel prominence. This study explored whether a V-bias is more generally found in tone languages, extending research to an understudied African tone language, Akan, and to multilingual infants learning tone languages alongside a non-tone language (e.g., English), tested in Accra (Ghana). In two experiments using the central fixation procedure, we investigated infants' perceptual preferences for early familiar wordforms and their sensitivity to mispronunciations of these wordforms. Infants' language exposure was assessed using an interview questionnaire. In Experiment 1, we investigated infants' preferences for correctly pronounced bisyllabic CVCV familiar Akan words selected from the Akan CDI/checklist (Coffey et al., 2025) versus pseudowords, and how relative exposure to Akan modulates these preferences. Twenty-four 11- to 14-month-old multilingual infants were tested. As hypothesized, infants showed a familiarity preference for correctly pronounced familiar Akan words ($p = .03$), demonstrating recognition of early familiar wordforms. This preference was not modulated by exposure to Akan ($p = .63$), ranging from 10 to 88%, suggesting that even relatively low exposure is sufficient for these multilingual infants to acquire and recognize familiar Akan words. Following Poltrock & Nazzi (2015) design, Experiment 2 presented 24 11- to 14-month-old multilingual infants with consonant mispronunciations (one-feature changes: either place, manner, or voicing) and vowel mispronunciations (one-feature changes: height) of the familiar words used in Experiment 1. If Akan-learning infants have a V-bias, they should prefer the consonant over the vowel mispronunciations, indicating that vowel mispronunciations impede word recognition to a greater extent. Results showed no difference in looking time to consonant and vowel mispronunciations (p



= .57) and no effect of language exposure (neither to Akan: $p = .47$; nor to English: $p = .24$, the only non-tone language the infants hear). This indicates that Akan multilingual infants are equally sensitive to both types of mispronunciations and that this sensitivity is not influenced by the amount of lexical tone language input they receive. Together, these experiments provide the first evidence of early wordform recognition in multilingual infants in an African community, at the age reported in previous studies on monolingual infants learning Indo-European languages. Further studies will be needed to determine whether the lack of C- or V-bias results from insensitivity to phonological information or to equal sensitivity to consonant and vowel information.

O5.3 - 14-month-old English-learning infants encode positional variants of word-final /t/

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Details

Infants encounter substantial phonetic variation in their speech input, yet must determine which aspects of this variability should be encoded in lexical representations. An outstanding question in early word recognition is how infants represent optional allophonic variation: do they encode the canonical form, the most frequent surface variant, or an abstract, underspecified representation? American English /t/ provides an ideal test case as word-final /t/ is more often realized as a glottal stop ([ʔ]) in infant-directed speech than the canonical [t] (Khlystova et al., 2023). Across two experiments, we used the Headturn Preference Procedure (Jusczyk & Aslin, 1995) to assess 14-month-olds' lexical representations of /t/-final words, focusing on whether infants encode the canonical /t/, [ʔ], or an underspecified coda.

The design of the experiments was based on Swingley (2005). In both experiments, infants heard lists of familiar words, identified based on the MacArthur CDI, ending in /t/ (e.g., *foot*, *cat*) produced with either [ʔ] (Experiment 1) or canonical [t] (Experiment 2), along with lists of minimally different coda mispronunciations. Each infant heard 12 lists (6 familiar, 6 nonwords). All trials were completely infant-controlled. Looking times, serving as proxies for listening time, were analyzed using Bayesian hierarchical linear regression models, with fixed effects for Trial Type (potentially familiar vs unfamiliar), Trial Number and random effects for Subject.

Experiment 1: Monolingual English-learning 14-month-olds ($n = 28$, target = 30) heard lists of familiar words produced with final [ʔ] (e.g., *foot* → [fʊʔ]) and with minimal coda mispronunciations (e.g., *foot* → [fʊp]/[fʊk]). If infants' lexical representations contain underspecified codas at 14 months, they should treat both list types as equally familiar. If they encode the glottal stop variant, they should prefer the familiar forms pronounced with final [ʔ]. Preliminary results: we can say with 90% certainty (p -direction = 0.90) that infants listen credibly longer to lists of familiar words with glottal stop realizations ($\beta = 0.51$, 95% CrI [-0.25, 1.24]), suggesting that infants encode final glottal stop in their lexical representations

Experiment 2: Monolingual English-learning 14-month-olds ($n = 21$, target = 30) heard familiar words produced either with canonical [t] (e.g., *foot* → [fʊt]) or minimal coda mispronunciations (e.g., *foot* → [fʊp]/[fʊk]). Preliminary results: we can be 97% certain (p -direction = 0.97) that infants listen credibly longer to the canonically-produced familiar words than to the mispronunciations ($\beta = 0.85$, 95% CrI [-0.04, 1.77]), demonstrating recognition of the final [t] variant as well. This finding



demonstrates that infants do not exclusively encode the glottal stop variant but also represent canonical /t/ at 14 months.

Together, these results show that toddlers' early lexical representations are sufficiently flexible to support recognition of both the more frequent (glottal stop) and canonical ([t]) variant of word-final /t/. Infants at 14 months tolerate variability in coda realization while still encoding enough phonological detail to distinguish correct pronunciations from minimal mispronunciations. Whether the canonical variant is privileged in lexical access, as has been demonstrated for adults (Sumner & Samuel, 2005), remains to be determined.

O5.4 - Familiar wordform recognition in preterm 11-month-olds: evidence from the Head-Turn Preference Procedure

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Details

Lexical acquisition starts during the first year of life. One line of evidence of this is that full-term infants show a reliable preference for familiar over unfamiliar wordforms by 11-12 months, reflecting emerging lexical representations (for French: Hallé & de Boysson-Bardies, 1994; Poltrock & Nazzi, 2015; for English: Vihman et al., 2004; for Dutch: Swingley, 2005). The present study investigates whether this ability is also found in infants born preterm, given evidence that prematurity can affect later language outcomes. Indeed, preterm children often show persistent lexical delays from the second year of life onwards (e.g., Caravale et al., 2005; Saavalainen et al., 2006). Yet, little is known (though see Berdasco-Munõz et al., 2023, on early wordform segmentation) about the onset of lexical acquisition in this population.

Extending Experiment 1 of Poltrock and Nazzi (2015) from full-terms to preterms, we used the Head-Turn Preference Procedure and presented infants with trials in which they heard either ten familiar disyllabic French words or ten matched pseudowords. We already tested 23 French-learning preterm infants (mean GA = 33.8 weeks, range = 28–36) between 11 and 12 months of postnatal age (M = 11 months, 16 days). This current sample includes a majority of moderate and late preterms (20 out of 23), with ongoing efforts to test more very and extremely preterms (< 34 weeks GA) before the conference. Mean orientation times toward each type of word (familiar words versus pseudowords) were measured as the dependent variable. A two-way ANOVA including the original full-term sample from Poltrock and Nazzi (2015) showed a robust familiarity effect: infants oriented longer to familiar words than to pseudowords ($p < .001$). No main effect of group or interaction was found, indicating comparable performance between preterm and full-term infants. Within-group analyses confirmed a significant familiarity preference in both groups (full-terms: $p < .001$; preterms: $p = .005$, Figure 1). For preterms, no correlations were observed between the size of the familiarity effect and gestational age, birth weight, or duration of hospital stay.

These results provide the first evidence that preterm infants—most of whom were moderate or late preterms—recognise familiar word forms at 11 months postnatal age, on par with their full-term



peers. This finding extends previous evidence of early wordform recognition found in fullterm infants (Hallé & de Boysson-Bardies, 1994; Poltrock & Nazzi, 2015) and suggests that the core phonological mechanisms underlying early wordform acquisition are already functional in preterm infants. Note, however, that since at this point of testing, the preterm infants tested are mostly moderate and late preterm infants, they may have benefited from their greater neurodevelopmental maturity, leading to performance comparable to that of full-term infants. Ongoing data collection including a larger proportion of very preterm infants will determine whether these patterns extend across the full spectrum of prematurity. These additional findings will allow us to determine whether the lexical difficulties found in preterm children in later development are related to difficulties at memorising wordforms, or to other steps in lexical acquisition (e.g., the linking of soundforms to their meaning).

O5.5 - Cross-linguistic differences in infants' perception of phonetic and phonotactic differences involving the /s/-/ʃ/ contrast

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Details

Infants start acquiring the sound categories of their native language and showing sensitivity to language-specific phonotactic regularities between 6 and 12 months. However, some native contrasts, such as /s/-/ʃ/, are harder to discriminate in infancy (Nittrouer, 2001), and a previous study documented cross-linguistic differences between French- and German-learning infants' sensitivities to phonotactic regularities involving such perceptually low-salient phonemes at 9 months, with only French-learning infants exhibiting phonotactic sensitivity (Piot et al., 2024). The present study examined whether infants' sensitivity to such regularities would be stronger at different ages, and assessed whether their early phonotactic sensitivity would be associated with their ability to discriminate /s/-/ʃ/ in three cross-linguistic experiments with French- and German-learning infants.

Using the headturn preference procedure, Experiment 1 assessed infants' sensitivity to language-specific singleton regularities varying in frequency within and between the two languages (word-initial /s/ frequent in French, but infrequent in German; word-initial /ʃ/ frequent in German, but infrequent in French) at 6, 9 and 12 months ($N=146$). Experiment 2 tested sensitivity to biphone regularities characterized by cross-linguistic frequency variations similar to Experiment 1 (i.e., word-initial /s/- or /ʃ/-plosive clusters) at 9 months ($N=54$). Using a habituation procedure, Experiment 3 investigated infants' ability to discriminate the /s/-/ʃ/ contrast in word-initial position at 9 months ($N=48$).

Experiment 1 revealed a significant cross-linguistic difference in phonotactic sensitivity ($p = .018$) to singleton regularities in the 9-month-olds, with only French- ($p = .002$) but not German-learning ($p = .595$) infants showing a novelty preference for the non-frequent regularity in French (Figure 1). No evidence of sensitivity was found at the other ages. In Experiment 2, although the interaction was only marginal ($p = .089$), separate analyses failed to show evidence of phonotactic sensitivity in German-learning infants ($p = .552$), while French-learning infants showed a familiarity preference



for the frequent biphone regularities in French (/s/-plosive clusters, $p = .007$). In Experiment 3, we found a significant cross-linguistic difference ($p = .037$) in infants' ability to discriminate /s/-/j/, with discrimination in French-learning ($p < .001$) but no evidence of discrimination in German-learning infants ($p = .294$, Figure 2).

As predicted, results of the French-learning 9-month-olds confirm previous findings showing phonotactic sensitivity to low-salient sibilant regularities at this age in French. The difference between Experiment 1 (novelty preference) and 2 (familiarity preference) might indicate that singleton regularities are acquired earlier, or processed more easily, than biphone regularities in infancy (Chambers et al., 2011). The inconclusive evidence for phonotactic sensitivity and discrimination in the German-learning infants might be related to the /s/-/j/ contrast being less functional in German: corpus analyses showing much fewer minimal pairs involving this contrast in German compared to French, notably in word-initial position. Therefore, our cross-linguistic results might be due to language-specific differences in sound frequencies and functional load, which might have provided French-learning infants with converging cues supporting both discrimination of /s/-/j/ and acquisition of the phonotactic properties of these segments. Overall, our findings suggest that phonotactic and phonetic perception are interrelated in early acquisition.

O5.6 - A cross-sectional investigation of how rhythms enhance cortical tracking of unfamiliar languages

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Details

Musical training benefits have been reported in young infants demonstrating enhanced development of prelinguistic communicative gestures, neural processing of temporal structure, and word segmentation. In a previous study on Spanish-Basque bilingual infants, we proposed that rhythmic stimulation influences cortical tracking efficiency, the mechanism through which brain oscillations synchronize to the acoustic properties of external stimuli. We showed that Spanish-Basque bilingual infants showed higher cortical tracking of Spanish and Basque speech when it was preceded by rhythmical sequences that matched the syllabic structure and the melodic contour of the speech. It is unclear, however, whether rhythmic modulation generalizes to non-native languages. In this study, then, we focused on teasing apart whether rhythmic modulation is constrained by native language exposure or can generalize across languages by testing 6- and 10-month-old English monolingual infants. We hypothesized that infants would show higher cortical tracking to the speech sequences in both languages. Besides, we predict that the younger group will benefit more from rhythmic modulation than the older group, owing to their more universal processing of rhythm, compared to more accumulated language experience.

This cross-sectional study included 6- and 10-month-old monolingual English-learning infants, who have had no prior exposure to Spanish or Basque. We used electroencephalography to record neural responses to musical sequences and spoken sentences in the 6-month-old (N=21) and the 10-months-old (N=26) groups. Infants heard 64 Basque and 64 Spanish sentences produced in



natural infant-directed speech. Sentence presentation was preceded either by rhythmically regular musical sequences (regular condition) or by rhythmically irregular musical sequences (irregular condition). The regular sequences were constructed to match the syllabic structure and the melodic contour of the sentences. The irregular sequences were constructed by scrambling note duration and the melodic contour of the regular musical sequences. Only one type of musical sequence and language was used within a single experimental block. Cortical tracking of speech (speech-brain coherence) was calculated as the phase synchronization between the brain signal and the corresponding stimuli envelope weighted by their relative amplitude. Analyses were focused on the delta (~2Hz) and theta (~4Hz) frequency bands and conducted separately for each language.

Overall, infants showed enhanced cortical tracking at 10 months compared to 6 months across the two frequency bands and across languages. In the 6-month-old group, infants showed better cortical tracking in the regular condition compared to the irregular condition only in the delta band in the Spanish test. On the contrary, in the 10-month-old group, infants showed better cortical tracking in the regular compared to the irregular condition in the delta band in the Spanish test, and across frequencies in the Basque test. Therefore, our results demonstrate a rhythm-to-speech benefit in cortical tracking of non-native speech. We will discuss how the native and non-native language rhythmic properties might be modulating these effects, and how this might relate to the role of brain oscillations in early speech perception and the maturation of speech processing abilities, showing that cortical tracking is a flexible and adaptive mechanism that supports language acquisition through rhythm throughout infancy.

O5.7 - Infants' word recognition in code-switched speech: early adaptation in multilingual Ghana

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Details

Multilinguals regularly switch between multiple languages during conversations. This practice of code-switching is highly common in many African countries such as Ghana (Forson, 1988; Amuzu & Singler, 2014), where multilingualism is the norm (Bodomo et al., 2010), with infants being raised multilingually from birth (Omane et al., 2025). In Ghana, local languages like Akan often serve as the matrix language with English insertions during intrasentential switches (Dako, 2002; Quarcoo, 2012). In North American bilingually-raised infants, word recognition in code-switched sentences is impeded (Byers-Heinlein et al., 2017; Potter et al., 2019) — an effect in line with theories of processing costs associated with code-switching (Grosjean, 1998, 2001; Meuter & Allport, 1999). However, in Western contexts, code-switched input is rare (Kremin et al., 2022). Hence, we raised the question of whether processing costs would also arise in infants to whom code-switching in the input is the norm. We hypothesized that these costs would depend on infants' experience with code-switching in the input.

To probe this, using a field-experimental approach, we tested word recognition in code-switched contexts in multilingual Ghanaian infants (N = 25; age: 16-39 months, M = 29.6), all exposed to



Akan and English and to a total of two to five languages. Replicating Byers-Heinlein et al. 's (2017) task design, infants saw two familiar objects on screen (e.g., ear & rice) while listening to sentences stating the target word either in the same language (“Look! This is Max’s ear”) or switched language (“Hwɛ! Wei yɛ Max ear”). Infants were either assigned to an English (English→English, English→Akan) or an Akan block (Akan→Akan, Akan→English). Gaze behavior was manually coded offline to derive an index of word recognition: the change in proportion of looking time to the target object between pre- and post-naming phases. To measure experience with code-switching, we adapted the Language Mixing Questionnaire (Byers-Heinlein et al., 2017) to the Ghanaian context.

Overall (see figure 1), infants’ word recognition was above chance in all conditions ($p < .001$) except when sentences started in English and switched to Akan ($p = .29$). There was no effect of trial type (same-language vs. switched-language; $p = .37$) and no interaction between trial type and block ($p = .30$). Language-mixing experience interacted with trial type such that higher mixing exposure was associated with better word recognition in switched-language trials ($p < .05$).

Our results provide no evidence for general processing costs in infants hearing code-switched sentences; rather, as hypothesized, the effects seem to be related to the input: word recognition was efficient in all conditions that Ghanaian infants regularly experience: in sentences without language switch and when Akan sentences switched to English. Moreover, the more infants were reported to experience code-switching, the lower their switch-related processing costs were. These results indicate that infants adapt their processing routines to be efficient for their specific language environment. Our findings challenge the generalizability of code-switching costs observed in Western bilingual populations and highlight the importance of considering linguistically and culturally diverse samples to better understand the mechanisms that drive the development of efficient language processing procedures in infancy.

O5.8 - Uncertainty in word learning in 14-month-olds

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Details

Young infants struggle to learn similar-sounding words (Stager & Werker, 1997). Research shows that when infants have to learn acoustically similar words (e.g., /buk/ vs. /puk/), they benefit from speaker variability (Höhle et al., 2020). However, speaker variability appears to hinder word-learning when multiple acoustic cues (e.g., voicing and speaker gender) simultaneously signal label identity in word-learning tasks (Quam et al., 2017), despite the greater acoustic distinctiveness of the labels under these conditions. We hypothesize that learning minimal pairs in such contexts is more difficult because the task involves greater uncertainty. In information theory, uncertainty depends both on the number and the probabilities of the alternatives (Shannon, 1948), and higher uncertainty is associated with longer response times in adults, the celebrated Hick-Hyman law (Hick, 1952; Hyman, 1953). Accordingly, increasing the number of relevant stimulus dimensions should increase the number of possible alternative label–referent mappings (Fig.1A), thereby increasing uncertainty and modulating infants’ looking times in word-learning tasks.



To test this, 14-month-old German-learning infants (N=50) were familiarized across four blocks with two visual objects associated with two minimal-pair words (/tuuk/ vs. /duuk/) uttered by eight different speakers (16 trials per block; Fig.1B). Crucially, across participants, we varied the degree to which speaker gender was correlated with the visual referents along a continuum ranging from fully correlated to fully independent (Fig.1C) – a gradient version of Quam et al. (2017). That is, by progressively reducing the relevance of the speaker gender dimension as a cue to auditory labels, we reduced task uncertainty while keeping the occurrence of objects, voicing contrasts, and speaker genders constant across participants. After each familiarization phase, infants completed four preferential-looking trials in which the two objects were presented side-by-side, accompanied by one of the two auditory labels. Infants' looking times were measured using an eye tracker.

The time course of infants' looking patterns at test revealed three windows where significant looking-time differences emerged (Fig.1D). In the early window (Fig.1D:W1), infants looked significantly longer at the correct referent ($T_{sum}=75.12$, $P=.021$). In the second window (Fig.1D:W2), infants looked significantly longer at the incorrect referent ($T_{sum}=231.29$, $P<.001$). In the late window (Fig.1D:W3), we observed a significant correlation between infants' looking to the correct referent and the degree of correlation between speaker gender and voicing in the auditory stimuli ($R^2=.42$, $P<.01$; Fig.1D:W3): infants for whom gender and voicing were uncorrelated looked more at the incorrect referent, whereas infants for whom the two dimensions were correlated were more likely to shift their gaze back to the correct referent. Therefore, word-learning situations involving more relevant stimulus dimensions—i.e., situations that contain more possible label–referent mappings and consequently more uncertainty—lead infants to engage in additional verification of the correct visual referent. Our results demonstrate that, consistent with the Hick–Hyman law observed in basic perceptuo-motor tasks in adults, greater uncertainty prolongs the time infants take to verify the correct referent of a word.

O5.9 - Detecting systematic patterns in early vocabulary structure: Do similar word forms cue similar word meanings across languages?

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Details

Infants learning their first words face the challenge of mapping forms to meanings before having acquired the conceptual and grammatical knowledge that helps with inferring word meaning later in development (Imai & Kita, 2014). It has been suggested that vocabulary structure promotes early acquisition by providing statistically detectable phonological cues towards semantic category membership, such that words which sound similar also have similar meanings (Monaghan et al., 2011). Given their adeptness at learning from statistical regularities in their environment (Saffran, 2020), infants may exploit systematic patterns in the mapping between form and meaning to scaffold their word learning and grow their vocabulary (Christiansen & Monaghan, 2016). Indeed, corpus studies have shown that systematic mappings pervade the world's vocabularies (Dautriche et al., 2017) and are privileged in acquisition (Cassani & Limacher, 2022). However, the extent to which infants actually encounter systematic patterns in early development has never been examined across languages.



We conducted a comparative corpus study to investigate correspondences between semantic and phonological similarity in the early lexicon of 19 languages from different areas and language families, including English, French, Russian, Irish, Finnish, Persian, Cantonese, and Korean. Our analysis was based on around 700 words typically acquired between 16 and 36 months of age, as indexed by the cross-linguistic developmental vocabulary database Wordbank (Frank et al., 2017). For each language, we calculated the pairwise phonological and semantic distances between all nouns in the database, using Euclidean distances between phonological feature vectors as phonological distance metrics (Kalinowski et al., 2025) and cosine distances based on fastText embeddings as semantic distance metrics (Bojanowski et al., 2016). The association between pairwise phonological and semantic distances for each language was assessed by a Mantel test with Spearman's rank correlation coefficient and 100,000 random permutations. In line with previous evidence from the adult lexicon (Monaghan et al., 2014), we expected to find positive correlations, such that words would be more similar in form the more similar they were in meaning. Our results showed subtle, but highly significant negative correlations for Dutch, Norwegian, Danish, Finnish, and Cantonese, such that words were more distinct in form the more similar they were in meaning (p between $-.130$ and $-.111$, all $p < .001$). Results for all other languages were non-significant but qualitatively similar, except for German, Spanish, Portuguese, Persian, and Korean.

Our findings yield little evidence for systematic patterns in the early lexicon, indicating instead that vocabulary structure may support acquisition by maintaining discriminability between words of the same category rather than by facilitating categorization. Thus, the role of systematicity in lexical development seems less clear-cut than previously assumed. We suggest that any learning advantage for systematic mappings may be restricted to localized clusters which were not detected by our lexicon-wide analysis. Such systematic neighbourhoods may aid word learning only very early on, before the lexicon has reached a certain size at which discriminability becomes more important than categorizability. Hence, our study opens up exciting avenues for research into the small-scale structure and development of the early lexicon.

05.10 - From iconicity to arbitrariness: developmental changes in sound-symbolic word learning in Korean infants

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Details

Sound symbolism—the natural connection between sounds and meanings—is posited to facilitate early word learning (Imai et al., 2015; Imai & Kita, 2014; Perry, Perlman, Winter, Massaro, & Lupyan, 2017), though its applicability across diverse languages and age groups is underexplored. This study examines the universality of the *buba-kiki* effect (Köhler, 1929) with Korean infants and addresses three main questions: First, are Korean-learning infants sensitive to the *buba-kiki* type sound symbolism? Second, does this sensitivity drive word mapping differently at 14 & 28 months old? (3) Can infants generalize learned sound-symbolic links across variations in visual features, such as color?

We recruited 64 monolingual Korean infants, split into two age groups (14 and 28 months), and employed the Looking-while-Listening paradigm to assess their ability to learn word-object associations in sound-symbolically matched and mismatched conditions. In the matched



condition, labels aligned with shapes (e.g., round shape paired with [buba], spiky shape with [kipi]); in the mismatched condition, these pairings were reversed. The experiment consisted of four phases: (1) a pretest to acclimate infants to the procedure, (2) a habituation phase to familiarize them with specific sound-shape associations, (3) a test phase to assess learning of these associations, and (4) a generalization phase testing their ability to apply the learned associations to novel color-shape pairings. Gaze data were analyzed, focusing on the frequency of gaze switches from distractor to target as an index of infants' recognition of word-object associations. We fit a binomial generalized linear mixed-effects model ($\text{glmer}(\text{proportion} \sim \text{gaze_start} * \text{condition} * \text{age} * \text{phase_type} + (1 | \text{subj}))$, family = binomial("logit")), which revealed a significant four-way interaction among gaze start, condition, age, and phase type. Pairwise comparisons were conducted to further probe these interactions.

Results revealed notable age-based distinctions. Fourteen-month-olds displayed significantly more distractor-to-target gaze switches in both the filler and matched conditions, suggesting recognition of the congruent sound-shape association; however, this pattern did not appear in the mismatched condition, indicating that infants at this age find arbitrary associations more challenging. In contrast, 28-month-olds showed increased gaze switches across all conditions, reflecting a broader capacity for arbitrary word-object mappings. In the generalization phase, older infants demonstrated the ability to apply sound-shape associations to new items across varied colors, irrespective of shape-color pairing reversals, indicating flexible learning. In contrast, younger infants' performance in the generalization phase appeared limited by fatigue, impacting their ability to apply learned associations. The observed effect of sound symbolism on younger infants aligns with past research suggesting that iconic relationships between sounds and meanings can bolster early word learning. However, older infants' consistent recognition of mismatched pairs highlights a developmental shift toward more arbitrary associations as they progress in language acquisition.

These findings suggest that sound symbolism can support early word learning in Korean infants as young as 14 months and that the ability to generalize word-object mappings across varying features strengthens with age. This study underscores the potential role of sound symbolism in scaffolding early language development while highlighting age-related shifts in infants' capacity for flexible, abstract learning of word meanings.

Oral Session 6 – Emotion, Stress and Family Context

O6.1 - How to start a conversation? A five-year longitudinal investigation of the effect of parent question type on children's early emotion labeling

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Details

Parent-child conversations are key to children's emotion knowledge, yet little is known about how parents' initial questioning strategies shape children's ability to label emotions over time. Prior work emphasizes the role of parental mental state language and emotion-related talk, but most studies are cross-sectional and overlook how question type and timing matter. Guided by parental emotion socialization theory, the Theory of Constructed Emotion, and Vygotsky's Zone of Proximal



Development, this five-wave longitudinal study tested whether parents' initial open-ended versus yes/no questions predict children's correct emotion labeling concurrently and across early childhood.

Participants were 323 children (2–7 years old across waves) and their primary caregiver, drawn from a diverse community sample in the Denver metropolitan area. At each wave (2019–2023), dyads were video-recorded in their homes discussing a five-page wordless picture book depicting characters expressing happiness, sadness, anger, fear, or disgust. Parents were instructed to “tell a story” for each page without mention of emotions, allowing emotion discussion to emerge naturally. Transcripts were coded for (a) parents' initial question on each page, categorized as open-ended (e.g., “What’s happening?”) or yes/no (e.g., “Is she sad?”), and (b) children's correct emotion labels derived from a validated emotion dictionary. Conversation length, child age, and gender served as controls. Path models tested cross-sectional and longitudinal associations across Waves 1–5, using full information maximum likelihood estimation.

Descriptive correlations showed a consistent pattern: across all five waves, parents' initial open-ended questions were significantly positively associated with children's correct emotion labeling, whereas parents' initial yes/no questions were significantly negatively associated with children's correct emotion labeling. Emotion labeling showed significant stability across waves, and both question types showed moderate stability from Waves 1–4. Longer conversations were related to higher child emotion labeling at each wave.

Path model results indicated mostly adequate model fit. Cross-sectionally, parents' open-ended initial questions predicted significantly greater child emotion labeling at multiple waves, even after controlling for covariates. Parents' initial yes/no questions showed concurrent negative associations with children's emotion labeling at several waves, suggesting that these questions may constrain children's opportunities to articulate and explore emotion concepts during shared reading. Longitudinally, both open-ended and yes/no initial questions demonstrated wave-to-wave associations with children's later emotion labeling, though these effects varied by developmental period. The stability of child emotion labeling and parental questioning behaviors further suggests that early conversational patterns may create sustained trajectories in how families talk about emotions.

These findings underscore the developmental importance of how parents initiate emotion-related conversations. Open-ended questions help children observe, interpret, and verbalize emotions in context, while yes/no questions may restrict expressive depth, especially early in development. This study offers the first longitudinal evidence that both the type and timing of parental questions during wordless book interactions uniquely predict children's emotion labeling skills, highlighting the value of encouraging parents to use developmentally appropriate, open-ended language to support children's socio-emotional growth.

O6.2 - Prenatal intimate partner violence, parent-child emotion co-regulation, & the moderating effect of maternal social support

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Details

Intimate partner violence (IPV) during pregnancy is a highly prevalent public health concern with prominent developmental consequences. A recent *CDC Morbidity and Mortality Weekly Report* analyzing 2016–2022 Pregnancy Risk Assessment Monitoring System (PRAMS) data found that 5.4% of pregnant women reported experiencing IPV (Steele-Baser et al., 2024). These figures likely underestimate the true prevalence across the United States, given underreporting and lack of nation-wide data. IPV during pregnancy not only impacts maternal health but also increases the probability for developmental delays in children and disturbances in parent-child interaction outcomes, thus warranting a thorough investigation into the mechanisms of vulnerability and resilience in early life.

Extensive research has documented associations between maternal IPV and adverse child outcomes, including issues with secure attachment (Zeanah et al., 1999; Barnett et al., 1999), externalizing behavior (Graham-Bermann & Levendosky, 1998; Herrenkohl & Russo, 2001), and altered infant brain development with evidence of changes in cortical and limbic regions implicated in emotion regulation (Hiscox et al., 2023; Howell et al., 2016). However, fewer studies have examined IPV's impact on dyadic emotion co-regulation in infancy within a large-scale, heterogeneous sample. Furthermore, maternal social support during pregnancy has proven to significantly shape child socio-emotional outcomes. Systematic reviews suggest that social support may act as a moderator, weakening the strength of the association between prenatal adversity and child behavioral difficulties (Lähdepuro et al., 2023; Koutra et al., 2023). These findings posit social support as a critical resilience factor, yet few studies have directly tested its role in parent-child emotion co-regulation during infancy.

The present study aims to address these gaps by leveraging data from the HEALTHY Brain and Child Development (HBCD) study, a large-scale initiative following families from pregnancy through early childhood across the U.S. IPV exposure will be assessed using the eHITS measure, while maternal social support during pregnancy will be captured with the PROMIS Emotional Support 4a questionnaire. Parent-child emotion co-regulation will be measured when the infant is 3–9 months, using the Emotion Regulation in Context Assessment (ERICA), which provides a structured paradigm to quantify bidirectional regulation between mother and infant.

We hypothesize that (1) higher levels of IPV during pregnancy will correlate with lower ERICA scores, reflecting impaired dyadic co-regulation, and (2) maternal social support during pregnancy will buffer these effects, fostering resilience in parent-child interactions. Analyses will draw on the first HBCD data release ($N = 1,420$), which includes demographic and psychosocial measures, and the forthcoming second release in February 2026, which will add ERICA data and expand the sample size. Structural equation modeling will be used to test associations between prenatal IPV and ERICA scores, with maternal social support specified as a moderator buffering these effects. Infant age, sex, and study site will be included as covariates. Findings will inform intervention strategies aimed at strengthening caregiver-infant co-regulation in the context of adversity, advancing both basic developmental psychology research and public health application.



O6.4 - The effects of prenatal exposure to sociocultural stressors on HPA-axis development in infants

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Details

Objective: Racial/ethnic disparities exist in long-term physical and mental health outcomes. Exposure to sociocultural stressors, such as cultural adaptation (acculturative stress) and perceived discrimination, has been suggested to contribute to this phenomenon, but the mechanism and timing by which this occurs is not well understood. Alterations in the functioning of the hypothalamic-pituitary-adrenal (HPA) have been linked to later health outcomes, and the development of the HPA axis begins in the prenatal period. Thus, prenatal glucocorticoids (e.g., cortisol) are a widely proposed prenatal programming mechanism, yet few studies directly measure fetal cortisol and link it to outcomes later in development. Neonatal hair provides a non-invasive method to assess fetal cortisol. The current study tests the association between prenatal exposure to sociocultural stressors (discrimination and acculturative stress), fetal cortisol, and infant response to stress (biological and behavioral).

Methods: Pregnant individuals of Mexican descent ($N = 73$) and their neonates (50.7 % female) participated in the study between 2017 and 2020. Participants reported on their exposure to experiences of perceived discrimination (Discrimination Stress Scale), acculturative stress (Societal, Attitudinal, Familial and Environmental Acculturative Stress Scale). Neonatal hair samples were collected shortly after birth (Median_{days}=13.0, IQR_{days}=11–18) and analyzed for cortisol. At 6 months old, infants underwent a Still Face Procedure as an experimental stressor. Acute salivary cortisol response (area under the curve; AUCg) to the Still Face was collected as well as behavior scored for negative affect (vocalizations).

Results: Neonates who experienced higher exposure to maternal discrimination, but not acculturative stress, during pregnancy had higher hair cortisol than those exposed to lower discrimination ($F(1,70) = 3.78, p = .03$). Postnatal, but not prenatal, experiences of perceived discrimination were also associated with infant negative affect ($B(SE) = 1.140 (0.357), p = 0.002, CI[-1.848, -0.431]$). Neither pre- nor post-natal discrimination was associated with infant AUCg. However, cortisol levels in neonatal hair were correlated with infant acute salivary cortisol response (AUCg; $r = .265, p = .030$). Acculturative stress was not associated with infant measures.

Conclusions: Fetal and infant exposure to maternal perceived discrimination is a salient risk factor and has lasting effects on HPA-axis development. Future work should determine if these effects last into later childhood and beyond, with consequences for health disparities.

O6.5 - Mother-infant cortisol covariation across the day

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Details



Infants are born with immature regulatory systems and thus are reliant on their caregivers to regulate their emotions, physiology, and behavior (Bowlby, 1969). One physiological system known to be heavily influenced by caregivers' external regulation is the hypothalamic-pituitary-adrenal (HPA) axis, with the end product cortisol. In addition to its stress-activated release, cortisol is also released in a predictable circadian, daily pattern consisting of higher levels in the morning and lower levels at night (Smyth et al., 2013). A healthy diurnal pattern prepares the body for an activated, energized day and a restful night's sleep (e.g., O'Byrne et al., 2021). Conversely, experiencing chronic or extreme stress has the potential to disrupt (i.e., flatten) diurnal rhythms, which has been related to a host of mental and physical impairments. However, very few studies have examined the cortisol diurnal rhythm during infancy, nor have they examined maternal external regulation of this rhythm. We aim to fill this gap.

In a sample ($N = 97$) of 8-month-old Mexican origin infants ($M = 8.53$; $SD = 3.19$) and a sample ($N = 87$) of 18-month-old Mexican origin toddlers ($M = 19.00$; $SD = 3.36$), we aim to examine the bidirectional covariation of mother and infant salivary cortisol across the day. Further, we aim to examine within-dyad variation in maternal stress as a potential moderator of mother-infant diurnal cortisol covariation. Using an Ecological Momentary Assessment design, mothers collected their own and their infant's salivary cortisol three times a day (at wake, evening, and infant bed), for three days. Analyses employed a multilevel modeling approach to examine moment-to-moment cortisol covariation across the day.

Results from the 8-month sample indicated infants exhibited a typical cortisol diurnal rhythm, with significantly higher cortisol levels in the morning ($M = 0.43$ ug/dl; $SD = 0.36$) than at evening ($M = 0.26$ ug/dl, $SD = 0.44$; $t = -20.11$, $p < .001$) and at bed ($M = 0.23$ ug/dl, $SD = 0.48$; $t = -29.45$, $p < .001$). After accounting for the diurnal rhythm, mother and infant cortisol levels significantly covaried across the day, with maternal cortisol significantly predicting infant cortisol ($\beta = 0.21$, $p < .001$) and infant cortisol significantly predicting maternal cortisol ($\beta = 0.23$, $p < .001$). Interestingly, this covariation did not vary by time of day, meaning that mother and infant cortisol was just as strongly associated at first waking as when the infant went to bed. If accepted, this presentation will also include analyses from the 18-month-old sample, as well as maternal stress as a moderator of co-regulation.

In line with the conference theme of "Infancy in Context", these analyses represent the first to document the infant cortisol diurnal rhythm in the context of mothers' physiological and psychological experiences. Further, taking an emic, or within-culture approach, these analyses examine mother-infant cortisol co-regulation within a Mexican origin cultural context. These findings highlight the potential of maternal external co-regulation in the expression of infant cortisol diurnal rhythms.

O6.6 - Maternal distress and caregiving associations with infants' real-time parasympathetic regulation at home

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[Details](#)



Infants of mothers with anxiety and depression can show dysregulated parasympathetic activity, reflected in atypical respiratory sinus arrhythmia (RSA) patterns that compromise their capacity to manage stress and develop socio-emotional resilience (Conradt & Ablow, 2010). Maternal distress has been linked to diminished infant RSA withdrawal—the adaptive decrease in RSA supporting physiological engagement during distress—and to reduced maternal sensitivity (Cole et al., 2017; Edwards et al., 2012). Thus, it is essential to understand how maternal distress affects behaviors used to soothe infants at home, where most caregiving and regulatory learning occur. Distress in mothers may interfere with their approaching or picking up their infants (Bornstein et al., 2017). Yet, most published work on maternal regulation has relied on lab-based standardized distress-eliciting tasks that restrict physical contact and proximity, making it unclear whether natural variation in these behaviors influences the association between maternal distress and infant physiological regulation. To address this knowledge gap, the current work examines the association between moment-to-moment regulatory behaviors and infant physiological regulation during spontaneously occurring distress at home. **Methods:** Mother-infant dyads ($n=87$) were recruited as part of a broader study to measure behavior in the home. Each dyad recorded up to 72 hours of synchronized audio (LENA) and heart rate (Movisense Mov3) data across one week; 38 dyads had complete behavioral annotation, audio, ECG, and mental health data. Of these, 17 dyads were included in present analyses based on data usability. Infants averaged 3.9 months ($SD=2.2$, range=0.9-10.4). RAs coded 207 infant distress episodes ($ICC=.85$), maternal sensitivity ($\kappa=.85$), and proximity ($\kappa=.60$) from LENA audio. Holding was detected using a validated accelerometer-based algorithm ($F1=.83$; Yao et al., 2019). Maternal distress (anxiety and depression) symptoms were measured daily using the PHQ-4 ($M=3$, range=0–10), and mothers were classified as higher-symptom (≥ 3 ; $n=7$) or lower-symptom (< 3 ; $n=10$). To examine infant parasympathetic regulation, RSA time series were derived using a 15s sliding window at 5 Hz (Abney et al., 2021) and time-locked to 60 seconds pre-and post-distress onset. RSA withdrawal was calculated as change from pre-distress baseline to RSA values across this analysis window. We examined two primary hypotheses: higher maternal distress would be associated with (1) blunted infant RSA withdrawal, and (2) reduced frequency of caregiving behaviors. **Results:** Infants of higher-symptom mothers showed more blunted RSA withdrawal following distress. However, rates of sensitivity, proximity, and holding did not differ significantly by symptom group ($p>.05$). Post-hoc analyses examined whether within-person fluctuations in caregiving behaviors (e.g., occasions when mothers were holding, sensitive, or proximal more than their own average) were differentially associated with infant RSA withdrawal depending on symptom severity. More sensitivity, proximity, and holding were each associated with more adaptive RSA withdrawal within low-symptom dyads, but these behaviors did not confer the same physiological benefit in higher-symptom dyads. Together, these findings suggest that maternal distress is associated with infants' reduced physiological flexibility and diminished regulatory impact of otherwise adaptive caregiving behaviors in everyday home environments.

O6.7 - Investigating the molecular mechanisms of biological embedding and intergenerational transmission of conflict and displacement trauma: Early findings from a prenatal cohort study in the Rohingya refugee context in Bangladesh

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Details

Maternal trauma and adversity, past or present, can shape offspring development through “fetal programming” of later health and disease. Evidence implicates several regulatory pathways, including HPA-axis and immune processes, and points to infant DNA methylation as an early marker of trauma transmission (Glover et al., 2018; O'Donnell & Meaney, 2017; Moore et al., 2022; Van den Bergh et al., 2020).

There is a notable lack of studies that (a) take a comprehensive, multi-system approach to elucidating molecular processes and cellular mechanisms, and (b) examine the biological embedding and intergenerational transmission of pre-pregnancy conflict- and displacement-related trauma in populations residing in low- and middle-income countries.

Drawing on an ongoing prenatal cohort of Rohingya refugee and host-communities in Cox's Bazar, Bangladesh, we applied a data-independent acquisition (DIA) LC-MS/MS workflow to quantify thousands of proteins in saliva samples (stored at -80°C) collected from 350 pregnant women at recruitment and from their infants at 1 month postpartum. To date, we have conducted functional enrichment analyses using the “Proteins with Value Ranks” STRING algorithm, based on $\log_2$ -fold-change differences between pregnant women in the highest vs. lowest quartiles of PTSD symptom scores, and between their infants at 1 month.

Early findings suggest stress-linked programming of molecular pathways through which maternal trauma may become biologically embedded and transmitted intergenerationally. Between high- and low-PTSD pregnant women we see differences in key cellular stress- and damage-response processes. Specifically, we observe down-regulation of pathways related to genomic surveillance, oxidative-stress and senescence signaling, and epigenetic repression (methylation). This profile may reflect a stress-adapted “low-alarm” state in which oxidative damage accumulates while damage goes insufficiently addressed.

Among infants of high-scoring mothers, we find up-regulation of ribosome-mediated protein synthesis, alongside down-regulation of pathways involved in gas transport (central to cellular energy metabolism and reactive oxygen species clearance) and inflammatory signaling (particularly within the IL-1 family). In other words, infants of high-PTSD mothers show reduced antioxidant capacity but elevated protein synthesis, indicative of increased oxidative stress.

We will extend these analyses to: (1) examine functional enrichment patterns among mothers and infants exposed to high vs. low levels of pre-pregnancy war- and displacement-related trauma (rather than PTSD symptoms); (2) identify factors that moderate associations between trauma exposure (or PTSD) and enrichment pathways in pregnant women (e.g., age); and (3) assess factors that moderate links between maternal trauma exposure (or PTSD) and infant enrichment pathways (e.g., gestational age at birth).

We hypothesize that associations between trauma exposure and enriched pathways will be weaker than those observed with PTSD symptoms, and that PTSD severity will partially mediate these associations. We further expect maternal age ($M = 20.9$; range: 13–39) to affect the salivary



proteome. For infants, we hypothesize that gestational age at birth and maternal age will moderate enrichment patterns.

As forced displacement continues to rise globally, this work will help fill critical gaps in understanding the intergenerational impacts of conflict- and displacement-related trauma.

06.8 - Profiles of temperament in early infancy: Predictive associations with cognitive development and maternal behaviors as mediators

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Details

Past studies have linked infant and child temperament to different aspects of cognitive development (e.g., Lemelin et al., 2006; Vlaeminck et al., 2020), but this relationship is still not fully understood. Most of the existing research has relied on a variable-oriented approach (Ermanni & Bell, 2025; Gobeil-Bourdeau et al., 2022) and few studies have focused on the potential mediators in the relation between temperament traits and indicators of cognitive development. The current study had three main objectives: 1- to identify early temperament profiles in a general population sample of 6-month-old infants; 2- to examine the relationship between profile membership, maternal behaviors at 12 months and infant cognitive development at 24 months; and 3- to examine the mediating role of maternal behaviors in the relation between infant temperament and cognitive development. The sample consisted of 514 French-speaking mother-child dyads (58% boys) from the province of Quebec, Canada. Recruitment was conducted through social media and regional daycare centers. Mothers' mean age was 29.54 at study inception (SD = 3.69) and median annual family income was between 100-150KCAN\$. When their infant was 6 months old (T1) mothers completed the *Infant Behavior Questionnaire-Revised-Short Form* (IBQ-R-Short Form, Putnam et al., 2014). At 12 months, six different maternal behaviors were assessed using the *Comprehensive Parenting Behavior Questionnaire 1 year* (CPBQ-1, Majdandzic et al., 2016): challenging behavior, overinvolvement, warmth, negativity, and negative and positive discipline. Infant cognitive development was estimated at 24 months via the standardized score derived from the *Parent Report of Children's Abilities-Revised* (PARCA-R, Johnson et al., 2019). Latent profile analysis revealed four distinct temperament profiles among the infants: 1) *Moderate Reactivity and Regulation* (37.67%); 2) *High Positivity-High Regulation* (28.64%); 3) *High Negativity-Low Regulation* (13.60%); and 4) *High Positivity and Negativity* (20.09%). Analyses of variance showed differences between profiles for all but one maternal behavior (overinvolvement). Mediation models were then tested in Mplus 8.10 (Muthén & Muthén, 1998–2023) using structural equation modeling (SEM). Path models were used with ML estimator and Full Information Maximum Likelihood (FIML) methodology for dealing with missing data. Separate models were tested for each potential mediator. Mediation modeling was conducted in two steps. First, a model examining the direct effects of the temperament profiles on cognitive development was tested, while controlling for child sex (objective 2). Second, potential mediators (maternal behaviors) were included in the model to explore whether they could explain the previously observed associations (objective 3). Results first indicated mean differences in cognitive development according to temperament



profiles, with children in profiles 2 and 4 showing higher and those from profile 3 showing lower PARCA-R scores. Results also showed that three maternal behaviors (challenging behavior, warmth, positive discipline) partially mediated the relationships between temperament profiles and child cognitive development. This person-oriented study contributes to a better understanding of the nature and expression of temperament in infancy and its role regarding early child cognitive development, in association with different dimensions of the family environment, namely, the quality of maternal behaviors.

O6.9 - Early mother-infant behavioral synchrony predicts later chronic cortisol accumulation in infancy

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Details

Early caregiver–infant interactions form the basis of emotional, cognitive, and social development, and are characterized by biobehavioral coordination between the dyad. Behavioral synchrony predicts socio-emotional and cognitive outcomes and relates to physiological regulation, including more adaptive cortisol functioning later in childhood. However, most research has focused on salivary cortisol, which informs on HPA axis reactivity and short-term fluctuations, but does not reflect prolonged exposure to elevated cortisol. Chronic cortisol elevation has been associated with adverse outcomes in health and well-being throughout development. Hair cortisol concentration (HCC) provides a robust indicator of cumulative cortisol exposure over time. However, no studies to date have examined how maternal chronic cortisol levels and behavioral synchrony jointly contribute to infant HCC, despite theoretical emphasis on both biological and relational pathways to stress regulation.

Aims: This study investigated how maternal HCC and mother-infant behavioral synchrony relate to infants' hair cortisol accumulation from 9 to 12 months.

Methods: Seventy-four mother-infant dyads visited the laboratory when infants were 6, 10, and 12 months old. Only data from first and last visits were used in the present study. Behavioral synchrony was assessed using 3-minute video-recorded mother-infant interactions at 6 months in which mothers were instructed to teach their infants to play with a toy that is challenging for their age. Synchrony was coded using the Coding Interactive Behavior (CIB) system, which includes 44 Likert scales for mother-infant behaviors. Three constructs were obtained from averaging CIB scales: maternal sensitivity (e.g., maternal gaze, positive affect, affective touch), intrusiveness (e.g., maternal forcing, overriding) and dyadic reciprocity (e.g., dyadic reciprocity, interaction fluency). At the 12-month visit, 3-cm of hair samples (reflecting prior 3 months of cortisol accumulation) were collected from both mothers and infants.

Results: The linear regression analysis explained 21% of the variance in infant HCC. Maternal HCC positively predicted infant HCC ($\beta = 0.23$; $p = .034$), in line with previous studies showing mother-infant cortisol concordance. Behavioral synchrony indicators also predicted infant cortisol accumulation, in the following direction: a) higher maternal sensitivity predicted lower infant HCC ($\beta = -0.51$; $p = .002$); b) higher intrusiveness predicted higher infant HCC ($\beta = 0.27$; $p = .038$); and c) dyadic reciprocity was marginally significant in predicting increased infant HCC ($\beta = 0.34$; $p = .052$).



Including the interaction terms between CIB constructs and maternal HCC in the model yielded non-significant interaction effects and reduced model fit, suggesting that behavioral synchrony did not moderate the mother-infant cortisol relationship. Although previous studies have suggested caregiving (e.g., maternal sensitivity and responsiveness) as moderator of the association between maternal and infant HCC, our findings highlight behavioral synchrony as an independent predictor of infants' chronic cortisol accumulation.

Conclusions: Both maternal HCC and earlier mother-infant synchrony in a challenging task contributed to explain infants' stress physiology, predicting cortisol accumulation at 12 months. These findings provide novel evidence linking relational processes and chronic stress biomarkers in infancy, underscoring behavioral synchrony as a potential target for early intervention.

06.10 - Maternal mind-mindedness and sensitivity as predictors of mothers' touch behaviors toward their 6-month-old infants

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Details

Introduction: Maternal Mind-Mindedness (MM - ability to interact with the infant considering the mental states that underlie their behavior) and sensitivity (ability to appropriately interpret and promptly respond to infants' signals) are two well-known markers of mother-infant interaction quality. More recently, researchers are increasingly interested in characterizing maternal tactile behavior. A previous study by Crucianelli et al (2019) found that MM predicted specific maternal touch patterns at infant age 12 months. However, no study has addressed the predictive role of both maternal MM and sensitivity in mother's touch patterns.

Aim: To analyze whether maternal MM (attuned and non-attuned comments) and sensitivity would predict maternal touch behaviors (affectionate and intrusive).

Methods: Ninety-five mother–infant dyads from the Sao Paulo metropolitan area (Brazil) were assessed when the infants were 6 months old. Maternal mind-mindedness, sensitivity and touch behaviors were coded from 9-minute video-recordings of mother-infant interactions. For MM we used the Brazilian Portuguese version of the coding manual, and for maternal sensitivity, the Ainsworth Maternal Sensitivity Scale. Maternal touch frequency and duration were coded according to a scheme developed by our team into one of eight mutually exclusive categories: 1) Affectionate; 2) Static; 3) Playful/Stimulating; 4) Instrumental; 5) Incidental; 6) Attentional Directing; 7) Regulatory; 8) Intrusive/Negative. For this study, and in line with most of the literature on the topic, only affectionate and intrusive touch categories were considered. Generalized Linear Models (GLM) with poisson distribution were built having maternal affectionate and intrusive touch (duration and frequency) as outcomes and maternal MM and sensitivity as predictors.



Results: The model for affectionate touch duration indicated that higher maternal sensitivity ($\text{Exp}(\beta)=1.056$; $p=.008$) and a greater number of attuned comments ($\text{Exp}(\beta)=1.014$; $p<.001$) predicted longer duration ($D^2/R^2=0.045$; $p<.001$) of affectionate touch. No significant associations were found for affectionate touch frequency. Regarding maternal intrusive touch duration, the model ($D^2/R^2=0.122$; $p<.001$) showed that lower maternal sensitivity ($\text{Exp}(\beta)=0.847$; $p<.001$) and more non-attuned comments ($\text{Exp}(\beta)=1.046$; $p<.001$) were associated with longer durations of intrusive touch. For intrusive touch frequency, the model ($D^2/R^2=0.107$; $p<.001$) showed that lower maternal sensitivity ($\text{Exp}(\beta)=0.857$; $p<.001$) and more non-attuned comments ($\text{Exp}(\beta)=1.036$; $p=.016$) predicted higher frequencies of intrusive touch. No associations were found between maternal intrusive touch (duration or frequency) and the proportion of attuned comments.

Conclusion: Our findings suggest that maternal sensitivity and attunement of mind-related comments are predictive of mothers' ability to provide more positive tactile stimulation when interacting with their infants. In contrast, the opposite pattern emerged for intrusive touch. Our work confirms and expands the results by Crucianelli et al. by highlighting a role of both attuned and non-attuned comments, along with sensitivity, on affectionate and intrusive maternal touch at infant age 6 months.

Oral Session 7 – Motor and Sensorimotor Development

07.1 - Little feet, big beats: investigating auditory-motor entrainment in childhood

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Details

Auditory–motor entrainment, the spontaneous alignment of movement with rhythmic sound, reflects a deep interaction between auditory and motor systems. This process is observed when rhythmic auditory stimuli, such as metronome clicks, trigger synchronized motor responses, suggesting an auditory–motor coupling that operates beyond conscious, volitional control (Thaut, 2015). Although such entrainment is present in adult life, the developmental progression from infancy into the preschool years remains poorly understood. Recent work by Schmuckler & Paolozza (2023) showed that infants between 14 to 24 months of age adjust their gait to a single faster tempo, indicating an early sensitivity to rhythmic structure. However, it is not yet known whether young children can modulate their gait across finer gradations of tempo or whether developmental limits constrain how far external pacing can pull their gait from its intrinsic rhythm.

The present study focuses on 3-year-olds, assessing whether they spontaneously modulate gait when exposed to systematic changes in auditory tempo. Children walked across a pressure-sensitive walkway while hearing metronome beats set to 75%, 87.5%, 100%, 112.5%, and 125% of their baseline cadence, with no instruction to synchronize. Data from 4-year-olds, 5-year-olds, and adults were included as developmental comparison groups to contextualize early performance.

Three-year-olds showed emerging but clearly constrained entrainment. They reliably increased walking cadence in response to faster tempos and demonstrated some slowing at the moderately



slow 87.5% tempo. However, at the 75% tempo, the slowest condition, they showed little to no adjustment, frequently reverting toward their natural walking pace. This pattern suggests that while 3-year-olds can modulate gait when tempo changes are relatively small, there are limits to how far external pacing can pull their movement away from their intrinsic rhythm, particularly when a substantial slowing is required.

Developmental comparisons revealed a trajectory of refinement: four-year-olds displayed more systematic modulation than three-year-olds, while five-year-olds approached adult-like patterns of tempo-dependent changes in cadence and velocity. Adults exhibited the most precise and consistent modulation across all tempos.

Across groups, alignment decreased at extreme tempos, with participants tending to have faster step-to-beat alignment at the slow tempos and slower step-to-beat alignment at the fast tempos - patterns consistent with a pull toward intrinsic rhythmic preferences under challenging pacing.

These findings bridge infancy and early childhood research, demonstrating that gait-based auditory-motor entrainment is present by age three but remains limited in scope. Future work will examine how biomechanical load and post-cue continuation influence rhythmic stability and the durability of tempo adjustments during early development.

07.2 - Going up and down: Functional walking on slopes and stairs

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Details

Babies typically take their first walking steps on flat, open ground. But the greater environment is much more varied. Functional walking requires navigating elevations and other obstacles that pose different challenges for strength, balance control, and coordination. Walking up a slope or stair, for example, requires sufficient strength to hoist the body upward against the pull of gravity, whereas walking down requires sufficient balance control to curb forward momentum. Walking over a slope requires coordination of multiple steps, whereas walking over a stair requires only a single, controlled step. For adults, walking up a slope or stair is more strenuous than walking down, but walking down poses greater risk from falling; and coordinating a series of steps rather than a single step makes walking over a slope more challenging than a stair. What about infants who are just learning to walk?

We used a within-subjects design to test whether infants ($N = 52$) perceive different affordances for walking up and down an adjustable slope (0° - 40° in 1° increments) and stair (0 cm-30 cm in 1-cm increments), and whether the accuracy of infants' perception depends on direction of travel, obstacle type, and increment size. We held age constant ($M = 14.33$ months, range = 14.06 to 14.93 months), but allowed walking skill and experience to vary ($M = 2.17$ months of experience, range = 7 days to 4.55 months). Using a psychophysical procedure, we estimated each infant's walking *threshold* (increment at which the probability of walking successfully = 50%) in each condition (tested over two days). Then, we tested the accuracy of infants' perception of affordances at *minimum* increments (0° - 4° slopes, 0-2 cm drop-offs), *easy* increments (> 1 SD smaller than



threshold), *threshold* increments (± 1 SD around threshold) *impossible* increments (> 1 SD larger than threshold), and *maximum* increments (40° slope, 30-cm stair). For each trial, we determined whether infants attempted to walk and, if they attempted, whether they walked successfully.

Preliminary group data from 44 infants confirmed successful walking at the minimum and easy increments in each condition, but not at the impossible and maximum increments (Figure 1). Based on attempts to walk, infants indeed perceived affordances. In each condition, infants were sensitive to increment size—attempts to walk decreased at threshold and larger increments. However, the accuracy of infants' perception depended on whether babies were going up or down and whether walking over slopes or stairs. On slopes, infants were more accurate for going down than up (Figure 2A), but on stairs, infants were equally accurate in both directions (Figure 2B). When walking down, infants were more accurate for slopes than stairs (Figure 2C), but when walking up, infants were more accurate for stairs than slopes (Figure 2D).

Findings suggest that infants perceive affordances for walking, but their perceptions depend on multiple factors. In ongoing analyses, we will test whether individual differences in infant walking skill and experience determine the accuracy of their perceptual judgments and whether exploratory behaviors that generate information about affordances explain differences across conditions.

07.3 - Frequent, scalable and global use of “intelligent onesies” to quantify newborns' spontaneous movements in natural settings

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Details

Spontaneous general movements in the first months of life are a sensitive behavioural marker of early brain function and risk for conditions such as cerebral palsy, yet current General Movements Assessment (GMA) protocols require expert video coding in clinics and are difficult to deliver frequently at scale. We present the BabyGrow “intelligent onesie” system, which embeds inertial sensors into infant clothing and couples them with a Raspberry-Pi hub and secure remote monitoring, enabling high-frequency, home-based quantification of newborn movements (Figure 1).

Fifty-four families were recruited to complete weekly home recordings from birth to 34 weeks. Each kit contained an intelligent onesie with eight IMUs (accelerometer and gyroscope), a multi-port charger, Raspberry-Pi and touchscreen for initial Wi-Fi setup. Once plugged in, the Pi automatically connected to pre-registered sensors and streamed tri-axial accelerometry and angular velocity at 25 Hz, with remote status monitoring and troubleshooting via PiTunnel (Figure 1). Thirty-nine families contributed data (429 sessions; $M = 11.0$ per infant). Signals were filtered, time-aligned, segmented into discrete “movement bouts,” and parameterised with kinematic features (velocity, acceleration, range, symmetry, entropy, and rotational components). A stacked autoencoder learned low-dimensional representations of bouts; density-based clustering identified cross-limb movement patterns, and per-session cluster probabilities were fed into a feed-forward artificial



neural network (ANN) to predict Vineland social and communication scores at 3 and 7 months (Figure 2).

Engagement was heterogeneous: 28% of families never recorded and a further 13% discontinued after a few attempts, typically citing setup burden and postpartum fatigue. Nonetheless, 17 families (31% of those recruited) completed the longitudinal protocol. Across 39 participating families, 57.6% of sessions yielded full eight-sensor coverage; remaining sessions contained partial data largely due to transient Bluetooth dropouts that were correctable by interpolation. The machine-learning pipeline isolated 7,210 movement bouts and discovered 10 robust patterns of cross-limb movement. Cluster-based features predicted Vineland outcomes with high accuracy: ANN predictions correlated strongly with observed scores across ages and domains ($r = .78$, $p < .01$; Figure 2), suggesting that these movement patterns function as early digital biomarkers of socio-communication skills.

This work demonstrates the feasibility of frequent, caregiver-led recording of newborn spontaneous movements using intelligent garments and remote data infrastructure suitable for large-scale deployment. Despite notable attrition, families who continued found the protocol acceptable, and the sensing pipeline produced sufficiently reliable data for sophisticated pattern-recognition models. Crucially, spontaneous movement patterns captured in the first months of life already contain rich information about later socio-communication skills, highlighting the promise of sensor-based GMA as an early, non-invasive screening tool complementing clinical observation. Ongoing refinements—simplifying setup, streamlining charging and calibration, translating materials, and integrating additional modalities such as automated video analysis—should further reduce burden and support deployment in more diverse, higher-risk populations. Together, the BabyGrow workflow and findings point toward scalable, global infrastructures for early neurodevelopmental monitoring, risk stratification, and personalised intervention.

07.4 - The effects of difficult terrain on infants' attention and motor planning while walking outdoors

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Details

We rely on visual information while walking to avoid obstacles, navigate, maintain balance, and more. Despite its importance, how infants and children use vision while walking has been minimally studied. Laboratory experiments provide a few insights: infants often look at obstacles while stepping over them and gradually learn how to use vision to modify their steps in anticipation of an obstacle (not adult-like until 8yo; Franchak et al., 2010, 2011; Mowbray et al., 2019, 2020). During natural walking, adults flexibly adapt their gaze and gait in response to the environment (Matthis et al., 2018). On rough terrains, adults primarily look at the ground close to their bodies, slow down, and take shorter steps. To be useful in action planning, visual information needs to come at a specific time. For adults, information must be acquired at least 2 steps ahead to be most energetically efficient, but walkers often prefer to look a roughly constant time ahead – planned movements are preferentially guided by information acquired <1.5 s in advance. To fully understand how infants use vision to guide their still-developing walking, they need to be observed in natural



environments.

2-year-olds (N=7, average of 16mo walking experience) wore head-mounted eye trackers while walking outdoors on three terrains: a Sidewalk, loose Stones, and a narrow Wall (Fig.1). Infants were shown the paths to walk on and walked alongside an adult, but no other instructions were given. The presented data comes from a larger dataset of children aged 2- to- 6yo.

To study action planning we analyzed two measures of visual attention: the type of information infants used to plan their steps (how far ahead they look on the path) and how much of that information they needed (the proportion of looks when gaze was on the path); and two measures of gait: average step length and average cadence. Deviations from normal gait can make action planning more difficult.

Infants' attention on the Sidewalk was very similar to adults': infants looked 3-4 steps ahead and only 32% of their looks were on the path. Infants' average cadence was 2.5 steps/second. This suggests that when infants look on the path, they may be preferentially looking ~1.5s in advance, the information decay rate of adults.

We then analyzed how infants' behavior changed on the challenging terrains (Fig.2). The Stones have higher motor uncertainty – if they place their foot on a wobbly foothold, they may need to make unpredictable micro-adjustments to maintain balance. On the Stones, infants are careful: requiring more visual information (76% of looks are on the path, $p<0.001$), decreasing step length and cadence by 10% (p 's=0.01), and looking closer to their bodies (2-3 steps ahead, $p<0.001$). Although it may be easy for children to plan ahead on the Wall since the path is flat, the cost of a misstep is high and balance is challenged in a different way. Infants do not change how far ahead they look on the path, nor their cadence. Nonetheless, infants primarily look at the path (69% of looks, $p<0.001$), perhaps in response to the higher risk and a deviation from normal gait (step length decreases 10%, $p=0.01$). Notably, the older children in our dataset looked closer to their bodies and modified their cadence and step length on the Wall.

Our results suggest that even infants use vision to plan actions in adult-like ways, taking into account both visual and motor uncertainty. Across all terrains, infants preferentially accessed information ~1.5s in advance and flexibly modified their behavior in response to the unique demands of a terrain. We will conclude by proposing developmental trajectories based on our full cross-sectional dataset.

07.5 - Changes in decision stability and information gathering in action planning throughout development

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Details

Humans have a remarkable ability to anticipate future task demands and select actions accordingly, and this action-planning skill emerges early in development but undergoes substantial refinement across childhood. How real-time perceptual, cognitive, and motor processes jointly



support this developmental change remains poorly understood. We examined stability, biases, and neural signatures of action planning in 3–5-year-olds ($n = 35$) and adults ($n = 28$) using a novel psychophysics-based tool-use paradigm that required participants to integrate both the orientation of a tool and the task goal, pounding a peg (using the hammer-head) and poking a button (using the hammer-handle), into their grip choice. Each of the two goals imposes opposite action demands: efficient hammering required a radial, and often non-habitual underhand, grip, whereas button-poking required an ulnar grip, that competes against a participants entrenched internal model of the proper use of the tool.

We recorded eye-tracking (ET), EEG, motion-tracking (MT), and video *simultaneously* to capture the real-time cascade from perception to cognition to action. Our psychophysics approach allowed us to quantify bias and decision stability at the individual level using the point of subjective equality (PSE; where 90° indicates no bias) and the slope (stability; where $<90^\circ$ indicates probabilistic grip choices) of the S-curve. For the peg task, children showed more bias towards habitual grips and less stable selection (PSE= 127° , Slope= 44°) compared to adults (PSE= 105° , Slope= 62°), indicating inconsistent and unrefined planning. For the button task, children tended to adopt a more inconsistent strategy with a stronger bias toward overhand grips (PSE= 134° , Slope= 33°) compared to the peg task. In both tasks, planning was unstable, children did not consistently select the same grip for the same angle and goal but more stable towards non-ambiguous angles (0° or 180°) with strong dependence on the goal. Analysis of the EEG data showed underhand grips consistently produced more negative amplitudes in readiness potential, a slow, negative-going electrical potential associated with action planning. This finding demonstrates how future task demands influence neural activity before movement, and how this influence changes with development. Analysis of grip trajectories showed high interindividual variability across a range of measures, and clear differences as a function of tool orientation. ET data showed, that earlier fixation on the hammer and the goal positively corresponded with less planning stability in children.

Taken together, our findings demonstrate how planning becomes less biased and more stable by adulthood. When demands are ambiguous, children are more likely than adults to inconsistently use habitual action. Combined analysis of simultaneous ET, EEG and MT data also suggests these developmental changes relate to developmental changes in real-time, continuous interplay between the perceptual, cognitive and motor systems.

O7.6 - Brain and sensorimotor functional connectivity and growth measurements in near-term and term-born neonates: an fNIRS study

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Details

Introduction & Objectives: Resting-state networks (RSNs), measured through functional connectivity (FC), are detectable at birth (Desrosiers et al., 2024), and their early organization has been linked to later neurodevelopmental outcomes (França et al., 2024). Neonatal growth, captured through anthropometric measures (AMs) such as birth weight, length, and head



circumference, is also associated with variability in early brain structure and connectivity (Bulgarelli et al., 2024). However, the normative relationship between growth at birth and FC patterns in healthy neonates remains unclear (Huang et al., 2024). This study aimed to examine how neonatal AMs relate to resting-state FC in healthy term and near-term infants. We hypothesized that deviations from average growth, including small or large size for gestational age, would be associated with altered FC patterns, reflecting potential nonlinear relationships between early growth and brain network organization.

Methods: Functional Near-Infrared Spectroscopy (fNIRS) was used to record resting-state cortical hemodynamic data and FC was calculated in 121 neonates (67 males, 12 small for gestational age infants, 13 large for gestational age infants, mean postnatal age = 25.6 hours, SD = 13.89, mean gestational age = 38.63 weeks, SD = 1.39, mean birth weight = 3211.21g, SD = 618.46, mean head circumference = 34.67 cm, SD = 2.50, mean length = 49.69 cm, SD = 3.62). We utilized a generalized linear model and linear mixed effects models to understand the relationship between FC and AMs, including birth weight for gestational-age z-score (BGZ), head-circumference for gestational-age z-score (HGZ) and the Ponderal Index (PI).

Results: Channel-wise comparative analysis demonstrated that BGZ (β range = -0.102 to -0.074, FDR-corrected $p < 0.005$) and the PI z-score (β range = -0.088 to -0.074, FDR-corrected $p < 0.001$) showed negative quadratic relationships with several inter- and intrahemispheric channel pairings. HGZ demonstrated positive quadratic relationships with several channel pairings (β range = 0.051 to 0.074, FDR-corrected $p < 0.001$).

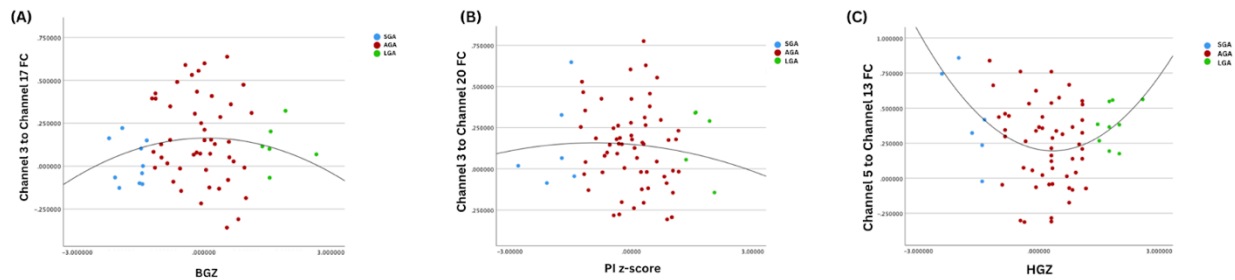


Fig. 1. Non-linear effects of BGZ, PI and HGZ on channel-wise FC in 3 example channel pairs. (A) Negative quadratic effects of BGZ on channel-wise FC between channels 3 and 17. (B) Negative quadratic effects of PI z-score on channel-wise FC between channels 3 and 20. (C) Positive quadratic effects of HGZ on channel-wise FC between channels 5 to 13.

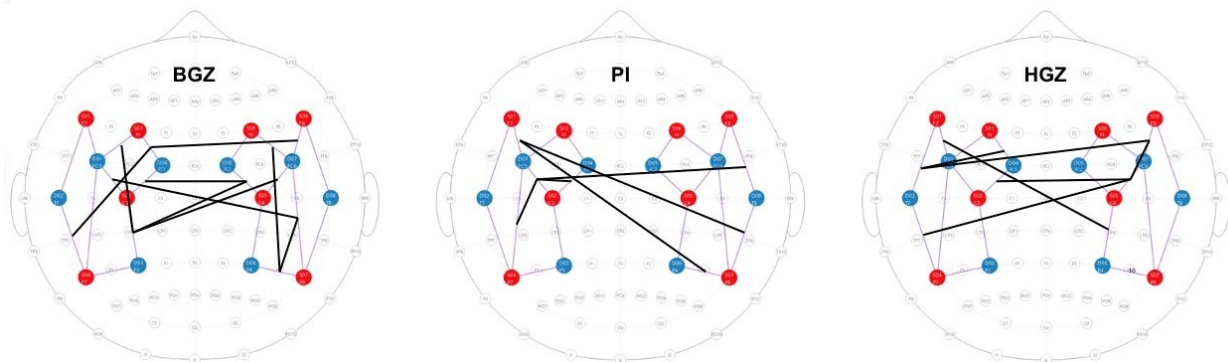


Fig. 2. Locations of significant FC-AM associations across the fNIRS channels. After FDR correction, significant channel-wise associations across all AMs were observed in both inter- and intrahemispheric regions, indicating FC variation across AM ranges that involves sensorimotor and temporal cortices.

Conclusion: These findings indicate that AMs are non-linearly associated with resting-state FC across several channels in the first days of life. The present study highlights the importance of considerations for early growth and brain network organization when studying early development.

07.7 - Multimodal imaging of somatosensory processing infants

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Details

Introduction: Sensory processing is one of the earliest-developing functions of the infant brain and forms a critical foundation for later cognitive and social development. Atypical sensory responses are also among the earliest markers of neurodevelopmental conditions such as autism. However, the underlying neural and metabolic mechanisms of early sensory processing remain poorly understood. This study combines broadband near-infrared spectroscopy (bNIRS), electroencephalography (EEG), and magnetic resonance spectroscopy (MRS) to investigate tactile-evoked brain responses in typically developing infants, with the aim of characterising early neurovascular and neurometabolic coupling.

Methods: Using an in-house bNIRS system developed at UCL, we measured changes in oxyhaemoglobin ($\Delta[\text{HbO}_2]$), deoxyhaemoglobin ($\Delta[\text{HHb}]$), and oxidised cytochrome-c-oxidase ($\Delta[\text{oxCCO}]$)—a marker of cellular energy metabolism—in response to passive vibrotactile stimulation of the right hand. Each stimulation block consisted of eight 200 ms pulses with jittered rest intervals (500–1000 ms), repeated over 10 blocks, with 12 seconds of rest between blocks. Infants either watched a cartoon or engaged quietly with a researcher. bNIRS optodes (4 sources and 8 detectors) were placed over the left primary somatosensory cortex, and concurrent EEG recordings were acquired to measure stimulus-evoked electrical activity. Additionally, MRS was used to acquire metabolic profiles from a voxel placed over the same cortical region.



Results: Preliminary bNIRS data revealed clear changes in haemodynamic and metabolic responses (HbO₂, HHb, and oxCCO) following tactile stimulation (Fig 1b).

Conclusion: Combined with EEG and MRS, this multimodal approach enables a comprehensive investigation of neurovascular and neurometabolic coupling in early sensory development. These findings may provide critical insights into typical developmental trajectories and inform future studies of early biomarkers in infants at elevated risk for neurodevelopmental disorders.

07.8 - Infant-caregiver motor synchrony differs across the transition to independent walking

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Details

Behavioral synchrony is fundamental to early social interactions, and synchrony arises across multiple domains: facial expressions, vocalizations, and locomotion. In a laboratory investigation of walking infants, caregivers' and infants' paths through the playroom showed high similarity (Hoch et al., 2021). Although both infants and caregivers sometimes led and sometimes followed each other's paths, caregivers were more likely to follow, suggesting that caregiver responsiveness to infant movement helped establish synchrony. However, because past work focused on only walking infants (and their walking paths), it is unknown how motor synchrony differs after infants learn to walk. Caregivers might respond to walking infants' transitions to standing by also standing up, preparing to follow if walkers decide to dash away. In contrast, a non-walker's caregiver might be less responsive because non-walkers can only stand still or cruise a short distance along a piece of furniture. We tested whether the likelihood of caregiver standing increases when 11- to 14-month-old infants switch to a standing posture, comparing whether caregivers of walking vs. non-walking infants differ in their responsiveness while controlling for infants' age.

Unlike past work that recorded play sessions in the lab, we used a novel sensing method to continuously detect infants' and caregivers' posture in context across an entire day in the home. We measured transitions to a standing position using machine-learning models that detected posture from inertial sensors worn by infants and caregivers. Standing detection in infant and caregiver posture models had strong agreement with human codes (> 90%). Here, we report data from 64 sessions containing $M = 6.1$ hours ($SD = 2.3$) of awake recording time per session (nap times were excluded). We found every time that infants switched from a sitting, prone, or supine position to a standing position based on sensor time series. Then, we recorded caregivers' standing state ± 4 min relative to the infants' standing transition (Figure 1): Caregivers of walking infants (red curve) were significantly more likely to stand following infant standing events, but standing in caregivers of non-walkers (blue curve) was not synchronized. These results were confirmed by a generalized linear mixed-effect model predicting caregiver standing vs. not standing outcomes from 1 minute before to 1 minute following the infant standing transition, which revealed a significant time x skill group (non-walker vs. walker) interaction while controlling for infants' age.

The current study is novel in capturing behavioral synchrony in infant-caregiver motor behavior in the context of home life, extending prior work that observed synchrony in laboratory play. The results highlight a new dimension of experiential change that is related to motor development.



Increased synchrony among walking dyads means that walking infants are exposed to different social contingencies. Most likely, the emergence of infant walking prompts a change in caregiver responsiveness: Whereas a standing non-walker cannot go far, a standing walker might be moments away from leaving caregivers' supervision.

07.9 - Development of flexibility: How infants cope with sloping ground and sloping shoes

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Details

Behavioral flexibility—tailoring motor behavior to variations in the environment and the body—is a hallmark of motor development. Flexibility is especially important for infants who must learn to walk at the same time as their environments and bodies are rapidly changing. Infants' everyday environments are replete with novel and varied ground surfaces and elevations. Infants' bodies change due to physical growth, increase in balance, strength, and coordination, clothing, footwear, and carrying objects. Thus, behavioral flexibility requires walking infants to perceive the relations between the environment and their body from moment to moment and decide whether and how to walk accordingly.

To test if infants—who struggle to walk under the best of conditions—can cope with variations in the environment and their bodies, we manipulated the slope of the ground and/or the slope of babies' shoes. Both manipulations were presumably novel. Infants ($N = 36$ 12- to 20-month-olds with 10 days to 6 months of everyday walking experience) were encouraged to walk over flat ground and up and down slopes while wearing flat- or slope-heeled shoes in nine conditions (Figure 1A-B). We were especially interested in comparisons with equivalent foot tilt, where environment-body relations were most apparent (Figure 1C). We focused on five outcome measures, each building on the last: (1) attempts to walk; (2) successful walks if infants attempted; (3) nonstandard footfall patterns (e.g., backsteps, double steps) if infants walked successfully; and modifications to (4) step length and (5) step time if infants walked successfully with standard footfall patterns.

Infants coped far better with sloping shoes than sloping ground, even with foot tilt held constant. On flat ground, infants walked similarly in slope-heeled and flat-heeled shoes, and walking experience predicted how well they walked in both conditions. In contrast, sloping ground required infants to alter their walking patterns or avoid walking entirely. Accordingly, on slopes, infants were more likely to avoid walking, fall if they attempted to walk, use nonstandard footfall patterns if they walked successfully (Figure 2C), and modify step length and step time (Figure 2D-E) if they retained standard footfall patterns. As on flat ground, walking experience predicted infants' ability to cope with slopes: Infants with more experience fell less on slopes, and they modified their step length and step time if they maintained standard footfall patterns.

By equating foot tilt, we demonstrated that variations in the environment (sloping ground) were more challenging than variations in the body (sloping shoes). Moreover, everyday walking experience enhanced infants' ability to adapt to the additional challenges posed by sloping ground.



Thus, everyday walking experience facilitates behavioral flexibility for coping with novel changes in the environment and the body.

Oral Session 8 – Language, Environment, Vocabulary and Communication

O8.2 - Semantic complexity in child-directed screen media across age groups

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Details

Children are increasingly turning to online platforms such as YouTube to consume screen media with traditional broadcast television usage declining (Ofcom, 2023), highlighting the importance of understanding how children attend to and learn from this content. Experimental work shows that infants attend most to information optimally predictable for learning, including more regular linguistic structures and to audiovisual stimuli of intermediate complexity (Gerken et al., 2011; Kidd et al., 2012; Kidd et al., 2014). However, whether their real-world media environments reflect these attentional preferences is less understood. Whilst child-directed songs show lower information rates than adult-directed, with simpler songs being more popular (Labendzki et al., 2025), this pattern has not yet been tested in screen media. Further, it is unclear whether these preferences change across development alongside children's capacity to process more complex information.

We aimed to quantify differences in semantic complexity of screen media content viewed across different developmental stages and examine associations with popularity. We expected overall semantic complexity to be lower in videos viewed by younger children consistent with developmental differences in linguistic processing. We expected complexity to be associated with popularity in both ages but given inconsistent evidence regarding whether this association is linear or quadratic, we tested both model forms.

We analysed a corpus of naturally viewed YouTube videos from two age groups (1-3 years and 6-8 years, N=232 and 191 respectively) from middle- to high-income and well-educated families in the United States. For category breakdowns for each age group, see Figure 1. We word-transcribed video audio with WhisperX, then computed the semantic surprisal for each word using GPT-2, reflecting how unexpected a word is given its preceding context (Willems et al., 2016). We quantified popularity as the log of the number of views per day.

An ANOVA revealed a significant main effect of age group (1-3 vs. 6-8) in predicting mean surprisal, $F(1,413)=35.21$, $p<.001$, with lower surprisal found in the younger corpus ($t(413)=-3.78$, $\Delta\text{EMM}=-.60$, $p<.001$) (see Figure 2A). Significant main effects were also found for all covariates (video category, word rate, days since upload). To examine whether the relationship between surprisal and popularity was linear or quadratic, we fitted a model with both polynomial terms. There was a significant negative linear association between surprisal and popularity ($\beta=-8.81$, $SE=2.46$, $p<.001$) indicating that within both age groups, videos with lower semantic complexity are more popular



(see Figure 2B). The quadratic component was non-significant ($p=.25$), providing no evidence for a non-linear relationship.

Our findings confirmed that the screen media children consume becomes more semantically complex with age, showing that younger children's attentional preference for more predictable language is reflected in their naturalistic viewing choices. Across both age groups, simpler linguistic content was associated with higher overall viewership with no evidence for an optimal mid-range of complexity. However, view count may be too general a measure to capture attentional optimization. Next, we plan to examine how moment-to-moment engagement is modulated by temporal fluctuations in semantic complexity across development to better characterise these relationships.

O8.3 - A rule-based approach for identifying key child-directed speech in long form recordings

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Details

Children's language environments contain both child-directed speech (CDS) and overheard speech (OHS), yet the relative contributions of each to language development remain poorly understood. While CDS provides unique benefits for language learning (Shneidman & Goldin-Meadow, 2012; Ferjan Ramírez et al., 2020), and children can learn from OHS (Foushee & Srinivasan, 2024), we lack the ability to quantify these speech types at the scale needed to answer a fundamental question: How do CDS and OHS quantities vary across cultures, and do these differences predict developmental outcomes? Answering this requires hundreds of hours of manual annotation, which is prohibitively labor- and time-intensive since automatic tools cannot yet distinguish CDS from OHS (Cychosz, Villanueva, & Weisleder, 2025). This bottleneck slows researchers from conducting the large-scale, cross-linguistic, and longitudinal studies necessary to answer questions about language learning across diverse populations.

In the present study, we develop an automated, rule-based classifier for CDS directed to a "key" (focus) child (KCDS) and OHS that can be applied to long-form audios. Unlike similar approaches based on proprietary platforms such as LENA (Bang et al., 2023), which require recording hardware and closed-source processing pipelines, our approach uses VTC (Lavechin et al., 2020), an open-source software, to find and segment vocalizations in recordings from 7 datasets and 4 languages (North American and UK English, Tsimane', Tselal, & Yéli Dnye). To derive automatic KCDS/OHS labels, we cross two scenarios (Scaff et al., 2024) with 6 inter-turn interval thresholds (ITI). The "permissive" scenario allows overlapping speech and considers sequences of same-sex adult vocalizations as directed to the child; whereas the "restrictive" scenario discards overlapping speech. Across both scenarios, KCDS is identified based on whether input speech from other speakers is contingently timed in response to the key child's speech (KCHI). The time gap allowed



between turns to be classified as contingent responses is parametrized through ITIs of 300ms, 1000ms, 1500ms, 2000ms, 2500ms, and 5000ms. We use 1-5' sections with human annotations ("clips") to evaluate the ensuing classification through correlations, error rates, and confusion rates.

The duration of KCDS within each clip based on manual labels was correlated with that based on automatic labels, with stronger correlations observed for restrictive ($r = 0.73\text{--}0.77$) than permissive ($r = 0.62\text{--}0.63$; $N = 815$, all p s $< .001$). Clip-based error-rates ($(\text{speech_human} - \text{speech_automatic}) / (\text{speech_human} + \text{speech_automatic})$) were minimized with the restrictive scenario and higher ITIs (Figure 1). Finally, confusion analyses revealed systematic trade-offs across scenarios: the restrictive scenario showed higher precision but lower recall for KCDS, whereas the permissive scenario showed the opposite pattern (Figure 2).

This paper makes three key contributions: it provides an open-source, adaptable framework; demonstrates applicability across four typologically diverse languages; and employs multiple complementary evaluation metrics. This approach offers a scalable alternative for large-scale and cross-linguistic research on children's language environments, with parameters that can be refined for specific research contexts, finally allowing our field to study how CDS and OHS quantities and predictive value vary across cultures.

O8.4 - Peripheral vision may offer an alternative pathway for simultaneous label-object mapping in speaking and signing children

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Details

Word learning requires children to map linguistic labels to their referents. In spoken languages, this often occurs as children hear a word while simultaneously looking at the corresponding object. In sign languages, however, signs are thought to compete with the referred objects for the child's visual attention. Therefore, it has been assumed that signing children receive label-object input sequentially, rather than simultaneously, leading to a different word learning experience.

Signing dyads have been found to frequently shift gaze between signs and objects (Lieberman et al., 2014), suggesting sequential input. However, studies suggest two alternative pathways through which signers may receive label-object input. First, signing caregivers have been observed to align their signs with their children's line of sight, by displacing signs closer to objects (Holzrichter & Meier, 2000), potentially allowing for simultaneous input. Second, signing adults have been shown to recruit peripheral vision in language perception (Mastrantuono et al., 2017). This ability, if already present in children, could create another pathway for simultaneous input. The current study investigates which pathways of input are available for children's label-object mapping, and how frequently each occurs. Exploring these different pathways has the potential to redefine our current understanding of how visual input supports language development.

To assess children's visual input, 25 signing or speaking caregiver-child dyads (1-5 years old) engaged in two 10-minute-long spontaneous play sessions, wearing a head-mounted eye-tracker



(Fig. 1). This method enables us to quantify the input perceived from the child's own point of view, measuring not only what was in the child's central visual attention but also what was present in their periphery. We compared three possible pathways for label-object mapping in signing dyads: 1) simultaneous input of label and object in central vision, 2) sequential input, in which the child centrally attends to the object and sign consecutively, and 3) simultaneous input that includes the periphery.

Our results revealed that all three pathways are available to signers (Fig. 2). Although rare, simultaneous central input still accounted for 6.74% of input in signers, whereas—as expected—it was much more common among non-signers (56%). Consistent with earlier research, sequential input occurs more regularly in signers (18%) remaining a relatively frequent pathway for learning. Notably, if the periphery is considered, simultaneous input increased dramatically to 74% for signers, suggesting a high-frequency pathway that may have been previously overlooked. For non-signers, considering the periphery also increases simultaneous input (from 56% to 89%), suggesting that not just signers, but also non-signers might profit from peripheral input.

Our findings highlight a vital role of peripheral vision in language learning. Signing children receive rich, simultaneous label-object input through both central and peripheral vision. This broadens our understanding of visual learning pathways in sign language environments and challenges assumptions about the visual input in sign languages. Future research should explore how children process peripheral information and how different pathways contribute to learning outcomes, offering deeper insight into the mechanisms that support early sign language acquisition.

O8.5 - The role of follow-in naming and sustained attention in vocabulary growth

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Details

Social contingency – caregivers' timely and semantically appropriate responses to infants' behavior – has been linked to early vocabulary, yet the mechanisms underlying this link remain unclear. One possibility is that when caregivers align their speech with infants' attentional focus ("follow-in speech"), they scaffold word learning by naming objects that infants are already attending to. Another possibility is that vocabulary is supported by follow-in speech because it extends infants' attention, strengthening encoding of word-object mappings. We investigated these possibilities by examining longitudinal relations among follow-in speech, follow-in naming, sustained attention, and vocabulary development across the first two years of life.

Using the Rollins corpus of parent-infant interactions (Rollins, 2003), we analyzed 22 dyads at 9 months and 19 dyads at 12 months. Parent and infant behaviors were coded in Datavyu frame-by-frame (30 fps) for gaze, object-directed attention, speech onset, and semantic alignment. Follow-in speech was defined as parental speech occurring within 2 seconds of an infant's attentional shift to an object; follow-in *naming* episodes additionally required that the utterance contain the name of the object that the infant was attending to. Sustained attention was defined as object-directed looks lasting ≥ 3 seconds. Receptive and productive vocabularies were assessed at 12 and 18 months via the MacArthur-Bates CDI.



We tested two specific hypotheses. **Hypothesis 1** was that follow-in naming supports vocabulary because it provides timely, relevant lexical input, independent of sustained attention. **Hypothesis 2** was that naming promotes vocabulary via increasing sustained attention, which enhances encoding. For each hypothesis we predicted that the effects should manifest in the first year (9-12 months) but not in the second year (12-18 months), because infants in the second year rely on a wider set of word learning strategies, which likely reduces the contribution of parents' speech that immediately follows infants' attention shifts.

Results revealed that the *frequency of follow-in naming at 9 months robustly predicted receptive vocabulary at 12 months*, controlling for measures of language input, whereas follow-in speech without naming did not (Tables 1 and 2). The effect persisted regardless of whether naming extended infants' attention. Sustained attention alone did not predict vocabulary, nor did it mediate the effect of follow-in naming. Although follow-in speech extended infants' object-directed looking at 9 month by 1.4 s, this attentional boost did not account for vocabulary outcomes.

In contrast, no measure of follow-in speech or naming at 12 months predicted vocabulary at 18 months after controlling for 12-month vocabulary, consistent with the idea that by the second year, infants increasingly recruit alternative word-learning strategies and become less dependent on immediate alignment between attention and naming. Neither measure predicted productive vocabulary either at 12 or 18 months.

These findings support a lexical-input mechanism: caregivers' naming of objects in infants' focus during the first year – specifically within tight temporal windows of contingency – plays a distinct role in early receptive vocabulary growth. The results clarify how social contingency supports word learning and highlight the importance of parents' moment-to-moment coordination with infants' attentional shifts in the earliest stages of language development.

O8.6 - Big feelings, big influence? exploring effects of toddler emotions on naturalistic parental language input

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Details

Parent language input is a powerful contributor to early language development, yet far less is known about how emotional contexts—particularly toddlers' negative emotions—shape these everyday learning environments. Research has extensively documented that the quantity and quality of parent input predict vocabulary growth, grammatical development, and later academic outcomes (Hart & Risley, 1995; Hoff, 2006; Rowe, 2012). However, almost no work has examined how parents talk to their children when emotions run high, even though many early learning opportunities occur during daily routines that also elicit frustration, sadness, or distress. Toddlerhood is marked by rapid gains in expressive language and a normative rise in negative emotional expressions, which peak during the second year of life (Potegal & Archer, 2004; Rothbart, 2007). These emotional signals, along with temperament-related differences in reactivity,



may influence how parents scaffold communication (Laake & Bridgett, 2018). Although prior work links higher toddler negative affectivity to more directive and less linguistically complex parental input (Rowe, 2008), very few studies have evaluated these processes in naturalistic, in-home contexts or investigated how momentary distress and child temperament may shape language exposure.

The present study uses daylong, naturalistic audio recordings to examine whether toddlers' distress and trait negative affectivity predict parent language input. The sample included 25 toddlers (12–23 months) and their parents. Toddlers (M age = 16.60 months) were predominantly white and from highly educated, middle-class families. We collected full-day audio recordings using Language Environment Analysis (LENA), from which two 10-minute epochs of parent–toddler communication (one high in toddler distress, one low in toddler distress) were extracted, transcribed, and coded. Four indicators of parent language input were generated: word tokens, utterances, word types, and mean length of utterance (MLU). Paired-samples t -tests compared parent language input during high- versus low-distress epochs. Four cluster-robust regression models (which account for the nested nature of the data) examined predictors of parent language input, controlling for SES and toddler language ability. Paired-samples t -tests showed no significant differences across any language measures (MLU, $t(24) = -0.70$, $p = .49$; total tokens, $t(24) = -0.31$, $p = .76$; word types, $t(24) = -0.80$, $p = .43$; and utterances, $t(24) = 0.24$, $p = .81$), indicating that parent language input did not differ across distress contexts (see Table 1). Table 2 shows that across all regression models, none of the predictors (SES, language comprehension, negative affectivity, distress) significantly predicted parent input, although toddlers with stronger language skills received marginally higher exposure to word types. These findings suggest that parents may maintain stable levels of linguistic support even during emotionally challenging moments, highlighting the robustness of parental language input and pointing to the need for further research on how emotional dynamics shape early learning environments. Future directions include extracting additional epochs with more variability in distress and language input, and examining these processes in additional populations, including those at risk for language delays or socioemotional problems.

O8.7 - Men's voices in children's worlds: examining the relationship between male speech and language production in young children across the world

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Details

Research demonstrates that the quantity and quality of linguistic input children receive is related to their language development (e.g., Rowe, 2012). While most studies have focused on mothers as primary caregivers, recent social changes have prompted examination of fathers' contributions (see Ferjan Ramírez, 2022). However, large-scale and cross-cultural studies are sparse, and little research has investigated the relationship between speech from male speakers (both fathers and non-fathers) and children's language development.



The current study leveraged child-centered long-form recordings to examine the relationship between speech from male figures and children's language production across diverse contexts. We analyzed data from 563 families (child age: 89 days to 7.4 years, mean 1.89 years) from 14 corpora spanning multiple countries and cultures (see Fig. 1). We assessed the amount of male and female speech children heard and the number of conversational turns with these speakers. Children's language production was measured through the duration of their vocalizations. In a preregistered analysis, we ran a mixed-effects model that controlled for age, normative-development status, and recording duration. We hypothesize that the amount of male speech and conversational turns between the key child and males will relate to children's language production beyond female speech and turns with females. We explored whether speech from these speaker types will correlate, based on indications that mothers might talk less to children when fathers are present. For example, Shneidman et al., (2013) found that the amount of child-directed speech was equal in single- and multi-speaker families (but overheard speech was more plentiful in and multi-speaker families).

We found that children heard almost twice as much female speech than male speech (8.132 min/hour vs. 4.273 min/hour), and engaged in more than twice as many turns per hour (124.809 vs. 49). When controlling for female-speech duration, male-speech duration was not a significant predictor of children's vocalizations ($\beta = .003$, $SE = .04$, $p = .937$), whereas female speech was ($\beta = .099$, $SE = .016$, $p < .001$). A random slope for male speech by corpus explained a significant amount of variance, suggesting variance between the corpora in the effect of male speech. Conversational turns with males were a significant positive predictor of children's duration of vocalizations ($\beta = .26$, $SE = .039$, $p < .001$), accounting for turns with females ($\beta = .549$, $SE = .014$, $p < .001$, see Fig. 2). A random slope for male speech by corpus explained a significant amount of variance. Male and female speech were positively correlated ($r = .188$, $p < .001$), as were their turns with the child ($r = .487$, $p < .001$), suggesting children's exposure to male speech complements rather than replaces female speech.

This is the first study to systematically examine the relationship between male speech and children's language production cross-culturally. The findings indicate that direct engagement with male figures, captured through turn-taking, is uniquely related to children's language development beyond female turns. These results expand our understanding of how diverse speakers in children's environments contribute to language development and highlight the importance of varied, interactive partners in early communication.

O8.8 - Caregivers' blink timing serves as a rhythmically structured communicative cue during infant-directed singing

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Details

Infant-directed singing is a universal form of social communication between parents and young children (Trehub, 1997). During infant-directed singing, parents accompany their vocal singing with emotional facial expressions, communicative gestures, and physical movements (Trehub & Russo, 2020). Infant-directed singing entrains infant visual behavior to caregiver eyes, however, less work



has considered how parents structure visual social communicative cues when singing to their infants (Lense et al., 2022). A relevant social cue to consider is parents' blinking when singing. When a speaker blinks, they block the listener's access to information expressed by the speaker's eyes (Shultz 2011). In social contexts, blinking often signals a break in conversation or cues a speech turn (Nakano & Kitazawa, 2010). Individuals also tend to blink less during periods of greater attention (Shultz, Klin, & Jones, 2011). We investigated the frequency and timing of parents' blinking during singing interactions with their infants. We hypothesized that parent blinks will be timed based on the rhythmic structure of their singing to optimize social communicative cues (eye gaze) at rhythmically meaningful moments (e.g. phrase starts).

The current sample includes N = 14 mother-infant dyads of 9-month-old typically developing infants. Parents were instructed to sing naturally to their infants using songs of their own choosing. Parents sang an average of 2 songs to their infants with a mean tempo (beat inter-onset interval) of 422.9 ms (singing duration mean (SD): 81.8 (33.3) s). The rhythmic structure of singing (timing of beats and phrase starts) and parent blinks were manually coded from audio and video files. Peristimulus time histograms (PSTH) were used to analyze the alignment of the blinks with the phrase starts and with the metrically strong beats.

Parents' average (SD) blink rate was 18.2 (9.9) blinks/minute. However, blinks were not evenly distributed across their singing. Parents' probability of blinking exhibited a phasic structure reflecting the rhythmicity of song with alternating strong and weak beats (Figure 1). Parents' blink probability significantly increased before and after the strong beats, with a trend toward an inhibition of blinking at the strong beats themselves (Figure 1). Parent probability of blinking significantly increased between song phrases with increased probability of blinking before singing a new phrase (Figure 2).

Despite individual differences in how parents sang to their infants (e.g., song choice, tempo, etc.), we observed synchronization in blink timing across parents. When singing to their infants, parents unconsciously time their blinks based on the rhythmic structure so that their eyes (important for social cueing) are available at rhythmically important moments (i.e., strong beats). Times before phrase starts and before/after beats are of reduced communicative salience relative to the beats themselves. We have an additional N = 30 dyads being analyzed to expand the current sample size. In future studies we will examine this alignment of visual cues to rhythmic structure in parent-child dyads of children with varying developmental profiles (e.g., ASD, preterm birth) to examine how developmental status and social communicative attunement impacts parent behavior during singing interactions.

Oral Session 9 – Early Markers, Interventions and Developmental Risk

O9.2 - Defining the context: identifying salient aspects of infant feeding for predictors of infant anthropometrics

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[Details](#)



Understanding infant growth requires situating infants within the context of their earliest and most dynamic environment: their milk exposure and feeding experiences. Human milk is not only a nutritional source but is a complex and adaptive biofluid shaped by maternal physiology, feeding practices, and the infant's developmental needs^{1,2}. Yet, the field lacks consensus on which dimensions of human milk exposure, i.e. feeding frequency, feeding duration, frequency of feeding directly at the breast, blunt cumulative measures (estimate of percentage of diet that is milk) or combined measures, best predict early anthropometric outcomes. This work-in-progress analysis aims to address this gap by evaluating multiple candidate measures of milk exposure to determine which are most predictive of infant growth trajectories during the first year of life.

The analysis draws on longitudinal data from 30 mother-infant dyads followed from 3-12 months of age, with detailed, repeated measures of feeding practices and infant anthropometrics. Since our goal is to interrogate the contextual features of feeding human milk specifically, this analysis includes only human-milk-fed infants and does not assess formula feeding, allowing us to identify which milk exposure metrics should be prioritized in future milk research. Feeding context was captured using feeding frequency, feeding duration, and mode of feeding (direct breastfeeding, expressed milk, or mixed). These data allow for the creation of multiple operational definitions of “milk exposure,” including (1) number of feeds per day, (2) cumulative average daily minutes of feeding, (3) combined metrics integrating frequency and duration, and (4) stability of feeding patterns over time. Infant anthropometrics, including weight, length, and head circumference, were assessed at 3, 6, and 12 months.

The primary aim of this project is to identify which metric(s) of milk exposure most strongly predict changes in infant anthropometric outcomes across the first year. We hypothesize that feeding frequency will emerge as a more robust predictor of infant anthropometric outcomes compared to feeding duration. This hypothesis is grounded in the theory that frequency better captures the dyadic exposure to dynamic infant needs and demand, milk transfer opportunity, and energy intake patterns, whereas duration is more vulnerable to variation in infant sucking efficiency, maternal let-down, or mode of feeding^{3,4}. Using model fit indices within mixed-effects growth models and comparative predictive analyses, we will test whether feeding frequency, feeding duration, or an estimate of the percentage of milk in the diet serves as a more reliable indicator of growth, as well as whether a composite measure better accounts for individual variability in infant development.

By framing feeding as a context, rather than a static variable, this project contributes to a more developmentally grounded understanding of early nutrition. Identifying the most predictive and developmentally relevant metrics of milk exposure has the potential to improve the precision of early-life nutrition research, strengthen the interpretation of human milk studies, and enhance guidance for caregivers and clinicians supporting infant growth. This work aims to advance a more nuanced, contextually rich account of how infants grow within the everyday rhythms of their feeding environments.

09.3 - Looking beyond statistics: centrality of relationship in an evidence-based early intervention program

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Details

Research findings offer strong support for evidence-based early intervention programs (Anderson et al., 2003; Shonkoff & Richter, 2013) and highlight the importance of positive experiences in early years for healthy development (Lake & Chan, 2014; Sege et al., 2025). The first relationship a child develops is with the caregiver. Thus, it is imperative that the caregiver has the resources, knowledge, and support to form a healthy relationship with the child.

The Maternal, Infant, and Early Childhood Home Visiting (MIECHV) program is a U.S. based federally funded evidence-based early intervention program. It has been providing services to at-risk pregnant women and families with children ages 0-5 years across all 50 states, territories, and tribal communities for nearly 15 years. The program is assessed annually by analyzing quantitative data to measure 19 federally mandated performance outcomes. Measuring outcomes is imperative for continuation of funding and demonstration of program effectiveness. It is equally important to assess the effect of the program on parenting.

Historically, less attention has been given to the perspective and experience of the parents receiving home visiting services. This study aimed to contribute to the small but growing body of work in this area (Lee et al., 2023). It considered the centrality of the quality of the relationship between service provider and service recipient (Daro, 2010; Paulsell et al., 2010; Summers et al., 2007) and the importance of providing compassionate, person-centered services (e.g., Kania & Kramer, 2011; Karter & Daro, 2016; Nygren et al., 2018) to meet the families where they are while building on their strengths. Data collected from 764 parents of children aged 0-5 years, spanning a decade, consisted of parents' retrospective assessment of program effectiveness in key areas of their lives, overall evaluation of the program, and open-ended responses.

Participation in home visiting was associated with positive outcomes in all key areas of parents' lives assessed in this study, including parenting skills, stress reduction, ability to care for one's children, form supportive relationships, and gain access to community resources and services for themselves and their children. The effectiveness of this program appears to reside in its relationship-based approach. Though parents greatly valued the educational materials, developmental screenings, and handouts they received from the program, the aspect of home visiting they overwhelmingly emphasized as most beneficial was the compassionate, nonjudgmental, and open relationship with their parent educator. Parents who often joined the program questioning their parenting abilities, frequently stemming from intergenerational transmission of trauma and poverty, felt validated and empowered to parent their children.

It seems sensible to integrate home visiting into a wider network of services. A systems approach (e.g., Guralnick, 2011) would not only maximize resources but would also ensure uninterrupted continuation of services and provision of support to at-risk parents and their young children. Beyond achieving positive short-term outcomes, embracing such approach could have lasting impact by disrupting the intergenerational transmission of maladaptive parenting (e.g., Rothenberg et al., 2023), potentially transforming not only individual families but entire communities.



09.4 - Effects of the COVID-19 pandemic on early child development at 24 months

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Details

Objective: The COVID-19 pandemic was a novel public health event disrupting the psychosocial, economic, and educational environments in which young children live, learn, and grow. These disruptions may have lasting developmental consequences. We aimed to compare Ages & Stages Questionnaires (ASQ-3) developmental screening scores at 24 months between U.S. children born before and during the pandemic to better understand potential pandemic effects.

Methods: This retrospective cohort study included children born at term who completed a 24-month well visit between 3/1/19-12/31/22 at our university-affiliated primary care clinic that serves a primarily low-income population. We created 3 cohorts based on the child's date of birth and pandemic exposure: (1) *prepandemic* cohort turning 2 years old prior to the pandemic (born on or after 1/14/2017 and before 3/1/2018), (2) *transitional* cohort born prior to the pandemic but turning 2 years old after the start of the pandemic (born on or after 3/1/2018 and before 3/1/2020), and (3) *pandemic* cohort born after the start of the pandemic (born on or after 3/1/2020 and before 1/1/2021). We analyzed ASQ-3 developmental domain scores, a total score for all domains, and the percentage of children classified as atypical (≥ 1 SD below the mean) in each domain. Cohorts were compared using multivariable logistic or linear regression adjusted for child age at questionnaire completion, sex, and insurance type. We did not adjust for race/ethnicity because accessibility of this information from the electronic health record was limited. For the transitional cohort, we also constructed regression models to assess the relationship between ASQ-3 measures and the duration of pandemic exposure (in days) prior to the 24-month visit.

Results: Data were initially obtained for 664 children. Prematurity affected 9%, and rates did not significantly differ between prepandemic ($n=19$, 9.0%), transitional ($n=24$, 9.1%), and pandemic ($n=17$, 8.9%) cohorts. After excluding those with prematurity, 604 children were included in the analysis, with most being identified as Hispanic/Latino (37%) or Non-Hispanic Black (26%) and on government-sponsored insurance (77%) (Table 1). Table 2 presents 24-month ASQ-3 scores and atypical screening rates with unadjusted and adjusted odds ratios (ORs). Compared to prepandemic, the pandemic cohort scored lower for the mean Total ASQ-3 (250 vs 262, $p=.03$), Communication (45 vs 49, $p=.02$), and Personal-Social (49 vs 52, $p=.03$) and had higher odds of having an atypical score for Fine Motor (OR 2.2, 95% CI 1.2-4.2; $p=.01$), with males more likely than females to have an atypical score for Communication (OR 2.2, 95% CI 1.2-4.0; $p=.03$) and Fine Motor (OR 2.3, 95% CI 1.0-5.0; $p=.04$). There were no significant differences between the prepandemic and transitional cohorts. For the transitional cohort, the duration of pandemic exposure was negatively associated with Total ASQ-3 ($p=.048$), Communication ($p=.02$), and Personal-Social ($p=.03$) scores. On average, for every 30 days spent during the pandemic, scores dropped by 0.6 (Total ASQ-3), 0.3 (Communication), and 0.2 (Personal-Social) points. The other developmental domains were not significantly associated with pandemic exposure.



Conclusions: Our findings suggest a negative association of the COVID-19 pandemic with child development, especially for emerging language and socioemotional skills. While effects were modest at the individual level, the population effects may be large given the pandemic's universal reach with important educational implications.

09.5 - Parental questionnaire for early detection of language delays and risk of autism spectrum disorder in Mexican children

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Details

Early identification of language delays and neurodevelopmental conditions such as Developmental Language Disorder (DLD) and Autism Spectrum Disorder (ASD) is essential for supporting social, cognitive, and academic development. Yet in Mexico, under-identification and underdiagnosis remain pervasive, limiting access to timely assessment and intervention during the critical early years. The objective of this project is to develop and validate a culturally grounded short parental questionnaire designed to detect early signs of language difficulties and to identify children at elevated risk for DLD or ASD between 18 months and 3 years of age.

Methods

This project presents the development and empirical validation of a parental questionnaire grounded in the diverse sociocultural, environmental, and caregiving contexts of Mexican families. Parental reports have been used as screening tests in community settings, thereby reducing the demand on health services (Sim et al., 2019). Our questionnaire situates early communication within these diverse contexts.

The questionnaire integrates three domains fundamental to understanding early communication concerns: (1) parental concern items that capture caregivers' observations about delayed or atypical communication; (2) biological and developmental history items, including late milestones or familial factors associated with neurodevelopmental risk (Auza et al., 2023; Auza & Peñaloza, 2019); and (3) socio-behavioral items assessing interaction, responsiveness, social engagement, and repetitive patterns that may signal early characteristics of ASD. All domains initially integrated 30 items, from which the strongest indicators were selected through empirical testing.

The study is grounded in a sample of 539 monolingual Spanish-speaking Mexican families from urban and semi-urban communities that differ substantially in linguistic input, cultural communication norms, caregiver expectations, and access to pediatric or developmental services. Within this validation sample, 426 cases corresponded to children with language delays and 113 to children with profiles at risk of ASD. Empirical analyses from the initial validation phase included item discrimination and convergent validity with gold-standard clinical assessments. Sensitivity and specificity analyses were complemented by ROC curve examinations to evaluate the instrument's diagnostic accuracy.



Results

The questionnaire with only 15 questions demonstrated robust alignment with clinical screening outcomes. The ROC curve for identifying children with language delays reached 0.870, demonstrating strong discriminative capacity, while the ROC curve for detecting profiles at risk of ASD was exceptionally high at 0.991. These findings underscore the critical contribution of parental insight to early detection and indicate that the instrument captures developmentally meaningful behaviors that transcend contextual variability (Sansavini et al., 2021).

Conclusions

This research contributes a culturally responsive, empirically validated tool for the early detection of language delays and neurodevelopmental risk in young Mexican children. By ensuring usability among populations traditionally underserved by formal diagnostic systems, the questionnaire supports earlier referral, diagnosis, and intervention. In a second phase, the project will collaborate with health and education professionals across Mexico and Latin America to evaluate cross-context applicability.

09.6 - Early differences in conversational turn growth among infants with and without later autism

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Details

Intro: Our previous research demonstrated that there are dynamic changes in parent-child communication across the first two years of life, and these patterns may differ in typically developing children and children with autism (Swanson et al., 2019). In a small sample we reported that typically developing infants experienced an increase in conversational turns with caregivers across the ages of 9-15 months, a pattern not demonstrated in the infants that went on to be autistic. These results, and those of others, may suggest early disruptions to a “social feedback loop” in autism that may have downstream impacts on language development.

Objective: The objective of the current abstract is to investigate developmental changes to caregiver speech measured in the home in a well-powered sample of infants who go on to develop autism and their non-autistic peers.

Methods: This study includes data from 88 infants who went on to receive an autism diagnosis (High-Likelihood ASD or HL-ASD), and 158 infants who did not (High-Likelihood Negative or HL-Neg). All infants have older autistic siblings. Caregiver speech variables were generated from home language samples collected using LENA recorders when infants were 6, 12 and 18 months of age. Caregiver speech variables included adult word count (AWC), i.e., the number of adult words spoken to and near the infant who is wearing the LENA device, and conversation turn count (CTC), i.e., the number of times the infant vocalizes and an adult responds within 5 seconds and vice versa (the adult vocalizes and the infant responds). Data analyses focused on how CTC varied across time in the two diagnostic groups and linear mixed-effects models were fitted to analyze the pattern across groups. Simple slopes were calculated for each group separately. In all the models,



CTC was the dependent variable with child chronological age at recording and diagnostic group (HL-ASD; HL-Neg) as the predictor variables. The mixed model included a group * time interaction term.

Results: Results of longitudinal models indicated a significant group * time interaction, with CTC increasing more conservatively in the HL-ASD group than in HL-Neg group [$F(1,134) = 15.07$, $p < 0.01$]. For every monthly increase in participant age, CTC increased by 13 more in the HL-Neg group than in the HL-ASD group. Tests of simple slopes revealed that the increase in CTC with age was significant in the HL-Neg group [$F(1,87) = 45.62$, $p < 0.001$], but not in the HL-ASD group [$F(1,47) = 0.85$, $p = 0.36$]. Though AWC decreased with time in both groups, the results were not statistically significant.

Discussion: Infants who developed autism showed stable patterns of the number of adult-child conversation across 6-18 months of age, while infants who did not go on to have autism showed increases in adult-child conversations across this age range. Together, the results highlight early alterations in social communication dynamics that may reflect early communication challenges in infants who go on to be autistic. The current work will be extended to include analyses of infant vocalizations and adult words counts.

09.7 - Developing a gesture score for infants 6-23 months using baby toolbox

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Details

Measuring gesture production in infancy is essential for characterizing early communicative and social development. Gestures, which typically emerge before spoken language, represent infants' earliest intentional communicative acts, used to share interest and express needs and wants (Bates, 1975; 1979). Delays or deficits in gesture are associated with later delays in spoken language (Colonna et al., 2010) and can serve as an early indicator of a later Autism diagnosis (Manwaaring et al., 2018). Despite its importance, there are few standardized measures of gesture; most assessments overlook nonverbal communicative behaviors altogether. As a result, prior research has relied heavily on naturalistic observation, which is not standardized and is costly and burdensome to collect and code. One of the few standardized and normed measures of gesture — the CDI: Words and Gestures (Fenson et al., 2006) has serious limitations: it is designed only for infants at 18m or younger and does not distinguish true communicative gestures with other behaviors such as symbolic actions.

In this study, we evaluated a gesture score focusing on “true gestures” (e.g., pointing, showing, nodding) for infants aged 6–23 months using a large normative sample, with the goal of providing a standardized indicator for researchers studying early social-communication and gesture development.

Gesture-related items were drawn from data collected during the Baby Toolbox norming study (Han et al., 2025). The Baby Toolbox is a developmental assessment designed to measure



neuropsychological, motor, and social-emotional functioning in children aged 1–42 months. Although the Baby Toolbox was not built to assess gesture per se, two Baby Toolbox measures (Caregiver Checklist and Social Observation Measure, see Blackwell et al., 2025) include 18 items deemed to assess gesture production and comprehension (see sample questions in Table 1). Participants included $n=1,060$ infants age 6–23 months old who participated in the Baby Toolbox norming Study, which was recruited to match the 2020 US Census in terms of race, ethnicity, and caregiver education.

Preliminary multiple group IRT score modeling revealed that the latent theta gesture score showed a robust positive relation with age (Spearman $\rho=.75$, see Figure 1). It also had moderate absolute agreement ICC(1,1)= .59 and moderate test-retest reliability (Pearson $r=.65$, $p<.05$) in a subset of children who completed the Baby Toolbox twice ($n=91$). The gesture score also was positively correlated with the Baby Toolbox language ($r=.61$, $p<.05$) and social communication composites ($r=.70$, $p<.05$) as expected.

Isolating gesture-related behaviors for a validated, dedicated score has substantial potential for both researchers and clinicians. Our findings indicate that the Baby Toolbox gesture score is reliable and meaningfully associated with concurrent language and social-functioning abilities, as expected. Future work will determine whether this score can predict later language and social outcomes and evaluate how it compares to more labor-intensive, gold-standard methods of gesture coding.

O9.8 - Newborn babies with a high likelihood of developing autism show different motor lateralisation early in life

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Details

Objective: Although motor function is not currently considered part of the diagnostic criteria for autism, the co-morbidity of autism and motor differences is common. The co-occurrence provides an opportunity to seek early markers of autism from the first days of life. Motor development has been a key factor in analysing development in the first six months, when other brain functions like socialisation and communication have not emerged yet. This study aimed to investigate the motor lateralisation in newborn babies with high and low likelihood of developing autism.

Method: We analysed 939 weekly recorded videos of 70 babies, during free movement in the supine position, with high and low likelihood of developing autism. Babies who had a parent or sibling with a diagnosis of autism or ADHD were recruited with a high likelihood. We conducted state-of-the-art pose estimation models to extract body landmarks for each frame and calculated the canonical correlation between their main joints (shoulders, elbows, hips, and knees) over the first six months of life as an index of coordination across four coordination types (intralimb, interlimb, ipsilateral, and contralateral). We ran a Generalised Linear Mixed Model (GLMM) on the canonical correlation calculations, looking at the main effect of Age, Group, Body Side, Body Map (Upper and Lower body), and Coordination Type (intralimb, interlimb, ipsilateral, and contralateral)



and the interaction of Group with the other main effects.

Results: The results of GLMM revealed significant main effects of time, both linear and quadratic ($p < .001$), Body Side ($p < .001$), and Coordination Type ($p < .05$). Interaction of Group and Body Side ($p < .001$), and Group and Coordination Type ($p < .001$) were also significant. The result of post hoc analysis showed that, although there was no significant difference between the two groups in Body Side coordination (Fig. 1-B), the low likelihood group showed higher coordination in their right side and the high likelihood group showed higher coordination in their left side (Fig. 1- A).

Conclusion: These findings reveal a difference in the early behavioural laterality in high likelihood babies, which may result from different brain lateralisation, known to exist in populations with autism. Behavioural biases in infant motor behaviour are a promising new avenue for exploration in early screening of autism.

09.9 - Joint attention boosts sustained attention less in children with Down syndrome: Insights from dual head-mounted eye-tracking

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Details

Sustained attention (SA) and joint attention (JA) are foundational for young children's early learning and development (Breckenridge et al., 2013; Yu & Smith, 2016; Yu et al., 2019). Even though they are traditionally conceptualised as distinct processes (Hahn et al., 2018; Pérez-Edgar et al., 2010), emerging evidence indicates that JA provides a critical social pathway through which SA is scaffolded during early development in typically developing (TD) children (Yu & Smith, 2016). However, it remains unclear whether this is the case in neurodivergent development. In this study, we examined this question in young children with the most common neurodevelopmental condition of known genetic origin - Down syndrome (DS). Understanding this process is crucial for both developmental theory and for informing practitioners and parents about effective support.

Here, we simultaneously investigated SA and JA during free-flowing parent-child object play using dual head-mounted eye-tracking (Figure 1) in 15 young children with DS aged 3.0 to 4.8 years ($M = 46.93$ months, $SD = 7.88$) and 15 TD toddlers aged 1.4 to 2.3 years ($M = 21.10$ months, $SD = 2.83$) and their parents. The groups were matched on ability level using the Mullen Scales of Early Learning (Mullen, 1995).

The results reveal both similarities and differences in attention among children with DS and ability-matched TD children, as well as between children and their parents. Linear mixed-effects models showed that looks were predominantly object-centred ($b = -0.71$, $SE = 0.06$, $p < .001$), with children allocating more attention to objects ($M = 66\%$, 95% CI [63%, 68%]) than to faces ($M = 18\%$, 95% CI [16%, 20%]), while parents distributed their attention more evenly (objects: $M = 47\%$, 95% CI [45%, 49%]; faces: $M = 37\%$, 95% CI [35%, 40%]). TD children and children with DS did not differ significantly in the proportions, frequencies, and durations of JA and mutual face looking. However, children with DS exhibited significantly shorter durations of SA than their TD peers (DS: $M = 5.03$ s, 95% CI [4.62, 5.45]); TD: $M = 5.77$ s, 95% CI [5.28, 6.26]; $b = 0.14$, $SE = 0.06$, $p = .026$).



Importantly, our findings revealed that JA serves as a social process that boosts SA in both TD children and children with DS. Across both groups, longer parental-joining lags during SA-with-JA were positively associated with SA durations ($b = 0.06$, $SE = 0.02$, $p < .001$; Figure 2a) and JA durations within SA were likewise positively associated with SA durations ($b = 0.14$, $SE = 0.01$, $p < .001$; Figure 2b). These effects showed group-specific patterns: the parental-joining lag effect was marginally stronger in TD children ($b = 0.14$, $SE = 0.07$, $p = .067$), whereas the boosting effect of JA-within-SA was significantly weaker in children with DS ($b = -0.15$, $SE = 0.06$, $p = .027$). This study underscores the social foundations of early SA and highlights that both children with DS and TD children benefit from moment-to-moment parental attentional engagement, though the effect is weaker in children with DS.

09.10 - Oscillatory EEG dynamics underlie distinct neurodevelopmental profiles in infants with increased genetic probability for autism

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Details

Several ASD-associated genes increase the probability of autism diagnosis by 15–20%, yet the downstream impact of these genetic changes on neurobehavioral development remains difficult to predict. Early-life differences in neural organization, extracted from oscillatory dynamics of the EEG signal, may map onto specific genetic variants associated with emerging autism symptomatology. Leveraging neural markers to identify subgroups of infants with identified ASD-associated genes represents a promising precision-medicine approach for elucidating the mechanism through which genetic differences shape brain–behavior trajectories.

This approach is designed to determine whether early neural signatures can reliably differentiate genetically defined genetic groups.

We leveraged non-linear metrics extracted from longitudinal resting-state EEG recordings to stratify genetic subgroups within a cohort of 4- to 15-month-old infants with increased genetic probability for autism (IGP; unique $n=10$; total datasets, $n=33$) compared with infants with no known genetic probability (NGP; unique $n=19$; total datasets, $n=43$). Genetic status was determined through the Genomic Uniform-Screening Against Rare Diseases in All Newborns (GUARDIAN) study, and EEG data was collected by the PROGRESS Center at Columbia University. Infants were seated on their caregivers' laps and viewed a 5-minute resting-state, non-silent cartoon while high-density EEG was recorded (Magstim-EGI, 128-channels). Absolute resting-state EEG power in 2-second segments was averaged across whole-brain electrodes for six frequency bands (delta, theta, low alpha, high alpha, beta, and gamma) using the Harvard Automated Processing Pipeline for EEG (HAPPE). Relative power for each frequency band was then calculated as the ratio of absolute power in that band to total absolute power summed across all frequencies.



Individual slopes and intercepts of relative resting-state power trajectories were estimated for each frequency band.

Linear mixed-effects models examining quadratic intercepts (**Fig.1b**) and slopes (**Fig.1c**) of relative EEG power revealed a significant interaction between genetic status and frequency band ($p=.04$), with IGP infants showing a slower decline in relative delta power over time compared to NGP infants ($p=.01$). Latent profile analysis of relative EEG power was used to identify data-driven subgroups within the combined IGP and NGP sample. A five-class solution (AIC=-2325.4) provided the best overall model fit and yielded significant Bootstrap Likelihood Ratio Test (BLRT) comparisons relative to the four-class model (AIC=-2311.3, BLRT $p=.01$) and without significant improvement in fit relative to a six-class model (AIC=-2320.2; BLRT $p=.69$). Two separate classes of IGP infants (**Fig.2**) were primarily differentiated by patterns of low-frequency power (delta/theta) and increased high-frequency activity (beta/gamma).

Patterns of relative resting-state EEG delta power revealed meaningful heterogeneity in early neural organization, where IGP infants showed slower declines in relative delta power compared to NGP infants. Relative power metrics across all frequencies produced a well-differentiated five-class solution, indicating that distinct oscillatory profiles emerge early in development. These findings suggest that resting-state oscillatory dynamics capture biologically grounded variability that may reflect divergent neurodevelopmental pathways associated with genetic susceptibility. Identifying these neural subgroups offers a framework for linking specific oscillatory patterns to underlying genetic conditions, ultimately advancing mechanistic models of how early brain organization contributes to emerging autism symptoms.