International Congress of Infant Studies

Abstract Proceedings

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S1: Early language across-cultures: input, language processes and outcome measures

S1.1: Day-wide patterns in the use of child-directed speech in two non-Western, subsistence faming communities

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Across a handful of languages, child-directed speech (CDS) has been proposed to be beneficial for children's linguistic development, potentially because of its phonetic, grammatical, affective, and pragmatic characteristics in these languages. However, the cross-cultural utility of CDS is called into question by reports from communities in which direct speech to children is unusual. The quantity and quality of child-proximal talk is also influenced by activity context. Therefore, in characterizing CDS across communities we need to measure natural patterns in CDS during typical days at home. In the present study, we estimate how much speech is addressed to Tseltal Mayan children growing up in a rural indigenous community. We find, across multiple measures, that children indeed only rarely engage in direct verbal interaction with others, but that much of the day's CDS comes during short, sparsely distributed bursts of verbal interaction. We collected 8-11-hour recordings of 10 children's (0;0-3;0) waking days at home using a child-worn audio-and-photo recorder. We transcribed two types of non-overlapping 1-5 minute clips throughout the day for each child, totalling 50-55 minutes per child: (a) randomly selected clips ('random baseline') and (b) manually selected peak turn-taking activity clips ('peak turn-taking'). We used negative binomial mixed-effects models to test how child age, time of day, and number of speakers influenced CDS characteristics in the transcribed clips. The two clip types gave diverging views of Tseltal children's language environments. In the randomly sampled clips, CDS rate was low (mean: 3.6 min/hr), and most likely to be heard in the morning, with older children hearing more than younger children at midday. Older children were also more likely than younger children to hear CDS when more people were present. In contrast, the peak turn-taking clips featured a high CDS rate (average 13.3 min/hr), and was statistically unaffected by child age, time of day, or number of speakers present. We demonstrate similar differences between clip types for contingent response rate (child-to-other: 1.4 vs. 7.7 responses/min and other-to-child: 1.2 vs. 7.6 responses/min) and duration of interactional sequences (10.1 sec vs. 12.3 sec). We scanned the random samples for 1-minute clips that matched or exceeded contingency in the peak clips, only finding comparable 'peaks' for 6 of the 10 children. Based on these data, we very roughly estimate that Tseltal children under 3;0 hear approximately 1.95 hr of high-intensity interaction during a day at home, much of which is contained within short bursts of interaction. We discuss what this

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pattern of CDS suggests about the likely mechanisms by which children extract linguistic information from their environments. We will also present parallel preliminary results from a second, unrelated indigenous community, selected for comparison because of its previously-reported child-centric interaction style. We contrast findings at these two sites to broaden our discussion of how activity context, child age, and cultural norms influence the shape of linguistic input and, thereby, the strategies best adapted for language learning in each community.

S1.2: Exploring conversational turns and partners among Tsimane forager-horticulturalists

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Parent-child conversations have been described as playing a substantial role in language acquisition in urban societies (Snow, 1974; Hart and Risley 1995). However, the influence of conversational patterns (e.g. turn-taking, number of conversational partners) on language development in non-urban societies remains considerably understudied. We seek to partially fill this gap by examining the frequency of conversational turns by Tsimane forager-farmer children from the lowlands in Bolivia. We made day-long recordings of children's speech environments using child-friendly, wearable audio recorders with 25 children (aged 6-68 months; 28% female) from 15 families. For each recording, a trained phonetician annotated all vocalizations heard in one minute per hour; choosing the minute at random (mean= 13 coded minutes/child; range 4-16 min). Vocalizations were classified as originating from either the focal child, the "main female voice" (MFV, usually the mother), other female adults, other male adults, or other (i.e. nonfocal) children. We operationalized any vocalization preceding or following a focal child vocalization within 2 seconds as a conversational turn-transition (i.e., as prompts and responses to focal child speech, respectively). Children experience an average of 2 conversational turn-transitions per minute (range: 0.1-5.5). Overall, 44% of children's vocalizations were followed by silence; a pattern more apparent in the older children recorded. On average, fifty percent of all conversational turn-transitions involved more than 2 speakers. The great majority of unique conversational partners (i.e. turn-transitions exclusively between the focal child and another speaker) were fellow children and maternal turn-transitions significantly decreased with age. The accuracy and stability of these measures remain to be tested upon further data collection and analysis in the future. We conclude for this sample that young Tsimane children experience mostly multiparty turn-transitions and one-on-one conversations are rare for all ages. If early conversational turns are mostly composed of third-party conversations, does this mean that exclusive infant-adult verbal interactions are less important than thought for this rural setting? Or

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children raised in such contexts are capable of focusing attention on multiple speakers simultaneously, as it has been described for other rural contexts (Rogoff, 1993). They remain open questions for the moment, although they invite to further investigate how central parent-child interactions are for language learning and highlight how important it is to widen the scope of infant research in diverse socio-ecological settings.

S1.3: Spontaneous vocalizations from birth to age four: Insights from a mega-analysis of 13,785 hours of audio

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Children grow up in extremely varied environments, with families varying in child-rearing practices, household compositions, linguistic, and socio-economic circumstances. However, a mainstream assumption based on short recordings is that their language production follows a similar progression: Children start producing mostly cries and vegetative sounds, gradually transitioning to speech-like babbles and recognizable words, and eventually multi-morphemic utterances. The field is now turning to long-form recordings to study development, and it becomes relevant to ask: how does the full range of vocalizations that children produce spontaneously in their home environments change over developmental time? We re-analyze vocalization data collected by 16 research teams across 5 continents using the LENA system, in what may be the first collaborative mega-analysis of infant production. Each team provided the files output by the LENA's automated software. Before analysis, data were split into non-overlapping exploration and confirmation datasets, with only the former analyzed here (as per our pre-registration plan). The exploration dataset contains data for 35% of the typically-developing, monolingual children from the whole dataset, comprising 955 audio-recordings (13,785 hours of audio) from 277 children. The automated LENA output was first processed to extract the three key measures quantity (per hour), total duration (per hour), and average duration for the three vocalization types crying, vegetative (e.g. burps), and linguistic vocalizations. Spearman correlations that were complemented with linear mixed models controlling for corpus and child random-effects revealed three key results, which provided mixed support for our

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predictions (see Figure 1 and Table 1). First, while the quantity of cries remained stable, the average and total duration of crying bouts decreased with age. Second, all three characteristics of vegetative vocalizations increased with age. Finally, for linguistic vocalizations, the total duration and quantity increased with age whereas average length was stable. We also inspected cross-recording stability, using intra-class correlation coefficients estimated from mixed models declaring child nested in corpus as random factor. We focused on the subset of data with more than one recording per child within 2 months (224 recordings, 147 children, 12 corpora). In terms of percent of variance attributed to between-children and between-corpora variance, linguistic measures were more stable than crying and vegetative measures (Meanlinguistic=81%; Range=61-91%; Mcrying = 72%, R= 62-82%; Mvegetative = 40%, R= 21-64%). Together, these data suggest that the strongest and most reliable index of communicative development in LENA data pertains to vocalizations automatically classified as linguistic, a finding that can be employed in subsequent work looking, for instance, at structured variance sources (e.g., input quantity). That said, this rich dataset also reveals wide variation on linguistic metrics, inviting further exploration including for other automated measures. The lack of correlation between average linguistic vocalization length and age, and its low cross-recording stability may indicate that this software does not reliably capture gains in utterance complexity that typically emerge over toddlerhood, when infants move from single words to multiword utterances.

S1.4: Early language processing and language exposure across-cultures: UK and India

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Language development is a key predictor of later cognitive abilities. Thus, it is crucial to develop reliable, sensitive and culturally appropriate early measures. Language experience plays a key role in language development, but not many studies have looked at the relationship between natural language input and the underlying cognitive processes. Moreover, it is not clear how different aspects of language input impact language development across different cultures and languages since most data sets are from English-speaking industrialized countries. The objective of this study is to measure the relationship between natural language input and early language processes across two different cultures and languages (UK and India). We collected three days of LENA home recordings in both populations when children where 6 - 9 months old. We extracted measures of adult word count, conversational turns, and child vocalisations per hour, across days. To measure language outcomes, we tested the same infants (at 15 - 26 months old), on the Early Language Processing (ELP) tool. We developed and validated the ELP across the two populations with infants from different backgrounds (low and high SES),

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languages (English and Awadhi) and cultures. The ELP uses a portable eyetracker and is based on three well-researched tasks that measure basic language processing: The Computerized Comprehension Task (CCT; Friend & Keplinger, 2003), word processing speed (Fernald, et al., 1998), and referent selection and retention (Bion, Borovsky & Fernald, 2013; Samuelson, Kucker & Spencer, 2017). It consists of two blocks of 34 and 29 trials separated by a 5-minute retention interval. On each trial, a pair of pictures is displayed for 2000 ms. Then a gaze contingent character appears in the middle and names the target. The pictures remain for a 3200 ms response period. There are three types of trials providing multiple "outcome measures": Comprehension trials measure understanding of easy, moderate and difficult nouns, verbs and adjectives and speed of processing. Novel Mapping Trials measure novelty detection and mapping of novel names to novel objects. Retention Trials, measure memory for new word-object mappings. Data processing is ongoing but preliminary indications are that while the ELP is equally engaging for children from both cultures, children in the UK (n = 122) look overall more at the target across the different outcome measures than kids in India (n = 30). Preliminary data relating speed of word processing (RT of first look) and language input measures in the UK (n = 30), show clear relationships between input measures and speed of word processing such as that more adult words, turns and child vocalisations are related to faster processing in younger children. These input measures do not appear to continue to add benefit for the older children. This work provides a unique opportunity better assess the impact of language input on the different ELP measures within and across both populations.

S2: Environmental influences on infant attention: a global perspective

S2.1: Undernutrition in infancy impacts early brain development in The Gambia: An fNIRS study

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Background: One in three children growing up in low income countries fail to reach their cognitive milestones by school age (McCoy et al., 2016). The Brain Imaging for Global Health (BRIGHT) study is implementing longitudinal measures of brain development from 0-24 months in the UK and The Gambia, West Africa (Katus et al., 2019). The aim is to develop brain function-for-age curves and assess the impact of social and environmental factors in order to inform future interventions. This

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analysis focused on data collected in The Gambia and assessed the relationship between a functional near infrared spectroscopy (fNIRS) measure of infant habituation and novelty detection (HaND) from 1 -12 months and markers of early growth and iron status, as a proxy for undernutrition. Context: The study was conducted in West Kiang, The Gambia, a rural community comprised largely of subsistence farmers. Within West Kiang, undernutrition is widespread, particularly among infants and young children. Most families do not have piped water, flush toilets or electricity within their homes. Methods: The fNIRS HaND paradigm investigates (i) the development of cortical habituation responses to a repeating spoken sentence during a total of 15 familiarisation trials (trials 1-5 [Fam. 1], 6-10 [Fam. 2] and 11-15 [Fam. 3]), and (ii) cortical responses to novelty (during trials 16-20 when the sentence switched to a novel speaker). Valid data from 1 month (n=137), 5 months (n=138), 8 months (n=99) and 12 months (n=121) of age were assessed. Results: fNIRS results showed that on average, infants exhibit significant habituation within the familiarisation trials from 8 months of age (but not 1 and 5 months) and do not detect novelty at any age up to 12 months. This contrasts with the UK cohort in which habituation was evident from 5 months and novelty detection from 8 months (Lloyd-Fox, Blasi et al., 2019). A substantial response variation within the Gambian cohort was observed and analysis at the individual level suggested that some infants habituated and detected novelty in a similar pattern to UK infants. HaND responses at 5 months were positively associated with responses at 12 months. Preliminary analyses suggest that iron depletion, slower head growth and slower weight gain in early infancy (0-5 months), is associated with weaker habituation responses at 12 months. There is a trend towards a similar relationship between early head growth and habituation at 5 months, suggesting the effect is becoming stronger over time. Conclusion: Infants with poorer growth and iron depletion in early infancy show attenuated habituation responses at 12 months. Further analysis is needed to fully elucidate the relationships between growth, iron status and brain development over time, as well as the wider cognitive implications of attenuated habituation responses. References: McCoy et al., 2016, PLOS Med, 13(6); Katus et al., 2019, Gates Open Res, 3:1113; Lloyd-Fox et al., 2019, Dev Sci, e12817.

S2.2: Contributions of cumulative parent cortisol to the neural underpinnings of infant attention and emotion regulation

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Introduction: A wealth of literature has demonstrated that environments of risk are associated with differences in neural activity in infancy (Brito, 2017) and cognitive and emotion regulation abilities in childhood (Blair, 2012). Given that infants are

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highly reliant on their caregiver(s) for supporting development and self-regulation, one pathway by which environments of risk are thought to shape infant neurocognitive development is through the caregiver. In particular, the caregiver's level of (cumulative) stress, often measured physiologically by the hormone cortisol, may be an important factor contributing to the infant's neurocognitive function and development. However, research has yet to examine the associations between chronic parental physiological stress on infant neural markers of developing self-regulation abilities. Thus, in the current study we investigated the effects of cumulative parent cortisol on infant neural activity longitudinally from 3- to 9-months of age. Methods: Parents and their infants at 3-months of age were recruited from the New York City Metropolitan area to participate in this study. Families reflected a wide range of socioeconomic backgrounds (maternal ED=9-26 years, annual family income - $12k-$500K). Families were brought into the lab at 3-months of age (current N=54) and returned at 9-months (current N=22). At the 3-month visit, a hair sample was collected from the parent and assayed for cortisol and infant EEG was recorded during an attention eliciting video paradigm (task adapted from Xie et al., 2017). Frontal theta power (4-6 Hz; neural indicator of attention abilities) was calculated during phases of sustained attention (indexed by coding infant looks and measuring heart rate deceleration). At the 3- and 9-month visit, five minutes of baseline EEG was recorded while the infant watched a passive, non-social stimuli video. Frontal alpha power (6-9 Hz) asymmetry was calculated by subtracting left frontal alpha power from right frontal alpha power (neural indicator of emotion regulation), such that higher values correspond to increased power in the right hemisphere. Results: Regression analyses indicate that caregiver cortisol levels were negatively associated with infant theta power during phases of sustained attention, such that higher levels of caregiver cortisol were associated with lower theta power. While caregiver cortisol was not significantly associated with alpha asymmetry at 3-months, it was a significantly related to alpha asymmetry at 9-months of age. Specifically, higher caregiver cortisol at 3-months was associated with decreased alpha asymmetry at 9-months of age. Moreover, multilevel model regressions indicated a significant interaction between caregiver cortisol at 3-months and within-person change in alpha asymmetry from 3- to 9-months, such that higher cortisol levels were associated with a longitudinal decrease in alpha asymmetry change across infancy (Figure 1). Conclusion: Results suggest associations between chronic parent stress and the neural underpinnings of infant sustained attention at 3-months and emotion regulation at 9-months of age. Examining associations between caregiver stress physiology and infant neural activity may help elucidate early mechanisms connecting environments of risk to differences in infant cognitive and emotional development.

S2.3: Physiological stress, sustained attention and cognitive engagement in 12-month-old infants from urban environments

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Introduction 300 years ago, 5% of the world's children were born in cities, compared to over 55% today. However, surprisingly little research has examined how early exposure to High Density (HD) environments associates with biological and cognitive differences in children (Evans, 2006), and no previous research has examined how HD environments affect early development, during infancy. Methods To assess this, we recruited a cohort of 82 12-month-old infants from diverse backgrounds across the South-East of the UK, which shows both high- and low-density living environments (see Figure 1). Participating infants attended two sessions: at the first, infants wore miniaturized microphones and cameras, along with physiological stress monitors (electro-cardiogram, actigraphy) to provide a day-long recording of auditory and visual noise in home settings. Participating infants also attended a lab testing battery, where we assessed: i) infants' capacity to sustain attention towards an engaging target for an extended period of time, and ii) to recognize previously presented objects following a short delay (recognition memory); iii) infants' emotion reactivity to a mild stressor using the still face procedure (Weinberg & Tronick, 1996); iv) brain activity, concentrating on the theta band which is widely recognized as a neural marker of cognitive engagement and attention during infancy (Begus, Southgate, & Gliga, 2015). We recorded and controlled for, wider socio-demographic influences in our sample by measuring maternal education, household income, and adverse/stressful life events. Results Our results suggest that 12-month-old infants raised in high density (HD) environments show decreased Respiratory Sinus Arrhythmia (RSA), considered a marker of elevated physiological stress and that associations between HD environment and infant RSA are independent of socioeconomic status, lifelong stressors and maternal RSA. (p=.003) Based on previous research into the relationship between physiological stress and cognition (Arnsten, 2009), we predicted that increased physiological stress would associate with a cognitive profile including both weaknesses and strengths. Our findings were consistent with this. Behaviourally, HD infants showed poorer sustained attention (p=.01), along with increased reactivity during an emotion elicitation task (p=.004). However, they also showed increased recognition memory for novel, briefly presented stimuli (p=.033). When we measured neural activity we found that associations between visual engagement and theta power were higher in the HD infants (p=016). Discussion Overall, our results suggest that infants raised in HD environments show elevated physiological stress, even when other sociodemographic variables are controlled for. Behaviourally, HD infants show reduced sustained attention but superior memory for briefly presented stimuli. Future work should investigate how these early-emerging differences associate with altered long-term developmental trajectories and study how early learning environments can be optimised to take account of these differences.

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S3: Investigating the relationship between representing the self and the other in early development

S3.1: The role of self-awareness in selective facial mimicry of native over foreign speakers

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Introduction Research has shown that our identity is partially defined by our sense of belonging to certain social groups (Tajfel & Turner, 1986). Infants show a preference for in-group members from an early age (Liberman et al., 2017), which may be driven by a preference to interact with familiar others. However, it is likely that social categorisation based on self-comparison is only possible once infants have developed self-awareness. Self-awareness is thought to develop around 18 months, as indexed by the mirror self-recognition (MSR) test (Amsterdam, 1972). Here we investigated this relationship by asking whether the tendency to selectively mimic linguistic in-group over out-group members is associated with self-awareness, as measured by MSR. We hypothesised that 18-month-olds who show self-recognition would exhibit greater facial mimicry of the in-group than out-group model, compared to infants who do not show self-recognition. Methods 18-month-olds observed videos of a Native or a Foreign speaker performing facial actions (de Klerk, et al., 2019) while we measured activation of their corresponding facial muscles using electromyography (EMG) to obtain an index of mimicry (Fig 1). We used the mirror self-recognition (MSR) task to assess the infants' self-awareness. After normalising the muscle activity, we calculated a mimicry score per trial, per condition (EMG over the corresponding muscle region - EMG over the non-corresponding muscle). 47 18-month-olds were included in the EMG analyses, 23 were classified as Recognisers and 24 as Non-Recognisers. Results A repeated measures analysis on the Mimicry scores with Linguistic group (Native vs. Foreign speaker), and Action type (Mouth vs. Eyebrow) as within-subject factors and MSR status (Recogniser vs. Non-Recogniser) as between-subjects factor demonstrated a significant main effect of linguistic group, $F(1, 45)=5.089$, $p=0.029$, $\eta p2=0.099$ (Fig 2A) and no significant interaction between Linguistic group (Native vs. Foreign speaker) and MSR (Recognisers vs. Non-Recognisers), $F(1, 45)=0.009$, $p=0.924$, $\eta p2=0.001$ (Fig 2B). Infants showed significantly greater mimicry in the Native compared to the Foreign condition). However, a paired- samples t-test on the average mimicry scores in the Native and Foreign condition showed a significant difference only in the Recognisers, $t(22)=2.15$, $p=0.043$, and not in the Non-

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Recognisers, t(23)=1.32, p=0.198 (Fig 2C). Moreover, the average mimicry score in the Native condition was significantly different from 0 only in the Recognisers, t(22) = 2.49, p=0.021, and not in the Non-Recognisers, t(23) = 0.23, p=0.841. Discussion Only 18-month-olds with a more advanced level of self-awareness exhibited significantly greater facial mimicry of actions performed by the native speaker, compared to the foreign speaker. These findings are consistent with previous studies that have shown an effect of emerging self-awareness on other imitative behaviours in toddlers (Zmyj et al., 2013). Our results suggest that instead of making infants generally more imitative, a more advanced level of self-awareness may instead make infants more aware of themselves in relation to others, enhancing imitative responses selectively of those that they are motivated to affiliate with.

S3.2: The mapping of others to oneself in 16-26-old infants

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The common view regarding understanding other's mental states in human ontogeny is that infants start from a me-first position, and through themselves they begin to understand other people around them. Recently, however, Southgate (in press) proposed that infants at a young age may start out altercentric, focusing largely on others' perspective. Then, through development they would rely increasingly on their own point of view. In particular, through the emergence of self-representation, infants would increasingly focus on themselves, and begin to separate their own perspective from that of others. The development of self in infants has been traditionally assessed with the mirror self-recognition task (MSR), Children typically start recognizing themselves in the mirror between 18 and 24 months of age. While this behavior is often taken as a hallmark of self-representation, the mirror self-recognition task (MSR) has been heavily criticized. To consider the social aspects of self-concept, we developed a novel task where we test whether infants map a state observed on their parent's face to themselves. Infants aged 16 to 26 months were presented with a sticker on their parent's cheek or forehead (depending on condition) without seeing how the sticker had been placed there. The infant was then offered a sticker, and we observed whether infants spontaneously placed the sticker in the same location on their own face. Preliminary results in 50 out of 72 preregistered infants show that they differentially place the sticker in the matching location on their own face (Fisher's exact p< .001). Moreover, in a subset of infants who also received MSR task (n=38), those who recognized themselves in the mirror tended to place the sticker in the matching location on their face more often than infants who did not (Fisher's exact p= .042). These results suggest that infants actively intervene to emulate a state observed on their parent's face by mapping it to their own face. Thus developmentally, around the emergence of self-representation, the ability to map others to oneself might emerge as well;

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which combined with the recognition that others are distinct from oneself, may give rise to the challenge of flexibly switching between these two perspectives. This would predict that around the time of recognizing themselves in the mirror, since the infants would have the possibility to reference their own knowledge to themselves; infants would begin to show less altercentrism and more focus on their own perspective and knowledge. We are exploring this hypothesis via presenting infants with a task assessing altercentric modulation; and predict that those infants who would show evidence of self-recognition on the MSR, or the sticker task, would show a smaller modulation. A sample of n=128 infants is preregistered, data collection is ongoing, expected to finish April 2020.

S3.3: Autocentric or allocentric? Exploring the co-development of self-representation and positive social behavior

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Self-representation is traditionally defined as an autocentric skill. However, self-representation is intimately connected to our representation of others. For example, at least by 3 years, our representation of how others might view us or be affected by our behavior gives rise to self-conscious emotions (pride, guilt, shame). These emotions are known to motivate children to adjust their behavior to conform with ideal social standards. However, there is regrettably little developmental work exploring the social functionality of the self, or characterizing the extent to which the self-representation might truly be viewed as autocentric. We report two studies tracking the development of the self-system alongside the development of prosocial behavior, an allocentric skill set with a similarly early ontogeny. In line with social identity theories, we hypothesize that one of the primary functions of the self-system may be to promote the internalization of social standards and positive social behavior. Study 1 investigated the relationship between self-awareness and prosocial behavior in infancy (N = 92, 11 - 46 months), based on parental report. There were positive associations between self-representation (as measured by the Stipek Self-Concept Questionnaire) and prosocial behavior (as measured by the Early Prosocial Behavior Questionnaire), r = .503; even when controlling for the child's general cognitive and motor development (as measured by the Parents Report Of Children's Abilities scale), r = .259. These results suggest that there is a close relationship between the emergence of the self-system and prosociality. However, longitudinal work is needed to explore the directionality of the relationship; self-representation may drive prosociality by instilling a social conscience, but prosocial choices may also help us to learn about the self and how our actions are viewed by others. Study 2 tracked infants longitudinally across the period of emergence of self and prosocial responses (N =111, 11 - 34 months) to follow up 3 to 6 months later (N = 83, 14- 40 months), using the same parental-

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report measures reported for Study 1. A final follow up is planned for Jan 2020 (6 to 9 months later). Preliminary cross-sectional analyses show that phase 1 of this study replicated the positive relationship between self-representation and prosocial behavior found in Study 1 (r = .469, controlling for general development r = .332). Regression analyses across phases indicated that self-representation in phase 1 predicted a significant 25% of the variance in prosociality in phase 2. However, earlier prosociality also emerged as a significant predictor of self-representation in phase 2, accounting for 29% of the variance. This pattern of results might be interpreted as challenging the traditional view that the development of self-representation is primarily cognitive and autocentric. Social factors are predictive of the development of self-representation, and it is clear that the development of self-representation has substantive social implications. These observations suggest that further investigation of the interrelated development of autocentric and allocentric aspects of the self-system is warranted.

S3.4: Implicit self-recognition in infancy predicts self-conscious emotional reactivity in childhood

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Background: Self-awareness—the ability to represent oneself in thoughts is assumed to develop around the age of two, when children can recognize themselves in a mirror. Self-awareness is claimed to be necessary for the occurrence of self-conscious emotions, such as shyness because to experience shyness, children need to understand that they can be an object of others' attention. However, recent theories and empirical studies suggested that expressions of shyness can be seen already in the first year of life, long before explicit self-recognition occurs (e.g., Colonnesi, Bögels, de Vente, Majdand?ić, 2013; Reddy, 2000). This may be because children may acquire some level of self-awareness without explicit self-recognition (Rochat, 2003). Children who acquire self-awareness early in development may easily become aware that they are a subject of other people's evaluation, which may be unfavorable and may result in self-conscious emotions (Fenigstein, 1979; Lewis, 2001; Nikolić et al., 2019). Here, we investigated if early signs of self-awareness defined as implicit self-recognition in a mirror at 12 months of age predict more shy expressions and blushing (a physiological marker of shyness) in evaluative settings at the age of 4.5 and 7.5, after children internalize social rules and standards and, thus, the experience of evaluative self-conscious emotions becomes salient. Method: One-hundred-twenty children (63 girls) who were part of a bigger longitudinal study were included in the analyses. At the age of 12, we conducted the Mirror Self-recognition task (without and with rouge). Behaviors such as smiling, vocalizing, pointing to the mirror, touching the mirror, and touching the face while looking at the mirror and the

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duration of the looking at the mirror were micro-coded. At the age of 4.5 and 7.5, children were asked to perform a song on stage in front of a small audience while being video-recorded by an unknown woman. Their shy expressions (smiling with a gaze and/or head aversion) during performance were micro-coded and their physiological blushing (blood pulse amplitude) was measured with a photoplethysmograph. Results: The difference score between the rouge-mirror condition and the baseline mirror condition for each behavior was made and the principal component analysis was conducted. Touching the face, smiling, and looking at the mirror grouped as one factor, which we labeled implicit self-recognition. Vocalization and pointing to the mirror grouped together, and they reflected non-self-referential behaviors. The composite scores of these two components were made and used as predictors of (1) shy expressions and (2) blushing. A higher number of behaviors that reflect implicit self-recognition (but not other behaviors) significantly predicted more shy expressions at 4.5 (but not 7.5) and more blushing at 4.5 and 7.5 (Figure 1). Conclusions: Children who display early self-awareness measured as implicit self-recognition display more self-conscious emotions throughout their childhood. Early self-awareness may make children being more aware of how they are perceived by others, thus, making them more sensitive to others' opinions of themselves, which can result in heightened self-conscious emotional reactivity.

S4: Early markers for neurodevelopmental disorders: towards the identification of trajectories to atypical cognitive outcomes

S4.1: Social and non-social early markers of ASD: The relationship between disengagement of attention and joint attention in high-risk siblings at 12 months of life

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Recent reviews of HR infant studies describe clear overt behavioral markers of ASD during the second year of life, such as the impairment of the Joint Attention (JA) abilities: this deficit is considered one of the core symptoms of ASD and a specific target of early treatments. Interestingly, despite the social "nature" of ASD, evidence in the first year of life reported early signs of ASD within the non-social domain and, in particular, suggested that early neurocognitive markers could precede the

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emergence of later social symptoms; among these, a slower disengagement of attention (DA) has been found in 6 to 14 months old infants who subsequently receive an ASD diagnosis. It has been supposed that a deficit in the ability to flexibly switch attention (hence, a slower DA) could also underpin JA skills, because of the rapid attentional shift required to move attention between object and people; despite this, only a few studies directly correlated these two dimensions. The objectives of this study are: 1) to explore if infants at High risk for ASD (HR) show a slower disengagement of attention and reduced Joint attention abilities than infants at Low-risk (LR) at 12 months 2) to correlate DA and JA skills at 12 months 3) to explore if an early impairment in these two dimensions correlates with the developmental outcome at 18 months. The sample is composed of 23 HR infants (M/F:19/4) and 17 LR infants (M/F:10/7), aged 12 months old. The ability to disengage attention has been measured using a gap-overlap paradigm (Figure1), with a central stimulus and a peripheral one. The task has been settled up including simple geometrical shapes, without social/nonsocial connotation, in order to avoid the visual preference for certain classes of stimuli. The DA was measured with an SMI eye-tracker. JA skills has been measured with the Early Social Communication Scales, a semi structured observation. Both HR and LR underwent a clinical assessment at 12 and 18 months. HR infants are more attracted to the task than LR infants: in fact, they paid attention to a higher number of trials (p=0,004) than LR infants, that generally became fussy or bored more rapidly. HR infants also showed a slower disengagement of attention from the central stimuli than LR infants (p=0,043) and a lower number of JA behaviors than LR infants (p=0,000). Disengagement of attention was also negatively correlated with the number of alternating gaze to initiate JA (Pearson's r= -0.395; p=0,046) and with other JA behaviors, such as the declarative pointing (Pearson's r= -0,486, p=0,012). A slower disengagement also positively correlates with the risk range of the ADOS-2 at 18 months. This study found that a slower DA is correlated with a lower number of JA behaviors: if these results will be further confirmed, these could improve screening procedures and could better define the target of early treatments. These results also support the utility of using the eye-tracking to detect early neurocognitive deficits that couldn't be detectable through behavioral observation.

S4.2: Atypical ERP responses to multisensory integration in infants at risk for Autism Spectrum Disorder

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Sensory and perceptual processing has been extensively studied within particular modalities (e.g., auditory or visual) revealing that sensory processing might act as shared and/or unique impaired mechanism underlying different

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neurodevelopmental disorders, such as Autism Spectrum Disorder (ASD) vs. Developmental Language Disorder (DLD). Beyond abnormalities in sensory deficits, individuals with ASD perform poorly during conditions that require integrated information across multiple sensory modalities. Previous research showed that atypical multisensory processing emerges early in life, possibly before some of the socio-communicative deficits associated with ASD and the underlying brain-based correlates may be critically involved in the emergence of the core features of ASD. However, a dearth of research has studied neural processing of audio-visual (AV) integration in infancy and AV multisensory integration has never been studied in infants at-risk for ASD (HR-ASD) through EEG/ERP techniques. The aims of the study are: (a) to explore whether and to what extent the ERP measures of AV integration differentiate HR-ASD from TD infants at 12 months of age and (b) to assess the association between early AV integration abilities and clinical measures of sensory responsiveness. At 12 months of age, 21 HR-ASD (siblings of children with ASD) and 19 typically developing infants took part in the study. ERPs were recorded during an AV integration task measuring the McGurk effect. AV match and mismatch videos of female faces pronouncing /pa/ and /ka/ syllables were presented in a block design: two congruent and two incongruent AV pairs (see Figure 1). Mean amplitudes in frontal and temporal areas (left and right) in the time-window 350-650 ms were entered into ANOVA to evaluate the effects of stimulus conditions. In addition, clinical measures of sensory processing were measured by the Sensory Profile questionnaire. The results showed a significant Condition x Hemisphere x Region x Group interaction ($F= 2.86$, $p= .040$). Separate ANOVAs contrasting the four conditions by group in each cluster of channels showed a significant Condition x Group interaction in the temporal left region ($F= 3.69$; $p= .015$): only in the TD group, mean amplitude for the Mismatch condition was significant higher compared to both congruent conditions (Bonferroni ps $< .028$; see Figure 2). In addition, voltage difference between mismatch and congruent conditions in temporal left region was associated to clinical measures of sensory processing (sensory sensitivity, $r(39)= .583$; $p< .001$; visual processing score, $r(39)= .385$; $p= .016$): infants with greater voltage difference were characterized by higher scores in sensory sensitivity and visual processing. Differential brain responses to AV integration emerge at 12 months between TD and HR-ASD, specifically when auditory and visual stimuli cannot be integrated into a fusible percept (i.e. mismatch condition). Furthermore, these ERP responses are associated to clinical measures of sensory responsiveness, in terms of reduced reactivity to sensory input. Further research should explore the relationship between uni- and multi-sensory processing in ASD and the specificity of this early marker with respect to other neurodevelopmental disorders characterized by deficits in unimodal sensory processing deficits (e.g., DLD).

S4.3: Visual implicit learning abilities in infants at familial risk for Development Language Disorder

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Developmental Language Disorder (DLD) is a neurodevelopmental disorder affecting almost 5-7% of preschool-age children. Even though the diagnosis is made in preschool years, early risk signs can arise in the first years of life. Recently, inter-individual variations in implicit learning abilities allowing the extraction of transitional probabilities from sequences of items (Statistical Learning, SL; Saffran & Kirkham, 2018) and the extraction and generalization of high-order rules (Rule Learning, RL; Rabagliati et al., 2019) have been proposed as possible early markers of typical and atypical language development. However, although SL and RL are domain-general abilities associated to different components of language (i.e., phonology and syntax; Endress et al., 2009; Perruchet & Pacton, 2006), prospective studies investigating their predictive role as early markers of language proficiency are scarce. Here we present the first results of a prospective study in which infants at low-risk (LR) and high-risk (HR) for DLD are followed longitudinally from 6-8 to 24 months, and risk is defined as having at least a first-degree relative with a certified diagnosis. HR and LR infants are matched for age, sex, and the socioeconomic status of their parents (Hollingshead, 1975). At 6-8 months, infants are tested for their SL and RL abilities. In the visual SL task (N = 16/16 LR/HR), they are habituated to sequences of shapes organized into three pairs presented in random order, with a transitional probability between shapes being 100% within pairs and 33% between pairs. At test, the familiar sequence and a novel sequence, in which the shapes were presented in random order, appear in an alternate order for six trials. In the visual RL task, infants (N = 17/17 LR/HR) are habituated to triplets of visual shapes containing a high-order repetition-based rule (ABA) and presented at test with the familiar and novel rule (ABB), both instantiated by a new set of shapes. In both tasks, infants' ability to extract the structure embedded in the habituation sequences is inferred from their looking times to the familiar, and the novel test sequences being significantly different. In the SL task, habituation times do not differ between HR and LR infants ($p = .964$), and infants in both groups look longer to the novel sequences than to the familiar one at test ($ps < .040$). In the RL task, looking times during the first habituation trials are longer for HR than for LR infants ($p = .043$), and a significant novelty preference at test is present for LR infants ($p = .005$) but not for HR infants ($p = .882$). These results suggest that visual SL and RL abilities might play a distinct role in the development of language disorders, as SL seems to be preserved in HR infants, while RL seems to be impaired. We are now collecting follow-up information on language development at 24 months of age to have a better insight into the roles played by SL and RL in language development.

S4.4: Understanding variable outcomes in genetic syndromes: The importance of early developmental phenotyping

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Understanding variable outcomes in genetic syndromes: The importance of early developmental phenotyping With the increased availability of genetic testing, multiple genetic alterations have been associated with atypical developmental outcomes. As a growing number of individuals receive increasingly early diagnoses, there is both the clinical imperative and the research opportunity to find ways to implement deeper phenotyping, to reveal both general and more specific trajectories to cognitive outcomes for these individuals. Today I will focus on evidence suggesting that an understanding of early individual differences in cognition, for these groups, may provide some clues to understanding their variable developmental trajectories. First, I will discuss longitudinal data from young children with fragile X syndrome, a group associated with high risk of attention deficits in childhood. A series of longitudinal findings, using methods that allow for deep phenotyping, suggests that early group-level and individual differences in attentional processes predict differences in later behavioural difficulties. The second line of research focuses on children with Williams syndrome and Down's syndrome, to suggest that differences in attention between and within these supposedly homogeneous syndrome groups, as well as individual differences in domain-specific skills, predict variable classroom outcomes in emerging literacy or numeracy. A number of general conclusions emerge. First, links between genes, brain and cognition need to be situated in a developmental context, even in these relatively simple genetic disorders. Second, the increase in early diagnoses offers the opportunity to study developmental trajectories of risk and resilience for complex behaviourally-defined disorders that are in the main diagnosed much later in childhood, and their comorbidity. Finally, these findings suggest understanding good outcomes, as well as weaknesses, may help guide more syndrome-specific and effective intervention.

S5: The rhythm of our heart and mind: Neurophysiological responses to communicative rhythms in parent-infant interactions

S5.1: The impact of nurturing stroking versus non-stroking touch delivered by mothers and stroking touch by fathers on infants' regulatory cardio-respiratory processes

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The beneficial effects of nurturing touch for young infants were already observed in several types of skin-to-skin care. We will present two studies that examined, at the one hand, the underlying mechanisms of these effects in terms of respiratory sinus arrythmia (RSA) or parasympatho-inhibitory regulation in infants and, at the other hand, whether these underliers responded differently to maternal versus paternal stroking touch. In study 1, we examined RSA during a 3-min stroking versus non-stroking touch period delivered by mothers with a baseline before and after touch delivery (N = 45; age infants 4-16 weeks). In study 2, we compared, likewise, the impact of a 3-min maternal versus paternal stroking touch period in comparison with a baseline before and after touch delivery on infants' RSA (N = 50; age infants 4-16 weeks). During stroking touch, the mothers and fathers were asked to self-select their stroking speed and stroking body location. We registered infant ECG, respiration and made video-recordings. We calculated RR-interval (RRI), respiration rate (fR) and respiratory corrected RSA (RSAcorr) and analyzed the mean stroking speed of the mothers and the fathers along with selected body location. ANOVA-tests showed a significant different impact on infants' RSAcorr of stroking touch (increase) versus non-stroking touch (decrease) which was mediated by heart-rate and respiration. During and after stroking touch, RRI significantly increased whereas fR significantly decreased. Non-stroking touch had no significant impact on infants' RRI and fR. When comparing maternal and paternal stroking touch, we found no difference between both. Infants' RSAcorr significantly increased during and after stroking, no matter whether touch was delivered by fathers or mothers. Also these effects were mediated by both heart rate (HR) and respiration. Both mothers' and fathers' stroking speed occurred within the optimal stimulation range of c-tactile (CT) afferents and at body-locations known to be rich of CT afferents. CTs are a particular class of cutaneous unmyelinated, low-threshold mechano-sensitive nerves hypothesized play a role in the processing of affective touch and social bonding. We suggest CT afferents to be the a potential missing link between the processing of affective touch and the development of physiological and emotional self-regulation. Moreover, the apparent role of CT afferents within the building of early self-regulation as part of a multisensory intuitive parenting system that makes no difference between mothers and fathers might mitigate fathers' doubts about their paternal capabilities that are still present.

S5.2: The role of physiological synchrony for attachment

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Caregiver-infant interactions are at the core of the development of the infant's attachment system, but the underlying neurophysiological mechanisms are still unclear. A central feature of these interactions is the sharing of affective states, which has been proposed to emerge through bio-behavioral synchronization between mother and infant (Atzil & Gendron, 2017). Despite the empirical evidence in the behavioral domain (e.g. Lundy, 2003), less is known about the link between attachment and physiological synchrony. Accordingly, we want to investigate whether physiological synchrony in mother-infant interactions at 4-6 months of age is related to infant's attachment at 12 months of age. Here, we first tested 4- to 6-month-old infants and their primary caregiver (N=69 dyads) in three conditions and then again at 12 months of age. During the first measurement time point, caregiver and infant were either seated next to one another or the infant sat on the caregiver's lap as both were watching a calm aquarium video on a tablet (distal watching and proximate watching conditions). Next, mother and infant engaged in a 5-minute long free play without toys while both were seated face-to-face (interactive free play condition). We assessed physiological synchrony in terms of respiratory sinus arrhythmia (RSA) through electrocardiography (ECG). We used two standard single-channel ECG registrations (lead II derivation) for the mother-infant dyad. RSA was calculated with the Porges-Bohr Method. Next, mother-infant RSA time-series were cross-correlated to extract a physiological synchrony value for each dyad in each condition. During the second measurement time point, two trained raters observed each familiy in their home for two hours and assessed families on the attachment Q-Sort scales. Attachment security is indicated by a correlation value based on behaviors of a typical securely attached child, with r=0.30 separating secure attachment from insecure attachment. Preliminary findings reveal that mother-infant dyads (n=57) show lower physiological synchrony during the distal watching condition, t=-2.46, p=.02, compared to both proximal watching and free play conditions, p>.62 (see Figure 1). This shows that physiological synchrony arises in face-to-face interactive contexts as well as in close physical proximity, even when mother and infant are not interacting with one another. Taking attachment measures from the second measurement time point (n=12) into account, we find a negative correlation between physiological synchrony, irrespective of interaction condition, and attachment security, t=-2.15, p=.04. This finding indicates the potential role of physiological desynchronization in attachment development. We will further report analyses of social touch measures and discuss these results in the context of functions of physiological synchrony and variables predicting attachment.

S5.3: Effects of maternal infant-directed singing on infant physiological arousal

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Infant-directed (ID) singing is often intuitively used by caregivers during early interactions with their infants (see e.g., Cirelli, Trehub, & Trainor, 2018, for review). The characteristics of ID singing (i.e., high pitch, slow tempo, enhanced regularity of canonical temporal organization; Nakata & Trehub, 2004, 2011) enable even very young infants to be more attentive to and more engaged during ID than non-ID singing or speech (see Provasi et al., 2014, for a review). It has been argued that depending on its soothing or playful style, ID singing can help caregivers to direct infants' attention as well as regulate their affective states (Trainor, 1996). However, only few studies have examined the effects of soothing and playful ID singing on infant arousal (Cirelli, Jurewicz, & Trehub, 2019; Shenfield, Trehub, & Nakata, 2003). The goal of the present study was to investigate the effect of different maternal ID singing styles on infant physiological arousal (i.e., heart rate). Thirty mothers and their 7-month-old infants were observed during two singing conditions, the order of which was randomized between participants. Each singing condition was preceded and followed by a baseline (i.e., three baselines in total), during which mothers and infants watched infant-friendly videos (e.g., colorful aquarium) for 60 s without any further communication. During each singing condition, mothers were instructed to sing 8 verses of one of two songs: a playsong and a lullaby. Heart rate was measured via two-lead placement on the infants' chest. Heart rate variability (HRV) as an index of infant physiological arousal was computed as root mean square of successive differences for each singing condition and controlled for HRV of the preceding baseline. Higher HRV difference scores are indicative of lower physiological arousal. Preliminary analysis of 11 7-month-old infants (M = 226.36 days; SD = 6.30 days) shows a significant difference in HRV difference score between the lullaby and the playsong condition, $t(10) = 2.49$, $p = .032$, Cohen's $d = 0.75$), indicating decreased arousal in the lullaby condition (see Figure 1). Acoustic analyses of maternal singing revealed that playsongs had significantly higher pitch, faster tempo and loudness (see Table 1), suggesting that mothers differentiated in their singing between the two songs. Preliminary results of the present study suggest that infant physiological arousal decreased during maternal soothing singing, corroborating existing evidence (e.g., Cirelli et al., 2019). Maternal ID singing seems to play an important role for down-regulating of infant arousal, thus serving as a possible emotion regulation mechanism.

S5.4: Mutual gaze leads to phase reorganization and concomitant short-term increases in interpersonal neural synchrony

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We know that infants' brains are highly sensitive to gaze: adult direct gaze increases infants' engagement during early face-to-face interactions, reinforcing early social expressiveness (Bloom 1974). Further, direct vs averted gaze has been shown to elicit greater time locked neural responses and activate similar neural structures in infants to those of adults in response to communicative signals (Grossmann et al., 2008). We also know that temporally inter-dependent relationships arise between the brains of two or more individuals during ongoing social interaction. Recent work has demonstrated increased inter-brain phase synchrony around moments of behavioural coordination in both adult-adult and adult-infant pairings, for example, during moments of mutual gaze vs non mutual gaze (Leong et al., 2017). One possibility is that taken together these findings suggest a possible mechanistic role of eye contact and its concomitant neural responses in establishing inter brain connectivity. The aim of this study was to investigate whether moments of mutual vs non mutual gaze lead to greater increases in intra brain phase locking (i) and whether this, in turn leads to greater short term increases in inter brain phase locking (ii). We recorded dual 32-channel electroencephalography (EEG) from 10-12-month-old infants and their parents during free-flowing naturalistic play. The current analysis is based on an N=8 sample as this study is ongoing. Based on current testing schedules the sample size by July 2020 should be N=85. Parents were asked to stage a conversation between their infant and a hand puppet. The naturalistic paradigm created a comparable number of spontaneous instances of mutual (reciprocated) and non-mutual (non-reciprocated) looks to the partner led by either parent (mean 36/38 for mutual/non-mutual) or infants (mean 31/26).Intra brain phase locking was assessed through Inter Trial Coherence (ITC). The time-frequency properties of phase synchronisation between parents and infants, was estimated by means of the 1:1 as well as n :m phase synchronisation indices, in order to track possible differing dominant frequencies between infants and adults. Rayleigh's test for circular uniformity revealed significant phase clustering for both gaze types; following mutual gaze onsets ($R= 7.96$, $p<.001$) and following non mutual gaze onsets ($R=4.98$, $p=0.002$). A circular Watson-Williams test was calculated on averaged ITC values. This analysis did not reveal a significant main effect of gaze type ($F(1,11)=1.76$, $p=0.21$). Adult- infant dyads showed a greater (more positive) increase in ITC during the time window (- 100ms to 700ms) following mutual vs non mutual gaze onsets (although insignificant ($p=0.21$) based on current sample size of N=8). Additional analysis also revealed a significant main effect of electrode cluster, with ITC values being more positive over occipital compared to central ($F(1,15) =8.36$, $p=0.01$) and frontal electrode clusters ($F(1,9) = 5.9144$, $p=0.03$).We found that moments of mutual vs non mutual gaze lead to greater transient increases in ITC, (concurrently in both infants' and adults' brains) and greater short term increases in inter brain phase synchronisation regardless of whether the mutual gaze episodes were initiated by adult or infant. Our findings offer new insights into how neural synchrony develops on a sub second time scale.

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S6: Timing is everything: The temporal dynamics of labeling in typical and atypical language development

S6.1: The temporal dynamics of labeling shape object recognition

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Caregivers often present objects and their labels in synchrony (e.g., shaking an object just as they utter the word for it) for young infants. Such cross-modal synchrony powerfully attracts infants' attention and promotes learning word-object mappings. We tested whether synchrony also influences how infants represent objects themselves. Because synchrony enhances attention to information present across modalities (such as temporal overlap) and reduces attention to information specific to one modality (e.g., visual features of objects), we tested the hypothesis that word-object synchrony influences how well infants encode and subsequently recognize objects. Six-month-olds (N=60) were given three train-test trials. On each trial, infants were briefly familiarized to a word-object pairing and then immediately tested on their ability to recognize the object in silence. Infants were assigned to one of three Training conditions differing only in the temporal dynamics of word-object pairings, such that on all three train-test trials a word occurred 1) in synchrony with an object's motion, 2) out of synchrony with an object's motion, or 3) paired with a static object. Infants were then tested on their ability to recognize the familiarized object using visual paired comparison. The familiarized object was always present, and across Trial Types it was paired with a foil differing in both shape and color, in shape only, or in color only. Infants were given two successive test trials for each Trial Type, and the right-left target position of the objects was counterbalanced across them. Performance in each of the Training Conditions is depicted in Figure 1. Across all conditions, infants were able to recognize a familiarized object, and in fact looked longer at it, when paired with a highly dissimilar foil at test (i.e., the top panel of Figure 1; Shape-and-Color-Different Trials, $p<.001$). However, performance on the other Trial Types differed by Training Condition, $p<.05$. Infants in the Synchronous condition recognized the familiarized object in both Shape-Different and Color-Different trials. On Shape-Different trials, they showed a familiarity preference on Trial 1, and a novelty preference on Trial 2, $ps<.05$. They showed the opposite pattern on Color-Different trials (a novelty preference on Trial 1, and a familiarity preference on Trial 2, $ps<.05$). Critically, infants in the Asynchronous and Static conditions showed minimal evidence of recognizing the familiarized object in these trials, looking equally to the familiarized object and the foil. In sum, infants in all training conditions recognized (and were

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drawn) to the familiarized object when it was contrasted with one that differed in both shape and color. However, only infants in the Synchronous condition were able to recognize the familiarized object when the foil differed only in shape or in color. Moreover, their gaze was first drawn to an object that had the same shape. This suggests that word-object synchrony facilitates object recognition, and may especially highlight object shape. Thus, word-object synchrony may influence pre-lexical development by supporting the formation of robust, shape-driven object representations, in effect determining the meanings that infants establish for the words their caregivers use.

S6.2: Relative contributions of infant-directed speech and motion when learning new words

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When interacting with infants, parents modify how they speak and how they move objects. Infant-directed (ID) speech has a higher fundamental frequency more exaggerated pitch contours, and slower rate than adult-directed (AD) speech (e.g., Fernald, 1992). The typical functions ascribed to IDS are communication of emotional content (Fernald) and facilitation of associative learning (Kaplan et al., 2002). Infant-directed motion ("motionese", e.g., Brand et al., 2002) is also more exaggerated, and is thought to function to organize infant visual attention. Infant-directed speech and motion are usually studied separately from one another. To examine the relative contributions of speech and motion on infant attention and learning, we manipulated speech and motion type (ID vs. AD) in a novel word learning task. Infants (13-month-olds, n = 72; 15-month-olds, n = 53) participated in face-to-face interactions with an experimenter. The experimenter labeled a novel object and a distracter object, using ID or AD speech. For half of the infants, the experimenter moved the objects in synchrony with her speech during labeling. For the remaining infants, objects were held still during labeling. Novel word comprehension was tested immediately and the next day. To test whether infant comprehension was significantly different than would be expected by chance, mean proportion of correct choices were compared to chance performance (.50) in separate one-sample t-tests (Figure 1). For 13-month-olds, only infants trained in the ID-motion condition showed consistent performance at session 1, $t(17)=2.40$, $p<.05$, and session 2, $t(17)=3.49$, $p<.01$. For 15-month-olds, at session 1, only infants trained in the ID-motion condition showed reliable comprehension performance, $t(13)=2.47$, $p<.05$. At session 2, only infants trained in the ID-no motion condition showed reliable comprehension, $t(14)=5.17$, $p<.001$. In summary, 13-month-olds required IDS paired with synchronous motion to learn words, but IDS alone was sufficient for 15-month-olds to learn. Thus we showed developmental shifts in infants' weighting of speech and motion when learning novel words.

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Synchronous motion facilitated word learning in younger infants, but only when paired with ID speech. For older infants, ID speech, but not motion, improved memory for novel words. Previous research suggests that sleep promotes infant retention of recently encoded language (e.g., an object-referent mapping) and memory reorganization, possibly promoting generalization of previously learned information to new experiences (Gómez, Bootzin, & Nadel 2006; Friedrich et al., 2015). Multimodal labeling trials, followed by sleep, may have allowed infants to actively sustain and organize word memories at 13 months. By 15 months, multimodal information was no longer necessary, though IDS still supported learning. The findings illuminate developmental changes in infants' use of social information present in parent-infant interactions, and provide direct evidence that infants use ID speech and motion in early word learning. The form and timing of social interaction guides infants towards the correct referents for words via cues that 1) get and maintain attention, and 2) co-occur with the activity of labeling objects. These findings provide insight into how social cues present in the environment might facilitate word learning by structuring the environment in ways that capture infant attention.

S6.3: Maternal synchronous gesture adaptations during object naming to term and preterm infants: A longitudinal study

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Mother-infant interactions are typically dynamic and adaptive. During naming, mothers use synchrony between spoken words and object motions or actions more often at 6-9 months than at 12 months, to match their term infants' level of perceptual and lexical abilities. In comparison, mothers of preterm infants adapt their naming less to match their 6 and 12-month-old infants, who, in turn, show attenuated word learning (Gogate, 2019). Typically, mothers also facilitate infants' lexical learning by using showing gestures (e.g., shaking or looming actions) more often in synchrony with spoken words to scaffold preverbal infants' attention to naming contexts (Matatyaho & Gogate, 2008). It has not been established, however, whether the attenuated maternal adaptations during naming to preterm infants also extends to their use of showing gestures. The present longitudinal study examined maternal use of action-types during synchronous versus asynchronous object naming to moderately preterm and term infants at 6-9 (visit 1) and at 12 (visit 2) months. We hypothesized that mothers of term infants would adapt their use of showing gestures to match their infants' word-learning abilities more than mothers of preterm infants. Thus, mothers of term infants should use showing gestures more often to word-learning novices at 6-9 months than at 12 months, but not the mothers of preterm infants. Method Participants. Mothers and their term (GA 37-40 weeks, N= 38) or preterm (GA 32-36 weeks, N=39) infants were seen at two time points

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during visit 1, chronological age 6-9 months and visit 2,chronological age 12 months. Procedure. Mothers were asked to teach the names Gow and Chi for two toy objects, a cloth Martian and a Raccoon at visit 1, and the names Tah and Gih for two toy objects, a plastic porcupine and a crab at visit 2 (Figure 1A, 1B, & 1C). Coders independently coded each maternal object naming category, synchronous and asynchronous, involving hand-held object motions into seven action-types (shaking, looming, sideways, upwards, backwards, squeezing and motion combinations). To calculate action-type proportions, maternal actions of each type during synchronous or asynchronous object naming were divided by the total number of word tokens in synchronous or asynchronous naming. Results and Conclusions Mothers of preterm infants adapted less across visits in their action-use during naming. A mixed-ANOVA of maternal action proportions x Action-type (7, shaking, looming, backward, sideways, upward, squeezing, motion-combinations) x Naming-Style (2) x Visit (2) x Group (2) yielded a 3-way interaction of Action-type x Visit x Group, $F(6, 73) = 2.47$, $p = .03$, $\eta p2 = .03$. Post-hoc Bonferroni pairwise-comparisons revealed that mothers of term infants alone used Shaking object-motions, a type of showing gesture, more often at visit 1 than at visit 2 (Table 1). An Action-type X Naming-style interaction showed that mothers of both groups used shaking actions more often during synchronous (.73) than asynchronous (.43) naming, regardless of visit. Relative to mothers of term infants, mothers of preterm infants demonstrate attenuated adaptation of their showing gestures during naming. These findings highlight the dynamic and adaptive nature of mother-infant interactions.

S6.4: Children's hearing loss affects the synchrony between parents' object naming and children's attention to objects in parent-child interactions

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Many children with hearing loss show spoken language delays even after long-term use of hearing aids or cochlear implants. Most studies on language outcomes in children with hearing loss have focused on demographic, audiological, linguistic, and environmental factors. Another important, yet unexplored, area is how children's attention during parent-child interactions affects language development. A growing body of research with children with normal hearing suggests that children's sustained visual attention to objects during play is associated with their learning of novel words and long-term language development. The current study used head-mounted eye-trackers to examine the real-time attentional patterns of children with and without hearing loss in parent-child interactions. We examined the synchrony between parents' naming of novel objects and children's sustained attention to the named objects in joint play. Three groups of toddlers (age range: 12 - 37 months) along with their hearing parents participated in the study: children

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with hearing loss (HL), hearing children matched to the HL group on chronological age (CA), and hearing children matched to the HL group on hearing age (HA). During the experiment, parents and their toddlers played with novel objects and each object was paired with a novel name. Both participants' attention and parents' speech were recorded during the interaction. We examined 1) the quantity of parents' naming of the novel objects, 2) the quantity of children's sustained attention to the novel objects, which was defined as looks to the objects > 3s, and 3) the synchrony between parents' naming of the novel objects and children's sustained visual attention to those same objects. To investigate the synchrony between parents' naming utterances and children's sustained fixations, we categorized parents' utterances into Hits and Misfires. As illustrated in Fig. 1, a Hit was a naming utterance of an object that overlapped, either partially or completely, with children's sustained fixation to the same object; while a Misfire was a naming utterance of an object which did not overlap with children's sustained attention to the same object. We found that the parents in the HL group produced similar amounts of object naming as parents in the CA and HA groups. In addition, children in the HL group demonstrated similar amounts of sustained attention to the objects in play as their CA and HA peers. However, there were significant differences in the temporal synchrony of parents' object naming with children's attention to the named objects in the HL group compared to their CA and HA peers (see Table 1). Parents' naming of an object was less likely to overlap with children's sustained attention on the same object in the HL group. These group differences seem to arise as a function of children's hearing status, and not driven by children's chronological age or hearing age. Numerous prior studies have shown that naming objects that children pay attention to is positively associated with children's vocabulary development. Patterns of less synchronization between parents' naming moments and children's sustained attention may lead to difficulties in learning novel words and overall long-term language development.

S7: Individual differences in attentional control and Executive Functions in the first two years of life

S7.1: Early development of the executive attention network in infancy

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Executive attention (EA) refers to the ability to direct and engage attention according to internal goals or intentions. This ability is particularly crucial when current goals conflict with natural tendencies or previously reinforced actions. The

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first signs of attention control are shown over orientation of attention and are observable from about the second half of the first year of life. Infants are able to disengage attention from an object in order to explore a different object, or to move attention to a location where they expect that something of interest is about to appear. In adults, EA is supported by a network of fronto-parietal structures that are functionally connected. The aim of our study is to trace the early development of this network at the brain and behavioral levels. For this purpose, over 100 infants were recruited and longitudinally followed from 6 to 24 months of age. In experimental sessions, infants performed different eye-tracking tasks in which attention control was examined with disengagement, shifting and visual sequence learning paradigms. Additionally, we recorded brain activity with a high-density EEG system in order to assess functional connectivity between fronto-parietal regions in different frequency bands. Significant indices of functional connectivity in both theta and alpha bands are already observable from 6 months of age. Additionally, results reveal important individual differences in the early development of attention skills that are related to patterns of long-distance brain connectivity. This shows that executive attention skills emerge during the first months of life together with the function of a brain network controlling the endogenous orientation of attention. This work will be of great relevance to track the early development of this function and examine the impact of diverse variables that might affect it, such as home-environment, temperament, and the risk for developmental disorders involving attention.

S7.2: Monthly development of cognitive and attention inhibition in the first year

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Inhibitory control (IC) abilities in early development predict cognitive, academic, and socio-emotional outcomes in childhood, adolescence, and adulthood (Blair & Razza, 2007; Moffitt et al., 2011). Nigg (2000) defined 8 types of IC; in Diamond's (2013) simpler view of IC, which may be more appropriate for infancy, there are 2 main types: self-control/response inhibition and interference control (with the subtypes attention inhibition and cognitive inhibition). We focused on interference control; investigating attention IC and cognitive IC in infants is feasible because both can be assessed with established infant looking tasks (Bell & Adams, 1999; Holmboe et al., 2008). Attention inhibition is focused on the suppression of attention to competing stimuli and involves prefrontal attentional networks. Cognitive inhibition is focused on the suppression of previously acquired information and memories and involves frontal-parietal networks. Thus, based on behavioral and neurophysiological studies with adults, attention IC and cognitive IC appear to be dissociable (Diamond, 2013; Friedman & Miyake, 2004). We wanted

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to know if their behavioral foundations in infancy are also dissociable. Forty-seven infants (24 girls) and their parents were seen monthly in the research lab from 5 to 12 months. Infants were full term, typical birth weight, with no gestation or birth complications. At each lab visit experimenters administered the looking A-not-B task (Bell, 2012; Bell & Adams, 1999) as the cognitive IC task and Freeze-Frame (Holmboe et al., 2008, 2018) as the attention IC task. Task order was counterbalanced across infants and for each infant across monthly visits. Figure 1 shows percentage correct monthly performance on A-not-B cognitive IC task . Both non-inhibitory (original or "A"; Wilks' Lambda = .36, p=.002) and inhibitory (reversal or "B"; Wilks' = .41 p = .006) trials showed development across age (i.e., higher percentage correct). As expected, inhibitory (reversal) trials were more difficult, but this was true only beginning at 7 months (all t's > 3.92, all p's < .001) because at 5 and 6 months a low number of infants did the correct "A" trials required to proceed to "B" trials. Figure 2 shows proportion of valid looks to distractor on Freeze-Frame attention IC task across age (22 infants coded thus far). Both non-inhibitory (boring trials; Wilks = .51, p=.029) and inhibitory (interesting trials; Wilks = .41, p=.006) trials showed development across age (i.e., fewer looks). As expected, infants were less likely to look away during inhibitory (interesting) trials. This was true at each age (all t's > 2.65, all p's < .02). Holmboe (2008; 2018) reported that A-not-B and Freeze Frame were correlated at 9 months. We replicated that finding at 9 months with performance on the inhibitory trials for each task (r = .50). Performance on the non-inhibitory trials was not correlated (r = .12). Performance on attention IC and cognitive IC at all other ages was uncorrelated, suggesting dissociation. These data show development of two different types of IC before the first birthday. This work fills critical gaps in our scientific knowledge regarding normal trajectories of early IC development.

S7.3: Inhibitory control at 10 and 16 months on the A-not-B task and the Early Childhood Inhibitory Touchscreen Task

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Response inhibition enables us to overcome habitual responses and adapt our behaviour to new situations. Response inhibition is commonly measured in infancy with the A-not-B task. A new, alternative measure of response inhibition in infancy is the Early Childhood Inhibitory Touchscreen Task (ECITT), in which infants tap a target (button with a smiley icon) to trigger a rewarding cartoon. A plain button (which does not trigger a reward) is shown on the contralateral side of the touchscreen. On 25% of trials the locations of the target and plain button are reversed, so that infants must inhibit tapping the prepotent location to trigger the reward. Here we test whether there is evidence for coherence between the ECITT

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and the A-not-B tasks, as well as longitudinal stability from 10 to 16 months within each task. Infants completed ECITT (prepotent side counter-balanced across participants) followed by a brief prohibition task (not described here) then A-not-B (prepotent side, A, on the contralateral side to ECITT, using the format 2As-then-B at 10 months, and 3As-then-B at 16 months). Results below are preliminary. First, we established that infants exhibited the expected effect of condition on ECITT: At 10 months accuracy was higher for prepotent (M=.74,SD=.16) compared with inhibitory trials (M=.53,SD=.27)(t(92)=5.838, p<.001). At 16 months accuracy was also higher for prepotent (M=.86,SD.=.14) compared with inhibitory trials (M=.54,SD=.31)(t(76)=7.58, p<.001). Next we tested for longitudinal stability on each task (one-tailed, pre-registered analyses). ECITT inhibitory scores - accuracy on prepotent trials, minus accuracy on inhibitory trials - were not significantly correlated between 10 and 16 months (rs(43)=.012, p=.470). Nor were ECITT switching scores - number of correct switches made from inhibitory location or vice versa, as a proportion of all trials completed - (r(54)=.039, p=.390), or A-not-B switching performance (rs(44)=.074, p=.316). Thirdly we tested for cross-sectional agreement between ECITT and A-not-B (one-tailed, pre-registered analyses). No significant associations were observed between ECITT and A-not-B switching performance at 10 months (rs(72)=-.100, p=.202) or 16 months (rs(67)=-.006, p=.481). ECITT inhibitory score at 16 months was significantly associated with 16-month A-not-B switching performance (rs(69)=-.285, p=.009), but in the opposite direction predicted. Follow-up exploratory analyses (2-tailed) showed that a strong prepotent response on ECITT was associated with a lower level of prepotent responding on A-not-B (r(69)=-.366, p=.002). We conclude that ECITT shows promise as a measure of inhibitory control from as early as 10 months of age. However, consistent with studies with older infants finding low stability of individual differences on variants of the A-not-B task (Miller & Marcovitch, 2015; Wiebe, Lukowski, & Bauer, 2010) we find no evidence of longitudinal stability between 10 and 16 months on either ECITT or A-not-B. Nor did we find straight-forward evidence of coherence in inhibitory control performance across tasks at the same time-point. Instead, we report preliminary evidence that a strong prepotent response to side built up on one task can spill over onto subsequent tasks, despite considerable featural differences and a short break between tasks. We will discuss interpretations of this strong perseverative tendency.

S7.4: Early executive functions - The EEFQ in a Swedish longitudinal sample from 10 to 12 months

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Executive functions underly self-regulation of behaviour and are crucial for academic performance, health and general well-being (Barkley, 2012).

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Investigating especially the early development of executive functions could potentially help us to later on develop training programs to improve children's executive functions (Diamond, 2013). In this talk, we will present preliminary data from a large Swedish longitudinal study on the early development of executive functions during the first two years of life (N = 210). Here, we will present data from the first cohort when infants were 10 and 11.5 months old (n = 70). We measured early executive functions (i.e. inhibitory control, working memory, response flexibility, regulation) via parental report. For this purpose we translated the Early Executive Functions Questionnaire (Hendry & Holmboe, 2019) into Swedish. The data collection is currently ongoing. We will present the data alongside with data on parental education and parental leave as well as lab assessments of infants' cognitive development (Bayley Scales of Infant Development-III). Furthermore, we will give an outlook on the progress of our ongoing longitudinal study of early executive function development.

S8: Parent and child contributions to emotion regulation: Beyond main effects to complex developmental pathways

S8.1: Mother and infant contributions to infant negative emotionality over time

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Maternal sensitivity appears to contribute to better self-regulation over time, as evidenced by lower negative emotionality (Leerkes, Blankson, & O'Brien, 2009). However, the infants in most need of this support tend to elicit lower sensitivity, particularly in the context of heightened maternal risk (Lorber, 2012; Putnam, Sanson, & Rothbart, 2002). Thus, potential factors that impact this transactional relationship need to be identified. Helping mothers of emotionally reactive infants regulate their own emotions may be critical in promoting infant self-regulation. We examined maternal sensitivity and infant negative temperament over time to determine if child- or mother-driven effects varied as a function of mother's difficulties regulating their own emotions. When infants (N=248) were 6-months, 1-year, and 2-years old, mothers reported on their infant's temperament (IBQ-R; Putnam, Helbig, Gartstein, Rothbart, & Leerkes, 2014) and their own difficulty with emotion regulation (DERS; Gratz & Roemer, 2004). Mothers and infants participated in emotion-eliciting tasks at each wave. From these tasks, maternal sensitivity was rated using Ainsworth's sensitivity ratings (Ainsworth, Blehar, Waters, & Wall, 1978). Infant affect was observationally coded during tasks. The negative reactivity scale from the IBQ-R and the infant affect ratings were standardized and then averaged

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together to create an overall negative emotionality (NE) score at each time point. A cross-lagged model was tested in which infant NE at each time point was specified to predict subsequent maternal sensitivity and vice-versa. Maternal race and SES were entered as covariates. Maternal emotion regulation difficulty was entered as a moderator on prospective paths from infant NE at 6 months and 1 years to sensitivity at 1- and 2-years respectively. Results are presented in Figure 1. Maternal sensitivity and infant NE demonstrated significant stability over time, and concurrent associations were significant at each time. Three cross-lagged paths, noted by thicker lines in the figure, were significant as well. Maternal emotion regulation difficulties by infant NE predicted 1-year sensitivity=such that there was a negative association between infant NE and maternal sensitivity only among mothers with heightened emotion regulation difficulties (b=-.41, SE=.16, p<.05). Moreover, lower maternal sensitivity at 1-year predicted higher infant NE at 2-years (β=-.27, p<.01). Bootstrapped confidence intervals were calculated to test the conditional indirect effect and suggested that for mothers higher in DERS, there was a transactional effect by which reactive infants elicited less sensitive parenting which in turn led to more infant NE over time (b=.05, SE=.03, 95% CI [.01, .11]). Additionally, infant NE at 1-year predicted lower maternal sensitivity at 2-years as a main effect. Results support the presence of transactional processes in how infant and mother effects predict infant NE and maternal sensitivity over time. In the context of emotional risk, more reactive infants with mother who are higher in emotion regulation difficulties are at a higher risk of experiencing less sensitive parenting, which may reinforce NE over time. Results warrant further examination into infant and mother factors that predict and moderate this association over time.

S8.2: Mama tried: Contingent responding to distress does not increase rate of real-time soothing in infants high in negative emotionality

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Caregivers' sensitive responses to infant distress, i.e. consistent, contingent and appropriate responses, are thought to facilitate infants' regulation, or return to baseline levels of arousal (Posner & Rothbart, 2000). Both maternal depression and infant expression of negative emotion (NE) are associated with lower parenting sensitivity (Field, 1994; Crockenberg & Smith, 1982), with implications for children's' developing self-regulation capacities longitudinally (Kopp, 1989). Yet these associations could reflect different mechanisms in real-time. On the one hand, mothers' not responding sensitively may interfere with infant distress regulation. Alternatively, infants high in NE may be less likely to soothe regardless of their mothers' efforts. Finally, both these possibilities may be true, suggesting a feedforward system. We take an important next step in this literature by testing

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these competing hypotheses. In a sample of mothers with a history of depression, i.e. at elevated risk for perinatal depression, we examined the rates at which mothers contingently responded to infant distress, and tested whether the presence of a contingent response would facilitate infant soothing (i.e. return to positive or neutral affect) in real-time, relative to occasions when mothers did not contingently respond. Additionally, we examined whether these results differed across dyads according to the proportion of NE displayed by infants overall. We hypothesized that contingent responding would facilitate soothing, and moreover, that both child and mother effects would be present, namely, that mothers of high NE infants would be less likely to contingently respond to infant distress, and also that even in the presence of contingent response, high NE infants would be less likely to soothe. Video of five-minute face-to-face free play between mothers and their 3-month old infants (N=194) were annotated continuously for infant and maternal affect. We identified all instances of infant distress (NE) in each session. For each identified distress instance, we determined whether mothers exhibited a contingent response, operationalized as a shift in maternal affect within 3-second of distress onset. Next, we observed whether the infant returned to a positive or neutral state (i.e. soothed) within a 10-second window of distress onset. Overall, maternal contingent responding (MCR) to infant distress increased the likelihood of infant soothing relative to instances of distress with no MCR (mean increase of M=0.263, SD=0.445 t(124) 6.60, p<.001). However, there were no significant differences in the rate of MCR across clusters of infants with high- mid- and low-levels of NE [F(1,173)=0.012, p=0.914] (Figure 1a). Next, while MCR was associated with an increase in likelihood of soothing for infants with low and mid- levels of NE, the increase in likelihood of infant soothing due to MCR in the high NE cluster was not significantly different from zero (t(31)=1.69; p=.101; Figure 1b). Overall, our results suggest that although mothers of high NE infants contingently respond to infant distress at high rates, their infants did not benefit as much from MCR - that is, MCR did not significantly increase soothing of infant distress in high NE infants. We discuss potential longitudinal implications and integrate our findings with prior research on maternal sensitivity.

S8.3: Parental structuring of toddler negative emotion predicts children's use of distraction longitudinally

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<p>Several emotion socialization strategies are purported to promote children's self-regulation of emotion (e.g., Eisenberg et al., 1998; Morris et al., 2002). Structuring, a strategy known to promote children's cognitive development (e.g., Wood, 1980), is rarely studied as a strategy that promotes children's self-regulation of emotion. Structuring scaffolds children's autonomous functioning (Vygotsky,

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1978) and contrasts with making directing or prohibiting their behavior. In the case of emotion regulation, structuring should accomplish what Kopp (1989) posited - engaging young children's emerging cognitive and linguistic abilities to help them regulate their own emotion. We tested the hypothesis that parental structuring, versus directing/prohibiting, in response to 18-month-olds' negative emotion would predict developmental growth in children's autonomous use of distraction, an optimal strategy for dealing with the frustration of waiting for a reward (e.g., Mischel et al., 1972). Distraction entails redirecting attention and engages the emerging executive attention network (Posner & Rothbart, 2000).

 Participants were 127 economically strained, rural and semi-rural families (57 girls; 91% White). During an unstructured home visit when toddlers were 18 months, observers rated mothers' and fathers' responses each time the toddler expressed clear negative emotion. Structuring was defined by parents attempting to engage toddlers' cognitive skills to help them help themselves. Directing was defined by telling children what to do ("go play") or prohibiting their behavior ("stop crying"). Children's self-initiated use of distraction was observed in a laboratory wait task at child ages 18, 24, 36, and 48 months. Mothers instructed children to wait to open a gift until the mother completed some paperwork.

 A latent growth model tested the extent to which the frequency of parental structuring and directing at 18 months predicted linear change in children's use of distraction between 18 and 48 months and the intercept, centered at 48 months. Maternal report of child effortful control at 18 months was included as a covariate. Results showed that more frequent parental structuring in response to 18-month-olds' negative emotion predicted linear increases in children's use of distraction between 18 and 48 months ($b = .91$, $p = .03$; see Figure 1) and more frequent use of distraction at 48 months ($b = .96$, $p = .004$). In contrast, parental directing predicted decreased use of distraction between 18 and 48 months ($b = -1.3$, $p = .01$) and less use at 48 months ($b = -.97$, $p = .02$).

 Vygotsky's (1978) theory that adults scaffold children's skill acquisition appears to extend to parents' socializing children's emotion regulation. Structuring helps them develop the ability to initiate redirecting attention from something they want and become absorbed in a way that should help them wait. Interestingly, parents' use of directives and prohibitions may undermine the development of distraction as an emotion regulation strategy. Findings underscore the value of examining specific parenting responses to children's negative emotion, particularly during toddlerhood when children's rapid cognitive development provides an internal resource for the emergence of self-regulation. </p>

S9: The role of action understanding in early sociomoral cognition

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S9.1: Twelve-month-old infants use payoff information to disambiguate the goals of agents involved in a joint activity

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Participation in a joint activity is often ambiguous with respect to the motivations of the individuals involved, as these may be equally driven by a desire to help their partners (a prosocial goal) or to obtain personal benefits (a selfish goal). The outcome of a joint activity (i.e., who gets what), however, provides payoff information relevant for resolving this interpretive ambiguity. We hypothesize that when the costly involvement of an agent in a joint activity results in personal benefits, these readily justify her action as directed to a selfish goal. Conversely, when the agent's action results in a beneficial outcome for her partner but not herself, a prosocial interpretation of the agent's participation in the joint activity should be favored. In other words, cues of joint activity should be more likely to encourage a description of an agent's behavior as directed to help a social partner when her actions do not result in personal benefits which may otherwise explain her involvement. We tested this hypothesis in a violation-of-expectation experiment by familiarizing 12-month-old infants (n = 24) to a joint-pulling event featuring two pairs of puppets (AB and AC) acting on differently baited trays: one (for AB) in which each puppet obtained a cookie; and another (for AC) in which only puppet A obtained a cookie. At test, infants were sequentially shown puppets B and C giving an object to A (Figure 1). We predicted that if infants inferred a prosocial goal selectively when the puppets' participation to the joint activity could not be justified in terms of personal benefits (as in the case of puppet C), such inference should have been compatible with observing this puppet, rather than B, engaging in a new type of prosocial action (giving) towards her previous social partner (puppet A). To further examine whether the ascription of a prosocial goal led infants to positively evaluate the puppet, we assessed the infants' own preference for C over B via manual choice after the looking-time phase. As predicted, infants looked significantly less to the giving test action when carried out by C compared to B (M = 10.98 s vs. 16.74 s, p = .006, by two-tailed t-test; p = .030, by Wilcoxon signed-ranks test). On the contrary, no preference for the 'altruist' puppet (C) emerged (15/22 infants reached for C). The looking-time findings suggest that, despite being presented with dyadic interactions exhibiting the same jointness and synchronicity cues, infants inferred different puppets' goals depending on whether their actions resulted in symmetric or asymmetric payoff distributions. Two follow-up experiments are currently investigating whether infants reacted to the mere similarity of payoff structures between familiarization and test (C gets 0 and A gets 1 in both joint-pulling and giving events) independent of the interaction observed, and whether they inferred from the former a social goal preserving the direction of the cost-benefit relation of

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the joint-pulling events (C pays costs to benefit A) rather than, more broadly, actions producing asymmetric payoffs, even of opposite valence.

S9.2: 16-month-old infants perceive irrational individuals as having reduced moral rights

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Research with adults indicates that individuals with reduced cognitive competence are often treated as though they have fewer moral rights. Building on prior work that (a) infants can detect whether individuals are behaving irrationally and (b) possess an expectation of fairness, we asked in three violation-of-expectation experiments whether 16-month-olds would expect an irrational individual to be treated fairly. In Experiment 1, while E1 and E2 watched, E3 behaved either irrationally (irrational condition) or rationally (rational condition). To start, infants saw E3 color a drawing using a marker. Next, she wanted to color again, but her marker was placed behind a transparent barrier and she reached over the barrier for the marker. In the following two trials, the barrier was removed. In the irrational condition, E3 reached for the marker inefficiently as if the barrier was still there; in the rational condition, she reached efficiently. Infants then received two test trials, where E1 divided resources either fairly between E2 and E3, or unfairly, favoring E2. Here, infants in the rational condition looked significantly longer at the unequal than at the equal distribution, whereas infants in the irrational condition looked equally at the two distributions. In Experiment 2, we conceptually replicated Experiment 1. Infants again watched E3 color a drawing using a marker. In the next two trials, E3 needed a marker to color and she had two transparent containers in front of her: one with markers and the other one empty. In the irrational condition, she reached for the empty container; in the rational condition, she reached for the container with markers. As in Experiment 1, infants in the rational condition looked significantly longer at the unequal compared to the equal distribution, whereas infants in the irrational condition looked equally at the two distributions. In Experiment 3, we extended our results in two ways. First, we ruled out the possibility that infants viewed the unfair distribution in Experiment 2 (giving nothing to E3) as an acceptable outcome because they interpreted E3's reaching for the empty container as a preference for having nothing. When E3 reached for a container with forks instead of the container with the markers she needed, infants again looked equally at both distributive outcomes. Second, we showed that infants' equal looking time at the two outcomes in the irrational condition is not because they failed to form expectations for any of the experimenters' actions following E3's irrationality. Infants looked significantly longer when E1 distributed unequally by giving all the resources to E3, compared when she distributed equally. Thus, infants seem to perceive treating the irrational individual fairly, or favoring a rational

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compared to an irrational individual as acceptable outcomes, but favoring an irrational individual to a rational individual as an unexpected outcome. Together, results from Experiments 1-3 suggest that 16-month-old infants perceive irrational individuals, who either achieved their goals inefficiently (Exp.1) or acted in ways inconsistent with their goals (Exps.2-3), as having reduced moral rights, at least in the context of distribution of windfall resources.

S9.3: Social cognition in context: Infants' evaluations of helping in means-end sequences

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Imagine that a bear tries but fails to open a box that contains a toy, and is only able to open it and grasp the toy inside with help. If the toy in the box were switched with a different toy in a second box, what would be more helpful: opening the first box, even though the toy inside is now different; or opening the second box, which has the original toy that had been in the first box? Critically, one's answer may depend on what goal one attributes to the bear before the toys switched. In trying to open the first box that contained the original toy, was the bear's goal: to open the first box, regardless of what was inside; or to open the first box as a means to the end of getting to the specific toy in the box? Past work suggests that the way in which infants reason about actions done as a means to an end (i.e., means-end sequences) changes with age: Whereas infants above 12 months of age would think that the child in the above scenario wanted to open the first box as a means to the end of accessing the specific toy inside, infants younger than 12 months of age would think that the child simply wanted to open the box, regardless of what is inside. That is, whereas infants above 12 months of age have means-end understanding, infants younger than 12 months of age do not. The present studies ask whether these developmental differences in understanding multistep, means-end actions affects infants' social evaluations. Study 1 (n = 24) examined infants' evaluations at 15 months, whereas Study 2 (n = 24) examined infants' evaluations at 8 months. There are at least 2 possibilities for how infants evaluate helping in means-end sequences. One possibility is that infants' action understanding informs their social evaluations; given that past work demonstrates infants have means-end understanding by 12 months of age, infants who are younger than 12 months (8-month-olds) should infer that an agent's goal is the means and therefore prefer a helper who assists with the means (a Means-Helper), and infants who are older than 12 months of age (15-month-olds) should infer that an agent's goal is the end and therefore prefer a helper who assists with the end (an End-Helper). Alternatively, it may be that action understanding does not inform infants' evaluations, so that infants choose between helpers at chance. In both studies, infants saw one helper who assisted the bear (as in the scenario above) with the end of the means-end sequence, and a second

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helper who assisted the bear with the means of the sequence. Whereas 15-month-olds preferred reaching for End-Helpers over Means-Helpers, 8-month-olds preferred reaching for Means-Helpers over End-Helpers. The present results support the hypothesis that action understanding informs infants' social evaluation of helping in means-end sequences, and call for future work to continue characterizing the intersection of how infants understand others' actions and how infants navigate the social world.

S9.4: Toddlers consider others' goals when helping others

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By their second birthday, toddlers will help others fulfill unmet goals; for example, toddlers will bring an experimenter a pen that they want but that they cannot reach. This work implies that toddlers already understand other people's needs and take appropriate actions to meet those needs. However, in many helping tasks it is unclear if toddlers are helping based on other people's needs or are helping based on other factors (e.g., toddlers could help because they want to interact with the person requesting help). In two experiments we investigate whether toddlers use information about an object's affordances to fulfill someone else's unmet goal. In Experiment 1, N = 40, 24-month-old toddlers first learned how to complete a puzzle. An experimenter showed toddlers that different colored shapes fit in different parts of the puzzle. They then met a new experimenter who was trying to complete the same puzzle; however, the experimenter was missing the final piece of the puzzle. Two pieces were on the toddlers' side of the room, and toddlers could help the experimenter by bringing her one of the puzzle pieces. One piece fulfilled the actor's goal of completing the puzzle (need-fulfilling) whereas the other piece did not fulfill the actor's goal since it did not fit in the puzzle (not need fulfilling). Overall, we found that toddlers were significantly more likely to bring the need-fulfilling puzzle piece than chance (82.5% of toddlers brought the need-fulfilling piece), $p < .001$, binomial test. This suggests that toddlers will help fulfill an actor's need using the affordances of particular puzzle pieces. In Experiment 2 we wanted to conceptually replicate Experiment 1 and determine whether toddlers would still consider object affordances and demonstrate action understanding when there are additional items available to bring and potentially help with. It is possible that it may be increasingly difficult for toddlers to discern what object an experimenter needs when there are additional options. In this experiment, N = 42, 24-month-old toddlers participated. The experiment was identical to Experiment 1 except that toddlers could choose to help with one of three items (a puzzle piece that fits the puzzle, a puzzle piece that did not fit the puzzle, or a shoe). 69.1% of toddlers brought the needed item, which is significantly greater than chance, $p < .001$,

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binomial test. The remaining 26.2% brought the puzzle piece that did not fit and 4.8% of toddlers brought the shoe. Taken together, our findings provide initial evidence that toddlers use objects' affordances to fulfill an experimenter's concrete need. Future work can determine the scope of action affordances toddlers use when helping others. For example, we can examine whether toddlers recognize more subjective uses for objects (e.g. that food can fulfill someone's hunger). Additionally, future work can determine whether understanding object affordances is enough to motivate early helping behavior or whether toddlers must have additional skills/motivation in order to help.

S10: The I in team: Individual Differences in Infancy Shape Social Competence and Prosociality

S10.1: Children's positive emotions following helping others and seeing others being helped: Evidence for a developmental shift

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The motivations underlying young children's helping behaviour are at the center of ongoing debates (Dahl & Brownell, 2019; Warneken, 2015). At the heart of these debates lies the question whether young children's helping behaviour is motivated by social competence. It is possible that helping in young children is driven by social motivations to interact with others or mastery motivations to be competent in completing others' goal-directed behaviour. An alternative possibility is that young children are motivated to help out of a genuine concern for others' well-being and to see others helped Crucial data to address this question comes from studying the underling emotions of early prosocial behaviour directly and objectively. Here we investigated the kinds of positive emotions that young children express following helping behaviour. Recent work has documented increased positive emotions in toddlers following sharing (Aknin, Van de Vondervoort, & Hamlin, 2018). We were interested in the emotions that follow from toddlers' in comparison to pre-schoolers' instrumental helping. To this end we presented 2.5-year-old and 5-year-old children (n = 64) with scenarios in which an adult needed help completing an instrumental goal. We varied, within subjects, whether children could complete the goal themselves or whether - just as they were about to help - another adult provided the help. Our dependent measures were changes in children's upper-body posture, assessed via a Microsoft Kinect camera, as an indicator of changes in positive (postural elevation) or negative emotions (Hepach, Vaish, & Tomasello, 2017). The prediction was that if social competence drives helping then actively

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providing help should result in positive emotions and more so compared to merely seeing others being helped. The preliminary results show that changes in two-year-old children's body posture were similar after providing the help themselves compared to seeing an adult provide the help. In contrast, five-year-old children showed greater postural elevation after actively providing help compared to merely seeing an adult provide help (see Fig. 1). Our analyses are currently preliminary but suggest a developmental shift with regards to children's positive emotions specifically and emerging prosociality more generally. One interpretation of these data is that in the context of helping others, motivations for social interaction and competence emerge gradually in the first five years of life as children become increasingly flexible in managing their prosocial reputation (Engelmann & Rapp, 2018).

S10.2: Temperament and cooperative ability in infancy: Are effects of temperament mediated through children's social behaviour during cooperative tasks?

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Cooperation emerges in the first two years of life (Brownell, 2011; Warneken & Tomasello, 2007), with children first mastering tasks that require two agents to perform the same action to achieve a goal (parallel roles) followed by tasks that require both agents to perform different actions to achieve the goal (complementary roles). Although much is known about when aspects of cooperative ability emerge, little is known about the individual factors that influence early proficiency. Temperament is one individual factor that has received recent attention as a likely candidate in shaping cooperative ability. High negative affectivity and low regulation have been linked to lower cooperative behaviour in the pre- and early-school years (Laible, Carlo, Murphy, Augustine, & Roesch, 2014). Temperament also influences the amount of affiliative behaviour preschoolers display towards their cooperative partner during a complementary roles task, with surgency positively related to affiliative behaviour and negative affectivity negatively related to affiliative behaviour (Endedijk, Cillessen, Cox, Bekkering, & Hunnius, 2015). Moreover, preschoolers who displayed more affiliative behaviour were more successful on the task, suggesting temperament may influence cooperative success through the quality of the interaction. Whether these effects are seen in infants, when cooperation is first emerging, remains a mystery. Questions also remain as to whether temperament effects are mediated by social behaviours infants display during cooperative tasks, and whether this differs for parallel and complementary roles tasks. The purpose of this study was to assess relations between infant temperament at 10 months and social behaviour and cooperative ability during cooperative tasks at 14 and 22 months. As part of a larger

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longitudinal study, infants (N=226) were assessed in a laboratory over three sessions (at 10, 14, and 22 months of age). Temperament was measured via parent-report (IBQ-R; Gartstein, & Rothbart, 2003) when infants were 10 months. Infants' social behaviours (affiliative, antagonistic, engagement, joint coordinated engagement) and cooperative ability (spatial coordination, success in achieving goal, latency to success) during parallel and complementary roles tasks were measured when infants were 14 and 22 months. Preliminary analyses suggest temperament influences infants' behaviour in parallel and complementary role tasks at 22 months differently. In the parallel roles task, surgency predicted later cooperative ability, being linked to greater, and faster, success achieving the goal (see Table 1). In the complementary roles task, negative affectivity predicted later cooperative ability, being linked to faster success (see Table 2). Furthermore, an interesting pattern emerged of regulation being negatively associated with affiliative behaviour (complementary roles task) and affiliative behaviour being associated with slower success (both tasks). These results provide tentative evidence that surgency and negative affectivity influence both infants' cooperative ability and social behaviour during cooperation. Further analyses with the cooperation tasks when infants were 14 months will examine whether increase/decrease in social behaviours mediate the influence of temperament on cooperative ability. These findings provide further evidence demonstrating important links between children's temperament and their tendency to interact prosocially with others.

S10.3: Developmental pathways from infant social cognition to later prosocial behavior and theory of mind

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Many of the basic competencies required for social cognition emerge during the first year of life. Two key developments include an understanding of the intentional nature of human action (Woodward et al., 2009) and the capacity to initiate joint attention with social partners (Mundy et al., 2007). An important developmental question concerns the extent to which these early-emerging social-cognitive competencies underpin the development of socially competent behavior and reasoning beyond infancy. The goal of the current study was to shed light on this question using longitudinal data spanning infancy through the preschool years. We examined longitudinal relations between intentional action understanding and initiating joint attention tendencies assessed during infancy and both (a) prosocial behavior assessed during the toddler years, and (b) theory of mind reasoning assessed in preschoolers. A sample of 169 7- to 12-month-olds (M = 9.4 months) participated at Time 1. Infants' ability to reason about the intentional nature of a failed reaching action was assessed using an anticipatory-looking paradigm

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(Brandone et al., 2014). In addition, infants' attempts to initiate joint attention (e.g., through pointing, showing, gaze alternation) were coded during a semi-structured play task with an experimenter (Mundy et al., 2003). At Time 2, 79 participants returned to the lab as toddlers (M = 22.24 months) to complete a battery of prosocial behavior tasks. Instrumental helping was assessed through four tasks in which a researcher ostensibly needed help to complete a goal (e.g., retrieving a dropped crayon) (Warneken & Tomasello, 2006). Sharing was assessed via two tasks in which toddlers were given the opportunity to share snacks and toys with an experimenter who had none (Brownell et al., 2013). Finally, at Time 3, parents of 109 infants from the original sample (M = 40.46 months) completed the Children's Social Understanding Scale (CSUS; Tahiroglu et al., 2014), a parent-report measure of individual differences in theory of mind across the subscales of belief, knowledge, perception, desire, intention, and emotion understanding. Results revealed unique patterns of longitudinal relations between infants' social cognition and their later socially competent behavior and reasoning. First, infants' ability to process the intentional nature of a failed reaching action positively predicted toddlers' instrumental helping behavior (but not their likelihood of sharing) (see Table 1); conversely, infants' initiating joint attention behavior positively predicted toddlers' likelihood of sharing (but not their instrumental helping) (see Table 1). Second, longitudinal relations also emerged between infants' initiating joint attention behavior and their theory of mind as preschoolers - especially in the areas of belief and desire understanding (see Table 2). However, intentional action understanding observed in infancy was unrelated to later theory of mind. Together, these findings strengthen and expand existing evidence suggesting continuity in social cognition from infancy through the preschool years. Results demonstrate that early social-cognitive knowledge and interaction tendencies established in infancy underpin later prosocial behavior and theory of mind. The mechanisms explaining these unique developmental pathways will be discussed.

S10.4: A developmental systems approach to early helping behavior

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It has recently been proposed that the ontogeny of infants' early helping behavior is best understood as a developmental system. Namely, the dynamic interplay between several developmental processes, including infants' (1) the social human nature (affiliation and empathy), (2) social cognition (understanding others' needs and one's own competencies to help), (3) social interactions (social evaluation and social learning mechanisms), and (4) cultural learning (appropriation of cultural models). It is thus important to understand, how different developmental processes act in concert in the early emergence of helping behavior. Here, I will present two recent empirical studies that look at (1) the interplay between infants'

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understanding of others' needs, motor development and early helping behavior and (2) the way mothers' culture-specific scaffolding in the first year predicts the development of infants' helping behavior in the second year. In the first study, we test the main hypothesis that infants' understanding of others' needs translates into helping behavior, when critical motor and social competencies have emerged, early in the second year. We assessed the understanding of others' needs in an eye-tracking paradigm and the helping behavior of 10- (n = 41) and 16-month-olds (n = 37). Furthermore, we assessed the motor and social abilities of 16-month-olds. Critically, while infants understood others' needs already at 10 months, fine motor and social interaction skills moderated the link between infants' prosocial understanding and helping behavior at 16 months (Figure 1). This provides first evidence that infants' helping behavior relates to their understanding of others' needs. Furthermore, we found that fine motor, gross motor, and social interaction skills predicted early helping behavior by themselves. In a second study, we tested how mothers from Japan (N = 90) and Germany (N = 79) assign tasks to their 10- and 16-month-old infants. We found culture-specific scaffolding towards 16-month-olds: Japanese mothers showed higher levels of sensitive scaffolding (high-pitch voice and use of diminutives; cf. Rothbaum et al., 2000) than German mothers ($p < .05$). German mothers showed higher levels of deliberate scaffolding (asking and pleading) than Japanese mothers ($p < .001$). We had the chance to conduct a follow up study with infants that were 10 months at the first assessment (T1) when those infants were 24 months old (T2), in Japan (N = 31). Intriguingly, we found that culture-specific scaffolding (namely sensitive scaffolding), as well as maternal assertive scaffolding at T1, was highly predictive for infants' helping behavior at T2 (see Figure 2). These findings highlight that the emergence of infants' helping behavior is the result of a developmental system that includes infants' understanding of others' needs and also their motor and social competencies, but is also shaped, from early on, by the way mothers encourage their infants to engage in daily activities.

S11: The origins of causal thought

S11.1: Stop in the name of contact: How infants learn about the causal properties of people and objects

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The ability to perceive causal relations is a cornerstone of cognitive development (e.g., Oakes & Cohen, 1990; Leslie & Keeble, 1987). Despite the impressive body of research on this topic, little is known about the age at which infants understand that

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people and inanimate objects are governed by different causal constraints: people can cause action at a distance whereas inanimate objects are governed by contact relations. There is also debate about whether the mechanism that underpins this knowledge is domain-general (e.g., associative learning) or domain-specific (e.g., core-knowledge systems). In three experiments we sought to: (1) to examine the developmental origins of this knowledge in 4-month-olds (Experiment 1); (2) to replicate the only unpublished study on this topic by Spelke, Phillips, and Woodward (1995) with 7-month-olds (Experiment 2); and (3) to examine on what basis 7- and 11-month-olds distinguish people from objects (Experiment 3). Four- (Experiment 2) and 7-month-olds (Experiment 1) were habituated to events in which first a cartoon person or object moved behind a central screen and then a second, half-occluded person or object exited stage-right. Infants were then shown alternating Collision and No-Collision test events in which the second person or inanimate object moved following contact (Collision event) or no contact (No-collision event) from the first person or object. Preliminary analyses revealed that the 4-month-olds, $p < .01$, and the 7-month-olds, $p < .05$, looked longer at the No-Collision test event in the Inanimate Object condition than in the People condition. However, the 4-month-olds tended overall to look longer at the No-Collision events, $p < .001$, suggesting a preference for self-propulsion. Experiment 3 examined whether 7- and 11-month-olds' knowledge about people and object causal action is based on an inborn "core-knowledge system" or a domain-general associative processing mechanism. Experiment 3 was identical to the previous experiments except that the people possessed object features and the objects possessed people feature. Infants were expected to have looked longer when the objects moved in the absence of contact, irrespective of their perceptual features, if they espoused a core-knowledge system that encoded people and object motion. However, 7- (and, to a lesser extent, 11-month-olds) were expected to have looked longer at the No-Collision event in the People condition--because the people possessed object features and, as such, may have been mistaken for objects. Preliminary results revealed that the 7- and 11-month-olds looked longer at the No-Collision test event in the Inanimate Object condition than in the People condition, both p's $< .005$. However, and similar to the 4-month-olds in Experiment 2, the 7-month-olds preferred the No-Collision test event to the Collision event, $p < .05$. This research has implications for theories that discuss infants' developing knowledge about people and object causal action.

S11.2: Reverse engineering the origins of causal knowledge

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What are the origins of causal knowledge? How do newborn brains learn to transform sensory inputs into rich causal inferences about the world? One

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possibility--dating back to David Hume (Hume, 1739)--is that causal knowledge is learned from experience, inferred from the frequent co-occurrence of previously experienced events. A second possibility--inspired by work with human infants (e.g., Leslie & Keeble, 1987)--is that newborn brains are endowed with causal primitives that scaffold the development of causal knowledge. Despite a great deal of interest in this topic, two main barriers have hindered progress. First, the field lacked high-powered methods for studying newborn cognition and for controlling the environments in which newborn subjects are raised. To understand how experience shapes causal knowledge, we must be able to control and manipulate the causal experiences provided to newborn subjects and measure their behavior with high precision. Second, the field lacked comprehensive pixels-to-actions models (artificial agents) formalizing the core learning mechanisms in newborn brains. If we understand the mechanisms that underlie causal knowledge in newborn brains, then we should be able to engineer them. In this talk, we will first describe high-powered experiments exploring whether newborn chicks have innate knowledge of causal agency, in the absence of all prior experience with objects and agents. A seminal study reported that newborn chicks prefer to associate with self-propelled objects over objects that moved as a result of physical contact, suggesting that knowledge of causal agency is part of a newborn's innate representational repertoire (Mascalzoni, Regolin, & Vallortigara, 2010). While this study tackled an important theoretical question, the study had three limitations: noisy measurements (low signal-to-noise ratio), small effect sizes, and high analytic flexibility. Using a preregistered design, we attempted to reproduce this finding with an automated method that eliminated experimenter bias and allowed over 400 times more test data to be collected per chick. We found no evidence that newborn chicks prefer objects that exhibit self-propelled motion (mean=51%, SE=5%, t(11)=0.29, p=.78, Cohen's d=0.08). However, the chicks demonstrated a strong preference for familiar objects over novel objects (mean=74%, SE=2%, t(11)=9.94, p=0.0000008, Cohen's d=2.87), showing that our automated method can produce robust results. These results challenge the claim that knowledge of causal agency is an innate core learning mechanism. We will then discuss how this controlled-rearing research provides valuable benchmarks for building pixels-to-action models formalizing the development of causal knowledge. By raising newborn animals and artificial agents in the same environments, we can directly compare the learning abilities of biological brains and artificial brains. To mimic the development of causal knowledge in newborn brains, artificial agents should not have hardwired knowledge of causal agency. Rather, this knowledge should emerge as the agent acquires experiences with objects and agents. More generally, by creating an experimental system linking biological intelligence to artificial intelligence, we illustrate how this 'reverse engineering' framework can be used to characterize the origins of causal knowledge.

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S11.3: Not all information is created equal: Investigating infants' sensitivity to confounded information in a causal reasoning task

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Identifying a cause of any phenomenon, by distinguishing spurious correlations from unconfounded evidence, is a challenge in every day reasoning as well as fundamental to the scientific process. Sensitivity to confounded information is of particular importance when one cannot generate data for oneself, as is the case in most scenarios for infants. Before the age of 2 years, infants have limited means of acting on the world themselves and much of their learning depends on observing others' interventions and drawing the correct inferences. We investigate whether infants recognise when the information they are expecting or observing is confounded or not, whether they use this distinction to correctly ascribe features to novel objects, and predict future events based on these inferences. Specifically, infants are familiarised with an adult female placing objects on the surface of a box ('blicket detector'), which produces an audio-visual effect when contacted by some of the objects ('blickets'), and not others. The objects are then sorted into 2 possible boxes on either side of the scene, depending on whether they have produced an effect. Following this, pairs of the sorted objects will be placed on the box, providing further information on the causal structure. Infants learn that a single 'blicket' is sufficient to activate the box, and two also activate the box. In the following test trials, infants will see a new unknown object placed on the box, paired with one of the known (and visually marked) objects, providing either confounded (when paired with a 'blicket') or unconfounded information about the novel object when the box activates. Our approach allows us to investigate whether infants distinguish between the two scenarios by measuring infants' expectation of information as indexed by pupil dilation, as well as EEG theta activity, a neural rhythm shown to predict the degree of learning (Begus et al., 2014; Guderian et al., 2009) and to index an active and selective preparation for encoding information, in infants and adults (Begus et al., 2016; Gruber et al., 2013). If infants recognise which of the two situations offers the opportunity to learn about the functionality of the new unknown object, a greater increase in pupil dilation as well as theta activity would be expected in the unconfounded compared to confounded trials. Furthermore, we investigate whether infants correctly infer which category the new object belongs to (when such prediction is possible, i.e. in unconfounded trials), by measuring anticipatory looks towards either of the two boxes into which the objects are sorted at the end of the trials. We expect infants to demonstrate preferential anticipation towards the correct box when the information they observed was unconfounded, and chance performance when that was not the case. Initial data suggests this design successfully elicits anticipatory looks in infants. The accuracy of infants' predictions will be analysed in relation to the preceding measures of information

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expectation for each infant, offering insight into the learning mechanisms and individual differences in early causal reasoning. Data collection is on-going with 3 age groups (12, 18, and 24 months), planned N=24 per group.

S11.4: Disconnected causal representations in the first year of life

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Much of the developmental work on "Causality" starts with the assumption that we are talking about a single origin for the vast and complex set of causal concepts we use as adults. Michotte argued for an innate perceptual module (1947/1953), Piaget for the experience of causal agency (1920), and Hume for a kind of associative inference (1748). Previous work has often argued that one or these is the "true" origin of causal thought, but there is an alternative: There are multiple completely independent representations of causality in the infant mind, that may be integrated later in development. Past work has demonstrated a dissociation: Infants can track situational causal roles in Newtonian collisions (causal agent and causal patient), but fail to do so in "entraining" events, in which an agent makes contact with a patient and then both objects move together, with the agent appearing to apply continuous force to the patient. Here, we test whether inferences that infants have been shown to make about objects based on their role in entraining events (Setoh, Wu, Baillargeon, & Gelman, 2013) are also made based on their role in launching events, which might suggest that launching is the foundational causal representation, or if there is a full double dissociation, indicating that there are multiple, parallel causal representations in the first year of life. In Experiment 1, we replicated the result that 10-month-old infants can make inferences about the dispositional status of an object (i.e. whether it is an animate agent) based on its role in an entraining event with an unambiguous agent: Infants looked significantly longer when a self-propelled fur/feather-covered entity is shown to be hollow compared to a fur/feather-covered entity that was entrained by a human actor, paired $t(15)=2.35$, $p=.03$. Experiment 2 found that when these two objects are instead the agent and patient of a launching event, infants showed no significant difference in looking time when each object was revealed to be hollow, $t(15)=0.51$, $p=.6$. To better understand whether causal role in launching events supports dispositional inferences, we built on previous work showing that infants do not look longer when objects that do not have fur are shown to be hollow, even if they appear self-propelled (Setoh et al., 2013). Experiment 3, which is ongoing, involves showing infants a launching event with a fur-covered object and a colorful box, varying between-subjects which object was the situational agent. Preliminary results (N=28/32) suggest that infants infer that furry causal patients of launching events nonetheless should have insides: Infants look longer when the fur-covered object is revealed to be hollow, ($M=23.9$, $SD=11.5$) compared to the box ($M=18.2$, $SD=11.2$), regardless of the causal role of

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each object (Fur agent, fur vs. plain: 22.8 vs. 18.9; Fur patient, fur vs. plain: 24.9 vs. 17.6). If these results hold, they complete a double dissociation: Infants track situational agency in launching-like events but cannot infer dispositional status from causal role, while they can make inferences about dispositional status in entraining-like events but fail to infer situational agency.

S12: The structure and function of biobehavioral synchrony in early development

S12.1: Infant-mother physiological synchrony moderates infants' self-regulation

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Dramatic changes in infants' abilities to regulate their emotions occur during the first year after birth. Early on young infants demand a good deal of scaffolding or co-regulation from their parents which they receive through face-to-face interactions, close physical contact, and vocal and affective turn-taking. These behaviors are all examples of interpersonal coordination that involve a dynamic and continuous matching of actions that are partly the social partner's and partly the infants' own reflected back to them. A growing collection of research suggests that changes in vagal activity, as measured by respiratory sinus arrhythmia (RSA) -- an index of cardiac activity related to respiratory function -- provide a measure of the individual's capacity to engage in social communication and emotion regulation. However, less is understood about the co-regulatory RSA patterns of infants and their social partners and how these patterns moderate infants' abilities to regulate their bio-behavioral state. <p> The question addressed in this research is whether synchronous interactions extend to physiological regulation of state. In this study, we employed a novel, continuous measure of RSA synchrony in mother-infant dyads to examine to what extent differences in physiological synchrony moderate infants' affect regulation during a mild stressor, the Face-to-Face-Still-Face (FFSF) Paradigm. Dyads (n=114) first interacted during the Play phase, which was followed by the maternal Still-Face phase and then the resumption of social interactions in the Reunion phase. Baseline RSA was computed by extracting the average RSA of the infant during a 30s period preceding the Play phase. Infants' RSA Change was computed by subtracting the difference in average RSA during the Play phase from the Still-Face phase; lower RSA values during the Still-Face phase was an index of physiological regulation. A composite score of infants' behavioral distress (involving facial and vocal expression and gaze direction) was coded every 30s, which

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provided 12 total indices of distress throughout the three FFSF phases. Our procedure for constructing a continuous measure of RSA involved computing RSA in 10s epochs and then applying a 10s sliding window to each data point sampled at 5 Hz (Figure 1). A cross-correlational analysis involving infants' and mothers' time series for the Play phase was calculated as our measure of physiological synchrony. <p> We used growth curve modeling to test how behavioral distress changed as a function of three factors: Baseline RSA, RSA Change, and Physiological Synchrony. Without considering physiological synchrony, the evidence suggested that infants' distress followed the prototypical pattern of increasing during the Still Face phase and then decreasing during the Reunion phase (Figure 2). Critically, however, we found that among infants who had difficulty regulating their distress during the Still-Face phase (i.e., increased RSA), those who had previously experienced positive physiological synchrony with their mothers in the Play phase attenuated their distress in reunion. By contrast, infants who experienced negative physiological synchrony with their mothers in Play continued to show distress into Reunion. These results suggest that physiological synchrony is an important index of maternal sensitivity and co-regulation of infants' state.

S12.2: Tuned in: Neural synchrony in mother-infant dyads

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Interpersonal synchronization of brain activities has been documented between adult dyads as well as child-caregiver dyads, but there is an ongoing debate on its functional relevance and the conditions under which neural synchrony arises. A growing body of research suggests that neural synchronization emerges in interactive contexts of caregiver-child cooperation and communication (Liu et al., 2016; Reindl et al., 2018). Behavioral coordination during such interactions is suggested to be associated with neural synchronization, but neural synchrony could also be an epiphenomenon due to similar perceptual input rather than a biomarker of mutual engagement. Here, we examine mother-infant dyads in both interactive and non-interactive contexts in order to test under which circumstances neural synchrony between mother and infant occurs. We hypothesize that neural synchrony depends on mutual behavioral attunement and temporally fine-tuned reciprocity rather than similar perceptual input per se. Consequently, neural synchrony should be enhanced in interactive contexts as compared to non-interactive contexts, even in close physical proximity. We tested 4- to 6-month-old infants and their mothers (N=69 dyads) in three conditions. Mother and infant were either seated next to one another without physical contact or the infant sat on the mother's lap as both were watching a calm aquarium video on a tablet (distal watching and proximate watching conditions, respectively). Next, mother and infant engaged in a 5-minute long free play without toys while both were seated face-to-

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face (interactive free play condition; as depicted in Figure 1). We assessed neural synchrony through dual functional near infrared spectroscopy (fNIRS) measurements in 22 channels, which were located over bilateral inferior frontal and medial prefrontal regions. Wavelet transform coherence was used to calculate neural synchrony in the same channels of both participants. Preliminary findings reveal that mother-infant dyads show no difference in interpersonal synchronization of brain activation patterns during both non-interactive watching conditions, $t(4155)=1.04$, $p=.55$ (see Figure 2). Thus, physical proximity and touch did not significantly affect neural synchronization. However, when both watching conditions are contrasted with the interactive free play condition, we find a significant increase in neural synchrony during free play, $t(4155)=4.12\text{-}5.14$, $p<.0001$. The results indicate that sharing a situation with the same visual input, even in close physical proximity, may not be enough for mother-infant dyads to establish neural synchronization. In contrast, neural synchrony was enhanced in an interactive face-to-face free play situation in which both saw each other, not the same stimulus, and were able to respond to one another. We will further report analyses of behavioral synchrony as well as social touch measures during free play which are currently underway. We will discuss these results in the context of variables affecting neurobehavioral synchronization and the functional significance of neural synchrony in early caregiver-child interactions.

S12.3: Neural synchrony predicts novel word learning from storybooks

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Successful learning, starting early in infancy, requires social interaction with adult caregivers. Joint book reading provides a rich environment for language learning, facilitating better learning of new words compared to passive listening. However, the neural mechanisms that facilitate this interactive context for learning are largely unknown. Previous work using fMRI in adults has shown that neural synchrony (measured with inter-subject temporal correlation, or ISC) relates to the quality of communication between a speaker telling a story and a listener later hearing the story. Moreover, we recently found that infant and adult brains are dynamically synchronized during natural, interactive communication - both with each other and with behaviors such as mutual gaze, infant smiling, and adult pitch variation. However, an important question remains about the basic value and purpose of examining neural synchrony: does neural synchrony predict young children's learning in real time? Here, using dual-brain functional near-infrared spectroscopy (fNIRS), we simultaneously and continuously measured the brains of 3-year-old children and an adult experimenter (Figure 1), who read aloud a digitally presented, custom-designed storybook (N = 45 dyads). The narrative of the story (which focused on a girl traveling through space) included exposure to four novel object-

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label associations, each of which was presented three times. The onset of each page was precisely synchronized across participants, enabling alignment of stimulus presentation with the fNIRS recordings. After each dyad read the story together, the child answered a series of questions via touchscreen, which assessed their learning of the novel words as well as object functions and character roles. We found that real-time learning of story information was correlated with time-locked neural synchrony across children--a measure of engagement with the story structure--in brain areas previously shown to be involved in high-level story comprehension in adults. This was true in parietal channels both for overall learning (collapsed across all question types; $r(43) = .31$, $p < .05$; Figure 2B) and for word learning in particular ($r(43) = .33$, $p < .05$). Furthermore, children who showed higher (vs. lower) overall story comprehension had significantly stronger child-child ISC in parietal cortex, based on a median split analysis ($t(39) = 2.87$, $p < .01$). Adult-child ISC did not show as robust a relationship to word learning, but children who showed higher (vs. lower) accuracy in identifying novel words at test did have marginally stronger ISC with adults in the prefrontal cortex. Finally, we found that children were able to learn quite complex information from these stories, including character motives and object functions, reinforcing the idea that naturalistic, real-life stimuli can be effectively harnessed to optimize engagement and learning in lab settings. This investigation provides the first demonstration that neural synchrony predicts young children's ability to learn new information, in this case novel words and narrative details. Our approach represents an important step toward understanding how teaching agents (caregivers) help infant brains to extract structure from their everyday learning environments.

S12.4: Parental frontal brain activity tracks infant attention during shared play

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When a parent pays attention to an object while they are engaged in shared activity with their 12-month-old infant, this immediately increases the duration of attention that the infant pays to that object (Yu & Smith, 2016). As yet, though, our understanding of how these social influences on attention are substantiated in the brain is currently limited. Previously we have examined how infants' brain activity co-fluctuates with their attention during tabletop play (Wass et al., 2018). Our results showed that, whereas infants' brain activity within theta (3-6Hz) and alpha (6-9Hz) ranges strongly forwards-predicted their attention patterns when they were playing alone, the same forwards-predictive relationship between infants' brain activity and their attention patterns was lower during joint play. This is despite the fact that infants are, overall, more attentive during joint play. One possibility is that infants'

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increased attentiveness during joint play is driven not by intra-individual differences (in each individual considered separately), but by inter-dyad differences (across the dyad). The present study investigates this hypothesis. Method: We recorded from dual, 32-channel EEG concurrently from infants and their parents while they engaged in joint play and solo play (see Figure 1a, 1b). 24 and 25 parents contributed usable data for the Joint Play (JP) and Solo Play (SP) conditions respectively; for infants, it was 21 and 25 for JP/SP respectively. Mean (st.err.) infant age 345.1 (12.1) days; mother age 34.7 (0.8) years) and for 22 dyads for Solo Play; mean (st.err.) infant age 339.2 (10.3) days; mother age 34.1 (1.0) years). Results: We conducted two complementary analyses to examine how the parent's brain activity tracked the infant's attention patterns during joint play: first, we examined how parents' brain activity changed relative to the onsets and offsets of infants' looks (Figure 1c). Significant clusters of electrodes were identified using bootstrapping analyses (Maris & Oostenveld, 2007). We observed a significant ($p<.001$) increase in parent low alpha power across frontal electrodes, time-locked to the onset on infant looks (Figure 1c). Follow-up analyses suggested that this was not a result of changes in the parents' own attention patterns relative to the onset of infant looks. These relationships were not present during solo play. Second, using cross-correlations we examined how continuous fluctuations in the infants' attention patterns related to fluctuations in the parent's brain activity (Figure 2). Our results suggested that parents' brain activity in theta and low alpha bands significantly tracks the attention patterns of the infant (bootstrapping $ps<.001$). Using t-tests corrected for multiple comparisons, our results suggested parental tracking of infant attention was strongest across frontal areas (Figure 2). These relationships were not present during solo play. Discussion: Overall these results suggest, for the first time, that parents show fast-paced neural tracking of infants' attention patterns during joint play. We discuss future plans to investigate how this neural tracking from parents relates to the increased visual attentiveness that infants show during social play.

S13: Rhythm perception in infants: neural, pupillary, and motor entrainment to speech

S13.1: Tracking speech rhythm in the 7.5 month old infant brain is related to word segmentation performance at 9 months

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Young infants are very sensitive to the rhythm of speech (Nazzi et al., 1998). Rhythmic cues help infants to identify words and phrases in continuous speech,

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which is necessary to start building a lexicon (Cutler, 1994). Neurons in the brain process information in a rhythmical way, and can take over the speech rhythm to focus on salient aspects of the input (Lakatos et al., 2008). This cortical tracking of speech might be a possible neural mechanism through which infants can effectively use rhythmic cues for early language learning. In the current study cortical tracking was assessed in 7.5-month old Dutch-learning infants (N=108) in an EEG experiment, in which infants listened to stretches of speech (nursery rhymes), as well as to rhythmically regular and irregular trains of complex tones (beeps). At 9 months the same 108 infants took part in a headturn-preference task assessing their word segmentation ability. Here infants were familiarized with passages containing a reoccurring bisyllabic pseudoword, and then in the test phase their listening times were assessed for familiar and novel word-lists. At 7.5 months the infant brains took over the rhythm of the regular beeps, as evidenced by a larger 2.5 Hz power over bilateral frontotemporal electrodes for regular compared to irregular beep trains (cluster p=.002; N=46 datasets with enough trials after artifact rejection). Speech-brain coherence to the nursery rhymes was assessed by looking at the consistency of the phase difference between the EEG signal and the speech amplitude envelope for frequencies from 1-7 Hz (encompassing the frequencies of occurrence for intonation, stress patterns, words and syllables). The infants showed significant speech-brain coherence over all electrodes from 1-7 Hz (N=58; cluster p<.001). In a next step, both the entrainment to the 2.5 Hz beeps and the speech-brain coherence were related to the infants' familiarity effect in the word segmentation headturn experiment. While there was no relation for the non-linguistic beep entrainment, results revealed a large left-lateralized cluster showing a negative correlation between the nursery-rhyme speech-brain coherence at 1.5-1.75 Hz and the familiarity effect (cluster p=.033; Figure 1; N=39 included in both experiments). This relation was delved in further by splitting the group in 'novelty responders' (N=19) and 'familiarity responders' (N=20) based on the word segmentation results. While the infants that showed a familiarity response in the word segmentation task did not show speech-brain coherence from 1.5-1.75 Hz, the infants that showed a novelty response in the word segmentation task showed clear speech-brain coherence at this frequency over left-frontal electrodes (cluster p=.008). To conclude, infant brains take over the rhythm of both simple beeps and speech. Specifically for the stress pattern rate (1.5-1.75 Hz), speech-brain coherence was related to the outcome of the word segmentation task - with the novelty responders possibly showing a more mature response. The current study gives evidence for the functional relevance of neural tracking of speech. Around 7-8 months of age for Dutch infants the cortical tracking of stress rhythm might be particularly important for starting to identify words in continuous speech.

S13.2: Changes in neural rhythmic entrainment during the first year of life

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Infant-directed speech is an auditory stimulus containing peaks in amplitude around twice per second, a rate which corresponds to the occurrence of syllabic stress in adult-directed speech in stress-timed languages. Cortical neural oscillations at similarly slow modulation rates are known to entrain to the rhythms of speech, and associations have been found between entrainment and speech comprehension in adults (Ding et al., 2016). Could the exaggerated rhythmicity of infant-directed speech facilitate the infant brain in "locking on" to speech rhythm and, consequently, play a role in how infants start to comprehend speech? The longitudinal BabyRhythm project examines how neural entrainment to sound, speech, and song develops over the first year, and how it relates to language acquisition from infancy into toddlerhood. One question arising is how entrainment changes developmentally during the first year. At 6 months and 9 months, infants were presented with auditory stimuli while EEG was recorded. These stimuli took the form of the syllable "ta" repeated by a speaker twice per second, and a drumbeat played at 2Hz. We anticipated that as the infants grew older, cortical tracking of the stimuli would improve, indicating that the infant brain was getting better at locking on to the simple rhythm of the auditory input. We hypothesised that EEG power and its central frequency in the delta band would differ between the stimuli and a silent resting-state, and that these responses would change with age. The delta band, operationalised as 0.5 to 3.5Hz, corresponds to the linguistic rate of stressed syllable production in English, which may be important in providing infants with a prosodic structure to entrain to. Theta band activity (3.5 to 6.5Hz) is also associated with language processing. Initial analyses enacted a fast-Fourier transformation on the data of a subset of 37 6-month-old infants, and applied the Frequency and Oscillations One-Over-F toolbox (Haller et al., 2018) to find peaks in delta and theta power (Figure 1). Peak amplitudes did not differ between the delta and theta bands ($\beta = 0.01$, SE = 0.035, $p = 0.71$) but were higher in delta than in alpha, beta and gamma bands (respectively $\beta = -0.14$, SE = 0.037; $\beta = -0.2$, SE = 0.045; $\beta = -0.15$, SE = 0.03, all $p < 0.001$). The group-level drum- and syllable-related delta band peaks occurred at 2.17 and 2.37Hz respectively but individual peaks were not significantly closer to the stimulus rate of 2Hz than the resting state peaks (group-level 1.38Hz). In the theta band, the resting state peak occurred at 5.33Hz and the drum and syllable peaks at 4.14 and 4.05Hz. The individual drum-related response was significantly closer to the harmonic frequency (4Hz) than the resting state peak ($\beta = -0.6$, SE = 0.21, $p < 0.01$). Six-month-olds' results point to a stimulus-related power increase within predicted frequency bands but not to tight entrainment to the stimulus. Processing of 9-month-olds' data is ongoing but age-

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related changes in peak amplitude and centre frequency may indicate enhanced processing and improved tracking of the auditory stimuli respectively.

S13.3: Individual variability in pupillary entrainment predicts speech segmentation with prosodic and statistical cues in infancy

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Infants can segment continuous speech by using prosodic cues (Jusczyk et al., 1999) and by computing transitional probabilities (TPs) between syllables (Saffran et al., 1996). Understanding how statistics and prosody interact is therefore a topic of considerable research (Johnson & Jusczyk, 2001; Thiessen & Saffran, 2003). However, participants' performance in speech segmentation experiments is mediated by the rhythmicity of the stimuli. Infants are better at segmenting speech stimuli composed of words of equal length (Johnson & Tyler, 2010). Listeners also entrain to auditory rhythm by either aligning endogenous brain oscillations with the peaks in the acoustic envelope of the stimuli (i.e., bottom-up cortical entrainment to vowels and vowels carrying prominence) (Giraud & Poeppel, 2012; Kalashnikova et al., 2018) or with the onset of reoccurring prosodically flat auditory sequences (i.e., top-down entrainment through contextual cues such as TPs) (Barczak et al., 2018). How these two types of entrainment impact speech segmentation in infancy remains poorly understood. Here we investigate the role of entrainment in 9-month-old German learning infants' (N=24) ability to segment speech with prosodic and statistical cues. Following Thiessen and Saffran (2003), infants were familiarized with a continuous speech stream (2min) in which statistical words signaled by TPs straddled prosodic word boundaries. In the test phase, infants were presented with prosodic and statistical words in isolation. We measured infants' pupil size with an eye-tracker. Pupils dilate in response to surprise and novelty (Hochmann & Papeo, 2014) - providing a spontaneous non-invasive physiological measure for word recognition (i.e., larger pupils to non-segmented words). Pupils can also entrain to auditory rhythms by temporally aligning changes in pupil size to perceived rhythm signaled by prosodic and contextual cues (Fink et al., 2018; Barczak et al., 2018). The temporal alignment of pupillary changes at word frequency during familiarization may therefore provide an alternative to electrophysiology for studying entrainment to auditory stimuli. We show that, as a group, 9-month-old German infants do not use a consistent segmentation strategy when prosodic cues are in conflict with statistical cues. The pupillary response to prosodic and statistical words at test showed no significant differences in the time domain (P>.05) (Figure1A). However, the temporal alignment of infants' pupillary oscillations at word frequency (i.e., the phase of the frequency response at which words occurred in the familiarization) was predictive of infants' pupillary response at test (ß=.054, SE=.02, P<.01). The more the pupillary oscillations during the familiarization were

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aligned with the onset of the statistical words (0 radians Figure1B), the bigger the mean pupil dilation at test for prosodic words when compared to statistical words. In contrast, the more the pupil oscillations were aligned with the onset of the prosodic words (3.14 radians Figure1B), the bigger the pupil dilation for statistical words when compared to prosodic ones. To our knowledge, this is the first demonstration that both acoustic as well as contextual cues can lead to entrainment in young infants. Taken together, we show that individual variability in how infants entrain to acoustic and contextual cues reveals a struggle between prosody and statistics in their ability to segment continuous speech.

S13.4: Infants show spontaneous motor entrainment while listening to rhythmic speech

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It is widely acknowledged that the perception of rhythm of speech is one of the most relevant aspects of language that tune infants into language acquisition (Gleitman & Wanner 1982). Adult studies indicate that rhythm is multimodal with intrinsic connections between speech and the body (e.g. in dancing, or coordinated gestures). So far, it has not been considered that infants' rhythm perception may be connected to motor entrainment. A coincidental observation inspired the present study: in artificial language learning experiments, when infants are familiarized with speech streams, they sometimes move their body rhythmically as if they were dancing. Artificial speech streams are highly rhythmic with syllables being organized in a repetitive order. Infants' spontaneous rhythmic body movements are enhanced in specific conditions, for example when hearing music (Zentner & Eerola 2010). This raised the question of whether specific acoustic rhythm cues (pitch, intensity, or duration) trigger infants' motor entrainment. 7.5-months-old infants use pitch and duration cues but not intensity cues for segmenting artificial languages (Bion et al. 2011; Abboub et al. 2016). We suspected that infants' rhythmic motor engagement is associated with performance in such tasks. For the present study, we used Abboub et al.'s (2016) data of the German-learning 7.5-month-olds (n=76), and unpublished data of 9.5-month-olds (n=82). In the experiment, infants were familiarized for three minutes with rhythmic speech streams, synthesized with either a French- or a German-sounding pronunciation. In three conditions, every second syllable was stressed (...NAzuGIpeFYro...) by pitch, duration, or intensity cues. In a control condition, no syllable was stressed (...nazugipefyro...). Afterwards, segmentation was tested with bisyllables that were either words (e.g. trochaic NAzu) or partwords (e.g. iambic zuGI) in the artificial language using the head-turn preference procedure. Video recordings were annotated for infants' rhythmic movements during familiarization. 42% of all babies occasionally moved rhythmically. An Anova of the average rhythmic moving times (Fig.1) showed an

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effect of condition (F=2.68, p<.05) and a pronunciation*condition interaction (F=2.97, p=.03), but no effects of age or other interactions. Further analysis revealed that the condition effect was only significant with the German- (F=4.43, p<0.01) but not with the French-sounding pronunciation. With German-sounding stimuli, infants showed longer body movements in the duration condition when compared to the intensity and control condition (both p's<.01); no other comparison reached significance. Moving times were marginally longer with German- than with French-sounding stimuli (p=.07). There was a correlation of moving times and speech segmentation performance (p<.001; Fig. 2): the longer the moving times, the longer were looking times to trochaic test items. The present study provides first evidence that infants' spontaneous rhythmic motor engagement while listening to rhythmic speech is systematic. Infants are motorically more engaged with native than with non-native speech, and it depends on the perceived rhythmic cues. The association between moving times and segmentation performance indicates that infants who are motorically more entrained continue preferring "familiar" trochaic items at test. Future confirmatory studies should show how motor entrainment contributes to language acquisition.

S14: Understanding infants' lives by the use of smartphones: Experience sampling and ambulatory assessment

S14.1: Using digital technologies for assessing infants' cognitive development in real-time

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Children's differences in cognitive development have pervasive, long-term influence on all important life outcomes, including educational attainment, health, and longevity. However, little is known about infants' differences in early life cognitive development. This omission is partially due to a lack of measurement tools that enable assessing infants' differences in cognitive development as they occur. In this symposium contribution, I will review the utility of two digital technologies that serve as ambulatory assessment methods to capture infants' differences in early life cognitive and verbal development. The first technology is a smartphone application (app) that enables mothers to report on the development and experiences of their infant between the ages of 2 and 15 weeks. App alerts are sent every two to three days. Items were adapted from the Mullen Scales of Early Learning to capture cognitive development; other measures include dietary and sleeping patterns of both mother and child. The app was validated against lab-based assessments in N = 20 mother-infant dyads (infant mean age = 8 weeks, SD

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= 4.2), showing that mother's responses to the app alerts matched the data obtained through observations from trained research assistants. In a second sample of N = 53 mother-infant dyads (infant mean age = 11 weeks, SD = 3.7), we observed that 50% of the variance in infants' day-to-day experiences (e.g. sleep, diet) occurred within the families, suggesting that early life experiences are very dynamic. We also observed coupling effects between mothers' and infants' behaviours, confirming that developmental differences occur in response to differences in early life experiences. The second technology is LENA (www.lena.org), which consists of digital audio-recorders that children 'wear' in custom-made clothes and that record everything that a child hears or says over the course of a day. LENA allows to unobtrusively observe children's early life language experiences and development. In a sample of N = 107 infants aged 24 to 36 months who were each recorded for 3 days, we found that about half of the variance in language experiences occurred within the families, confirming that early life experiences are highly dynamic across domains. We also observed that children who were exposed to more adult language showed better cognitive development and verbal skills than children who heard fewer words over the course of the day. Digital technologies enable collecting unobtrusively repeated measures of infant development, which is key to understanding the dynamics of early life experiences and how they influence infants' developmental differences.

S14.2: Online testing technology for infant touchscreen and looking time tasks

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Infant testing is personnel and resource expensive. Recently, there has been a surge in investment in online testing technology which would allow researchers to acquire data from infants in the comfort of their home or at other child facilities such as daycares, schools and children's fairs. Here, we present three variants of such technology, aimed at collecting data from infant and child participants as well as our user interface (Kinderstudien.de) that allows researchers to easily and independently program and conduct their own experiments. The first version of this software involved a touchscreen-based word-learning application that can be used with children of a wide range of ages, from as young as 22 months. Here, children were presented with two images in each trial and could choose by tapping on the image they wanted to hear the label of. In a yoked-control design, children were assigned to either an active or a passive learning condition. Children in the active condition were allowed to choose which of the two images they wanted to hear the label of. Children in the passive condition were not allowed to choose but received

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the stimuli chosen by the active children following the exact timing and sequence of the trials and labelled images in the active condition. We then tested children's learning of the word-object associations by showing them a number of objects as they heard the label for one of these objects and asking them to tap the labelled image. Here, we were able to obtain not only information about the accuracy of children's responses but also the time they took to make a response. A second extension of this software uses a single touchscreen device with an inbuilt camera which also provided data of infants' looking behaviour during the trials in the study described above. Across the two studies, we found that passive children performed more robustly than active children, either by choosing the correct object more often, faster and looking at the labelled object longer than the active children. We interpret these findings as a cautionary tale for active touchscreen-based tasks, since we suggest that active children might have been primarily interested in the possibility of choosing an object rather than choosing the right object or attending to the stimuli presented. Nevertheless, the fact that both groups showed learning of the novel word-object associations highlight the usefulness of such a setup for infant testing. A third extension of this software with the user interface allows researchers to easily program an experiment and send parents a link to this experiment which they can conduct in the comfort of their home. Parents are asked to provide informed consent first via an online form, and after they allow us access to their webcam at home, via video, before beginning the experiment. Since parents here provide us with access to their webcams, we can obtain response (time) data as well as looking time data remotely in such studies.

S14.3: Identifiying dynamic developmental processes during infancy by using the WeltentdeckerApp

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Assessing individual variability in infants' development requires the use of microgenetic research designs that measure development with high temporal frequency at the time when it occurs. In this talk, we present an integrative approach that combines a population-based prospective, longitudinal, and microgenetic research paradigm by means of a simple-to-use, smartphone-based developmental diary application (WeltentdeckerApp). The WeltentdeckerApp targets parents of children between birth and 6 years of age. Parents are prompted periodically to answer a short set of questions about their children's development in different domains (language, cognition, motor skills, and socio-emotional competences). These questions are extracted from a database of approximately 2000 questions (language incl. vocabulary, syntax, grammar: > 1500, motor (incl. fine and gross motor): 176, cognition: 34, social-emotional: 74) that have been validated per domain and for different age groups. In addition, physiological aspects such as

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height and weight and contextual aspects such as parental education, SES, languages exposure, and cultural background are assessed. The WeltentdeckerApp is available in German, French, Italian, and English. The assessment of children's development is therefore far less limited to specific regions, countries, and languages than in traditional research approaches and allows longitudinal assessment of children at different ages, world-wide. Data will be presented from the validation studies and we will offer a first analysis of the data of currently > 4000 parents who are using the WeltentdeckerApp with a current total number of > 180 000 data points. For instance, using this data, we replicated previous lab-based findings (Farrant & Zubrick, 2011; Morales et al., 2000) on the longitudinal relation of joint attention and language development. Analyses of a subset of infants (N = 198) indicated that the onset of early joint attention ability (i.e., child is looking from an object to parents and back) significantly predicted the age at which infants spoke their first words, $b = 0.51$, $p < .001$, $F(3,194) = 50.28$, $p < .001$, $R2 = 0.44$. There was no main effect of infants' sex, $b = -21.81$, $p = .563$, nor an interaction of sex and early joint attention ability, $b = 0.06$, $p = .495$. Infants who showed joint attention earlier in life also spoke sooner (Figure 1). This suggests that infants' development in the social domain is longitudinally interconnected with their language skills. By means of the novel microgenetic approach, we expect to learn more about such developmental processes and their dynamic interactions in children aged 0 to 6 years. (Figure 1. Kernel probability density, mean and standard deviation of the onset of infants' joint attention ability (red) and first words spoken (blue).)

S15: Brain & Behavior: New insights into neural correlates of infant emotion regulation

S15.1: Newborn amygdala connectivity to prefrontal and sensory regions is associated with early emerging regulatory behavior

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Background: It is known that poor emerging emotion regulatory ability is a core common feature across different forms of psychopathology. The earliest neural precursors of emotion regulatory skills are therefore of considerable interest. Given its role in emotionality and emotion regulation across the lifespan, coordinated

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functioning of the amygdala represents a natural starting point for such investigation. The current study examines coordinated functioning of the amygdala soon after birth in relation to emerging emotion regulatory ability at 6-months-of-age. Recent advances in neuroimaging processing and analysis are applied to increase capacity to identify the earliest neural precursors of emotion regulation. Methods: High quality resting state functional MRI data were collected in 51 newborn infants (scan age 22.5±9.1 days). Individual infant amygdalae were automatically segmented using a multi-template, multi-modality method (J. Wang et al., 2014) and then manually corrected in ITK-Snap (Yushkevich et al., 2006). Imaging data were processed in surface space using an in-house version of the Human Connectome Project Minimal Processing Pipeline modified for use in neonates. Two independent coders (percent agreement > 85%) rated regulatory behavior and emotionality at 6-months-of-age during the still-face episode of the Still-Face Paradigm using a previously established coding scheme. Latency to distress (LTD) was examined as an indicator of infant emotional reactivity and regulatory ability. Multivariate regression analyses were conducted to identify cortical greyordinates whose functional connectivity to the amygdala at birth was associated with future regulatory ability. Right and left amygdalae whole brain connectivity were analyzed separately. All analyses were adjusted for gestational age at birth and scan age. A cluster-based detection approach ($p<0.05$) was used to correct for multiple comparisons. Results: Stronger left amygdala connectivity to dorsal medial prefrontal cortex (dMPFC) was associated with greater LTD ($z = 3.2$, $p<0.05$). Stronger left ($z = 3.1$, $p < 0.05$) and right amygdala ($z = 3.9$, $p < 0.05$) connectivity to default mode network regions in bilateral temporal cortex were also associated with greater LTD. In contrast, stronger amygdala functional connectivity to sensory processing regions (right amygdala to visual cortex ($z = -6.2$, $p<0.05$) and left amygdala to somatosensory cortex ($z = -3.1$, $p<0.05$) was associated with shorter LTD (i.e. infants expressed distress more quickly in the context of this stressor). Conclusions: Already by the time of birth, specific patterns of amygdala coordinated functioning appear to be relevant for emerging emotion regulatory capacity. Interestingly, stronger neonatal amygdala connectivity to primary sensory processing regions was associated with a quicker expression of distress. This neural phenotype may indicate more amygdala involvement in detection of and response to environmental stimuli and thus greater emotional reactivity. In contrast, greater amygdala integration into brain regions typically involved in regulating emotions in older populations (dmPFC) was associated with a delayed expression of distress. These results indicate potential early neural foundations for emotional reactivity and regulation evident already in the neonatal period.

S15.2: Associations between amygdala connectivity and negative reactive temperament

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In the first few months of life, infants begin to exhibit differences in response to novelty. Infants that have a negative reactive temperament are highly distressed by novelty. These infants are significantly more likely to continue to exhibit fear of novelty in toddlerhood. Fear of novelty in toddlerhood is strongly associated with risk for anxiety and poor social emotional outcomes in adolescence (Fox et al, 2005; Penela et al, 2015). Negative reactive temperament is thought to emerge from heightened amygdala responsivity (Kagan et al, 1988). While recent research has linked parental reports of temperament to amygdala connectivity (Graham et al, 2016, Thomas et al, 2018), most work linking infant reactivity to differences in neurobiology has focused on the adult brain (Schwartz et al, 2012). The aim of the current study is to extend the prior literature on the neurobiological origins of temperament by evaluating the link between amygdala connectivity and behavioral assessments of temperament when these temperaments first emerge. To do so, we recruited 4- to 5-month-old infants, assessed temperamental reactivity, and collected functional magnetic resonance imaging (fMRI) during natural sleep (n=26; M=9.5 minutes of fMRI data). fMRI collected during natural sleep can be used to measure correlations in brain activity across the brain over time. Brain regions comprising networks are highly correlated at rest. fMRI data were processed using the CONN toolbox (Whitfield-Gabrieli & Nieto-Castanon, 2012). Temperamental reactivity was assessed in the laboratory by presenting infants novel visual and auditory stimuli and scoring the infant's affective response (negative or positive) to the stimuli using a 7-point likert scale. To identify amygdala functional connectivity, seed-based correlation analyses were run with a voxel significance threshold applied at $p<.001$ uncorrected and cluster threshold set at $p<.05$ FWE-correction. Results indicated that greater negative reactivity was associated with decreased amygdala-PFC connectivity. Connectivity between the right amygdala and the prefrontal cortex was bilateral (left cluster 136 voxels: $p<.009$; right cluster 234 voxels: $p<.0005$; See Figure 1. These results lend support to the hypothesis that negative reactivity is linked to amygdala connectivity. The direction of this pattern conflicts with previous reports of greater neonatal amygdala-PFC connectivity and parental reports of fearful temperament (Graham et al, 2016, Thomas et al, 2018) but is consistent with data from observational studies of fearful temperament in monkeys and with data on pediatric anxiety disorders (e.g., Birn et al, 2014). Together, this work illustrates the value of linking behavioral assessments of infant temperament with measures of functional connectivity.

S15.3: Maternal Anxiety and Neonatal Brain Response to Novel Sounds as Assessed with fMRI

Chad Sylvester(1), Cynthia Rogers(1), Michael Perino(1), Daniel Pine(2), Joan Luby(1), Christopher Smyser(1)

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Neonates with an enhanced behavioral and neural reaction to novelty (as measured by EEG) are at an increased risk for developing an anxiety disorder. Yet, almost nothing is known about the specific brain systems that respond to novelty in neonates and how variation in activity in specific brain systems relates to risk for anxiety. Here, we used task-based fMRI to measure brain activity across the cortex evoked by novel auditory stimuli ('oddballs') in n=45 sleeping neonates (mean age 27.8 days). In a subset of n=41 infants, variation in regional brain activity in response to oddballs was related to maternal trait anxiety on the State-Trait Anxiety Inventory (STAI-T). Results indicated that auditory oddballs elicited robust and widespread activity across the neonatal brain, including in auditory cortex and in portions of the brain that become the salience, default mode, cingulo-opercular, and somatosensory networks in adults. High maternal trait anxiety was associated with an increased initial response to auditory oddballs in different regions distributed across the brain, including regions in the cingulo-opercular and ventral attention networks. All statistical analyses were whole brain corrected at a level of $p<0.05$ using stringent cluster-based correction methods (voxelwise significance $p<0.001$, cluster size 1000mm3). In conclusion, neonates at high risk for anxiety on the basis of high maternal anxiety have increased neural responses to novel sounds across many different brain systems. These results suggest that the pathology associated with anxiety may begin already at birth and may include alterations in the basic brain mechanisms that respond to environmental change.

S16: Insights from outside the lab: Modeling observational data to understand language learning

S16.1: Using neural network language models to predict age of acquisition for early vocabulary

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What predicts what words are easier or harder to learn? We hypothesize that the complexity of the syntactic contexts in which words appear should also influence when they are acquired. To date, frequency has been the most important factor for predicting the Age of Acquisition (AoA) of a word (Goodman et al. 2008; Kuperman et al. 2012; Braginsky et al. 2019). However, frequency does not represent the complexity of the contexts in which words appear. In our current work, we use computational language models in concert with a broad array of child-language datasets to predict when words are acquired, exploring information beyond first-

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order frequency. We used the long-short term memory (LSTM) neural model architecture, a form of recurrent neural network used for language models (Sundermeyer et al. 2012). LSTMs learn representations of words which represent both the semantic and syntactic distributional information. Though more recent language models outperform LSTMs, they are a strong standardized baseline and have many useful analytic properties. They are known to be capable of learning long distance syntactic relations (Linzen et al. 2016). We hypothesized that the distributional information they capture would be a better predictor of AoA than pure frequency. We used CHILDES (MacWhinney 2000) to train our models and Wordbank (Frank et al. 2016) to test our models. We trained 39 LSTM language models on 39 individual child transcripts from CHILDES (chosen because they contained >20,000 words and >1:20 child/caregiver speech ratio; MacWhinney 2000), effectively treating models as participants. Models were trained on 100% of the child-directed utterances and 60% of the child's utterances. For each child model, we retrieved all the child-directed utterances which contained a word from the CDI form on Wordbank and calculated the average surprisal of the word in context (Levy, 2008). We then averaged those surprisal scores across all models. The resulting predictor is a proxy for the predictability of each word given the contexts in which it appears in the input. We then fit regression models predicting AoA (estimates were calculated using all of the English Words and Sentences CDI instruments from Wordbank and the Bayesian estimation model from Frank et al. 2019). We compared models with either average surprisal or average frequency or their combination as predictors using leave-one-out cross validation across all words (Table 1). Surprisal yielded better predictions (lower mean absolute deviation (MAD)) than frequency overall. Furthermore, we found that the reduction of MAD was due to better predictability of AoA for function words and predicates (Figure 1). Thus, the syntactic and semantic distributional information encoded by the LSTMs helps account for the difficulty that acquiring these types of words may present. Average surprisal of words in context is a better predictor of AoA than their frequency; the diversity in semantic and syntactic context in which words appear matters to word learning, beyond their overall frequency in discourse.

S16.2: Characterizing child-directed listening with corpus and model-based analyses

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Extensive research has focused on how we talk to infants and young children (e.g., the properties and benefits of infant-directed speech; Newport and Gleitman, 1977), but what about how we listen to them? Here we propose that parents and other adult caregivers contribute to the language learning process through "child-directed listening." Just as adults use rich expectations regarding what other people

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are likely to say in order to overcome ambiguity, noise, and variation in the speech they hear from other adults (Gibson et al. 2013), they employ a related set of abilities to interpret infants' vocalizations. Critically, child-directed listening allows caregivers to treat children's speech as communicatively significant, felicitous, and actionable--even when it bears little resemblance to the adult language. We present two analyses as initial steps towards characterizing child-directed listening. First, we analyzed lab-annotated "best-guess" transcriptions from developmental corpora as an approximation for how caregivers interpret children's vocalizations as words. Specifically, we compared these best-guess transcriptions of child speech in the Providence corpus (Demuth et al., 2006) with matched phonemic (IPA) transcriptions. While phonemic /kæts/ would typically be transcribed as "cats," we measured the prevalence of "annotator-recovered words" -- instances where the best-guess transcription is not supported by the phonemic transcription of the child's speech (e.g. /kæt/ ["cat"] annotated as "cats"). Focusing on a sound pattern that includes plural nouns (e.g., "cats"), possessives ("Mom's"), and 3rd person singular verbs ("sees"), we looked for words with transcriptions ending in "s" or "z," but where the matched phonemic transcription does not contain a corresponding sound (no word-final /s/, /z/, or approximations /ð/, /θ/, or /ʒ/). Analyzing 47,844 word tokens, we found high rates of annotator-recovered words during infancy, with the proportion of such word tokens per transcript decreasing into childhood (Figure 1). Next, we evaluated whether substituting these annotator-recovered words yields utterances that are more consistent with adults' linguistic expectations than the literal interpretation of children's vocalizations. As a stand-in for adults' linguistic expectations we used a state-of-the-art neural language model (GPT-2, Radford et al., 2018). We compared the model-estimated probability of two variants for each utterance in a subset from Analysis 1: one with the annotator-recovered word (e.g., "two little kitty cats"), and one with a literal interpretation of the phonemic transcript ("two little kitty cat"). If adults bring their prior linguistic knowledge to the task of interpreting infants' speech, estimated surprisal (negative log probability of an utterance under the model) should be systematically lower among annotator-recovered utterances than literal utterances. Indeed, this is the case (Figure 2; paired t-test, $t = -18.531$, $df = 602$, $p < .0001$), suggesting annotators' interpretations reflect their prior expectations. Taken together, these analyses suggest that adult language processing plays a critical role in the language learning process: adults use prior expectations to interpret (and thus act on) infants' vocalizations. Future research will investigate the implications of child-directed listening for development, including the nature of feedback available to infants in language learning.

S16.3: Characterizing the relationship between lexical and morphological development

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To learn the morphology of their native language, children need to generalize beyond their input (e.g. by extending pluralization of known words, dog-dogs, to novel words, wug-wugs). They also need to encode exceptions to these generalizations (e.g. goose-geese rather than gooses). How do children make these inferences in the face of sparse input? Do they generalize directly from their vocabularies on an item-by-item basis, or do they form global rules from independent criteria? In this work, we address these questions by using large-scale data to investigate relations among morphological development, vocabulary growth, and age.

 We use large-scale samples of parent-report data from Communicative Development Inventories (Fenson et al, 2007), aggregated in Wordbank (Frank et al, 2016). For three languages, we examine irregular verbs (e.g. go) for which there is both the correct past tense form (went) and overregularized form(s) (goed, wented). For each child, we code each item as stem-only (e.g. says go, doesn't say went/goed/wented), stem+correct (says go and went, doesn't say goed/wented), or stem+overregularized (says go and goed/wented). We predict these measures from age (16-36 months) and proportion of verbs produced. For each language and measure, we fit mixed-effects logistic regressions (random effects for stem) with fixed effects structures that are combinations of age, linear/quadratic verbs, and age-verbs interactions. Figure 1 shows fitted probabilities from the models that include all terms (which are justified by 10-fold cross-validation).

 First, we find that morphology learning is strongly related to vocabulary size, more than to age. Verb-only models perform better at out of sample prediction than age-only models, and explain more variance in both correct inflection (averaged over languages, 21.7% for verbs and 8.6% for age) and overregularization (7.7% verbs, 3.6% age). This supports morphology learning being coupled to lexical learning (or both being coupled to general language ability), rather than developing as separate competences.

 Second, the relation between morphology and vocabulary is modulated by age. For two children with the same vocabulary size, the older is more likely both to correctly inflect and overregularize (Figure 1, the gap between age curves). Additionally, the effect of vocabulary on both measures decreases with age (the difference between the curves' slopes). This suggests that there are developmental changes that affect morphological ability over and above vocabulary.

 Lastly, correct inflection and overregularization rates rise in tandem over age, rather than a discrete phases of overregularization then increased correct inflection (at least aggregated across children). Moreover, vocabulary effects on correct inflection and overgeneralization are correlated across items (Figure 2). Thus, rather than evidence for a global rule, we see evidence for verb-specific competition between regular and irregular forms.

 These analyses demonstrate that morphology learning relates strongly to vocabulary learning. Additionally, this relation is modulated by age and varies across verbs. By mapping developmental

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change across large samples and multiple languages, we paint an empirical picture that constrains theories of the mechanisms underlying morphology learning.

S16.4: Assessing cross-linguistic viability of infant word segmentation models

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When learning language, infants need to break down the flow of input speech into minimal word-like units -- i.e., segment it. Several strategies for infant word segmentation have been proposed. Although some have studied performance across several languages (e.g. Pearl & Phillips, 2018; Saksida, Langus & Nespor, 2017), no previous research assesses specifically how robust to cross-linguistic variability a wide range of strategies are. In this study, we report on the stability in performance of 11 conceptually diverse strategies on 8 typologically distinct languages represented by closely matched corpora. Our questions are: (1) Do strategies perform above chance for all languages? Strategies that systematically perform at or below chance would not be plausible for infants. (2) Is the rank ordering of their performance similar across languages? That is, is it the case that the same strategies perform poorly or well across languages? If they pick up on general linguistic properties, and not on language-dependent cues that may not be helpful for some languages, then we expect the rank ordering to be rather stable. The strategies used are inspired by laboratory research on infant word segmentation and are presented in WordSeg, an open source package (Bernard et al., 2018). Phonemization was done using grapheme-to-phoneme rewrite rules adapted to each language (Moran and Cysouw, 2018). Only adult-produced speech was included, where word boundaries had been removed. As for languages, we employed the ACQDIV database (Moran et al., 2016) of typologically distinct languages (Chintang, Indonesian, Inuktitut, Japanese, Russian, Sesotho, Turkish and Yucatec). All corpora were ecologically valid and gathered longitudinally, with transcriptions of child-directed and child-surrounding speech recordings (target children's age ranging from 6 months to 6 years). We found that (1) no strategy performed systematically below chance, but we cannot say that they all performed above chance for all languages either (Figure 1); (2) there was stability in the order of performance across languages, suggesting that strategies pick up on general linguistic properties (Figure 2). Overall, the more promising candidate was the Diphone Based Segmentation algorithm (Daland & Pierrehumbert, 2011), being systematically above chance and among the top in performance. DiBS implements an optimal boundary setting based on the Bayes' theorem and co-occurrence statistics. Thus, our results support previous experimental findings that infants may use such tools to acquire language. Moreover, differences in performance across

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algorithms were larger than differences across languages. Experimental evidence suggests slight variation in the timing of acquisition of different linguistic features (e.g. Slobin, 1985). Given the small differences across languages found for our unsupervised word segmentation algorithms, such variation could come from something else, such as meaning acquisition, which would require algorithms different from the ones explored here. To sum up, if infants do anything similar to these strategies, then they would be well-equipped to get a head start in segmenting word-like units regardless of what their native language is.

S17: How multiple exemplars help infants and young children extend their knowledge

S17.1: Multiple exemplars facilitate 9-month-olds' property generalizations

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We examined 9-month-olds' ability to generalize a newly learnt sound property from one category member to another in the context of basic-level categories (i.e., cats and dogs). Our goal was to examine the influence of variability on infants' acquisition of category-property associations from two directions. First, we explored how variability amongst category members impacts infants' property extensions. Second, we examined whether multiple exemplars facilitate property generalizations when category members are less perceptually similar. In Experiment 1, 9-month-olds were familiarized to two animal-sound pairings (e.g., Orange Cat - meow; Black Cat - bark) and tested with two types of test trials in a preferential looking paradigm. See Figure 1 for an overview of the procedure. Same trials entailed the presentation of the two familiarized animals side-by-side, while one sound played. During extension trials, infants were presented with a novel exemplar from each category accompanied by one sound. One group (n = 26) was tested on their generalization of the sound property to a new category exemplar that differed in color from its counterpart during familiarization (i.e., a same breed exemplar); another group (n = 27) was tested on their generalization of the sound property to a new category member of a different breed (i.e., a less perceptually similar exemplar). If infants learnt and generalized the sound property, they were expected to look toward the target animal (i.e., the animal that matches the sound) at rates significantly greater than chance. Infants in both groups learnt the original animal-sound association, as their proportion of looking to same trials was significantly greater than chance (M = .55 and M = .54). On extension trials, when asked to generalize the sound property to highly similar category member, infants' proportion of looking to the target was significantly greater from chance (M = .56).

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In contrast, when asked to generalize the sound property to a new category member of a different breed, performance did not differ from chance (M = .51). Thus, infants readily generalized the sound property to highly similar exemplars but did not extend the property to less perceptually similar exemplars. In Experiment 2, we asked whether familiarization with multiple exemplars would promote property extensions to category members that were more variable. Nine-month-olds (n = 27) were familiarized with three different exemplars from the categories of cats and dogs, and tested on their learning of the animal-sound mapping and the generalization of the sound property to a less similar category member. Here, infants' proportion of looking to the target animal was significantly greater than chance for both same (M = .54) and extension (M = .54) trials. Our results highlight the factors that impact infants' property generalizations at 9 months. A single exemplar was sufficient to promote property extensions to highly similar category members; however, infants required the presentation of multiple exemplars to make property generalizations to less perceptually similar category members. The results will be discussed in terms of the facilitative role of multiple exemplars, as well as the categorical representations that underlie infants' property extensions.

S17.2: Extending verbs to new events: Does the comparison of events over delays help?

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A problem in verb learning is how to extend verbs to new events, a key step to becoming a productive speaker. Prior studies show comparing multiple events can be useful (e.g., Scott & Fisher, 2012) but, in everyday life, events are often interspersed with other events and separated in time. Two studies test children's ability to compare events differing in similarity, over delays, and employing different methodologies. Study 1 shows children have more difficulty comparing events separated by delays when events are varied, and Study 2 shows that experience comparing similar events helps them learn how to compare more varied ones, even across delays. Study 1 used live events to examine children's ability to compare events when novel events were interspersed with familiar events and separated in time, asking whether this helped them extend new verbs. Two- (n=14) and 3-year-olds (n=10) saw 3 pairs of events that included a familiar and a novel event; each pair was separated by a 1 minute book reading delay. All novel events were similar to each other. At test, children enacted events using new objects; this was repeated for a second verb. A univariate ANOVA with Age (2: 2, 3) as a factor, dv= number correct enactments, showed a main effect of Age $F(1, 23)= 9.16$, $p=.006$. One sample t-tests showed only 3-year-olds' responses exceeded chance, $t(9) = 2.59$, $p=.029$. In a follow-up study, 3-year-olds were shown all varied events or only 1

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event before test, and children in these conditions could not extend the verbs, varied: t(10) = .48, ns; control: t(13)=-1.15, ns. Together, these results show 3-year-old children can compare similar events separated by delays, and that they need this comparison information to extend new verbs. How do children learn how to compare varied events? Studies have shown that seeing similar examples can help children learn how to compare events, but no study has included delays between events. In Study 2, 2- (n=24) and 3-year-olds (n=28) were shown a set of video events on an iPad. In one condition, they saw similar then varied events (similar first); in the other, they saw all varied events. Events were separated by a 1-minute distractor video. They pointed to one of two new events at test, repeated for a second verb. A 2 (Age: 2, 3) x 2 (Condition: SF, AV) univariate ANOVA reveals a main effect of Condition, F(1, 51)= 6.72, p=.013. One sample t-tests show only children in the similar first condition exceeded chance, t(26)= 3.55, p=.002. Across age, only children who could practice comparing similar events before seeing more varied ones could extend verbs to new events at test (see Figure 2). Although verb studies often show children related events one after another, delays between events are common in everyday life. These studies show how children may learn to use information across instances and over time, and show that this ability to compare events helps them extend verbs to new events.

S17.3: Why do multiple examples help children learn words? The roles of aggregation, decontextualization, and memory dynamics

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When young children learn words, they learn to extend these words beyond their initial referent. For example, children might use the word "cup" to refer to their own favorite plastic cup, but they will also use it to refer to other cups that they encounter. Furthermore, children remember these word-object associations and continue to generalize to new instances across long periods of time. In this talk, we illustrate how multiple examples (1) help children generalize words to new referents, and (2) remember word-object associations across time. Specifically, we propose that multiple examples support three key processes implicated in word learning: aggregation, decontextualization, and memory dynamics.
 First, in experiencing multiple examples of word-object pairs across time and across contexts, learners are able to aggregate the objects' features and begin to learn the structure of the category. Through aggregation, relevant properties become represented more strongly, whereas representations of irrelevant properties become weaker. Second, multiple examples support decontextualization. Young word learners are strongly affected by the contexts in which new words are learned, such that a change in context disrupts their learning. Multiple examples of word-object pairs help children separate referents from the contexts in which they appear

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(e.g., environmental or temporal context); in contrast to the changing context, the word-object pairing is invariant. In this way, multiple examples help children generalize words to new contexts. Finally, multiple examples facilitate children's long-term retention of words through memory dynamics. When children are presented with a single example (e.g., of a new object-label pair), they quickly forget it. However, the presentation of multiple examples across time provides children with the opportunity to engage in effortful retrieval during each presentation, which is theorized to help strengthen category representations and slow the rate of forgetting. In this talk, we will present evidence from 2- and 3-year-olds (i.e., young word learners) to support each of these ideas.
 In sum, children are sensitive to regularities in their environments, and these regularities help children learn their first words. By tracking multiple examples across space and time, children are able to aggregate category-relevant features and decontextualize objects, supporting generalization to new instances. Furthermore, multiple examples interact with memory dynamics to support children's long-term retention of words. Together, these processes play a powerful role in early word learning.

S18: Child evocative effects in the context of parenting across developmental systems: A behavioral and neurophysiological perspective

S18.1: Difficult temperament profiles and externalizing behaviors: The moderating effects on harsh parenting and dyadic inconsistency

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Harsh parenting interacts with children's difficult temperament (DT) to contribute to children's greater externalizing behavior problems. However, gaps remain in our understanding of how variations in DT and dyadic parent-child interaction processes contribute to externalizing problem etiology. While difficult temperament has often been studied as a temperament profile that is more sensitive to harsh parenting (Belsky, 2013), the definition of difficult temperament has been highly debated (Bates, 1983; Rothbart, 1982; Thomas et al., 1982). It may be this ambiguity in DT's definition that is leading to mixed results regarding the relation between temperament, harsh parenting, and externalizing behaviors (e.g., Kochanska & Kim, 2013; Bradley & Corwyn 2008). To clarify the definition of DT, person-oriented approaches would allow researchers to pinpoint which components of DT may act as drivers between temperament profiles, harsh parenting, and externalizing. The present study examined 1) latent profiles of DT

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and 2) two moderators to represent coercive family processes: a) harsh parenting and b) observed inconsistency in parent-child interactions (e.g., in discipline and compliance). Participants were 150 parent-child dyads from low-income families. Families were assessed at child age 30-months (M = 29.76, SDage = 1.8), 36-months (M = 36.48, SDage = 1.32), and 48-months (M = 48, SDage = 1.44). At 36-months and 48-months, dyads completed a 2-hour lab visit that included a dyadic task that required parents and children to work together to complete a set of puzzles that were above the child's cognitive ability level in order to win a prize. Children also completed an individual task designed to measure effortful control. Dyadic tasks were then coded offline by trained and reliable coders for parent and child behaviors. Using Latent Profile Analysis, four temperament profiles emerged: high reactive, exuberant, low reactive, and inhibited, BIC = 3683.34, BLRT = 49.94, $p < 0.001$. Using these profiles, we next examined the effects of harsh parenting, finding that harsh parenting significantly moderated the relation between DT profiles and later externalizing behaviors, $F(7, 99) = 3.33$, $p = 0.003$, $R2 = 0.19$. Further exploration of this moderation showed that HP was only a significant moderator for the exuberant profile, $b = 2.01$, $t(107) = 2.00$, $p = 0.04$, 95% CI [0.01, 4.01], such that those with exuberant temperament who experienced HP showed greater externalizing behaviors at 48-months. This initial moderation was further moderated by dyadic inconsistency with a significant three-way interaction, $b = -0.12$, $t(76) = -2.11$, $p = 0.04$, 95% CI [-0.24, -0.07]. This interaction revealed that for exuberant children, at low and mean levels of HP, children who experienced higher levels of dyadic inconsistency showed higher externalizing behaviors at 48-months. These results help to clarify which components of difficult temperament may act as drivers increasing the risk of later externalizing behaviors. Additionally, results offer novel information about exuberant child temperament and suggest pathways via harsh parenting and dyadic inconsistency by which this temperament profile may contribute to children's greater externalizing problems.

S18.2: Maternal anxiety and infant negative affect trajectories: The role of neural and environmental factors during infancy

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Parenting practices predict socioemotional competence in infancy and beyond. In particular, maternal behaviors, such as sensitivity and intrusiveness, form part of the proximal environment in which infants develop (Gutman & Feinstein, 2010). Parenting behaviors are tethered by parents' individual characteristics. For example, maternal anxiety seems to hinder maternal warmth and increase hostility (Seymour et al., 2015). Although parents construct most experiences that infants encounter, we must also consider the role of infant individual characteristics as a joint influence on child development (Slagt et al., 2017). For instance, individual

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differences in electroencephalogram (EEG) delta-beta synchrony have been associated with early risk. Delta-beta synchrony is the coupling between delta and beta power, and is thought to reflect neural processes of emotion regulation. Enhanced positive delta-beta synchrony has been in fact associated with dysregulated fear and high cortisol reactivity in children (Brooker et al., 2016), and anxiety in adults (Knyazev et al., 2006), suggesting its role in psychopathology risk. Several studies have identified links between parent psychopathology and child temperament. However, no study has examined the joint influence of parenting and infant delta-beta synchrony on early trajectories of infant negative affect, an early precursor of psychopathology. The present study examines how maternal anxiety predicts changes in infant negative affect trajectories, and the moderating role of parenting behaviors and infant delta-beta synchrony. We collected mothers' reports of anxiety (STAI; Spielberger et al., 1970) and infant's negative affect (IBQ; Rothbart, 1981) at 4, 8, and 12 months postpartum. When infants where 8 months, we collected infant resting-state EEG and observed mother-child interactions during a free-play task, from which we coded maternal warmth and intrusiveness. First, we used a conditional growth model to examine changes in infant negative affect trajectories as a function of age and mothers' own anxiety trajectories (N=246). Fixed effects indicated that infant negative affect increased from 4 to 12 months (β=.38, $p < .01$), and that mothers with higher anxiety across time had infants with higher negative affect at 4 months (β=.01, $p < .02$). Maternal anxiety also interacted with age, such that when maternal anxiety was high (> 53.9), the slope of age and infant negative affect was zero, suggesting that although these infants showed higher anxiety at 4 months, their trajectories were stable over time. Next, we tested the moderating role of parenting behaviors and infant delta-beta synchrony on these associations. Parenting behaviors were not significant moderators, although our power was limited by the number of dyads currently coded (N=60). In contrast, there was a significant age by delta-beta synchrony interaction (β=.78, $p < .03$), indicating that infants with higher synchrony scores generally showed steeper trajectories of negative affect (Fig.1). Delta-beta synchrony marginally interacted with maternal anxiety (β=.03, $p < .06$). Regions of significance analyses suggested that maternal anxiety was significantly related to negative affect only for infants with synchrony scores between r = .16 and r = .85 (Fig. 2). We discuss these results in the context of delta-beta synchrony as a neural marker of emotion regulation.

S18.3: Infant physiological regulation with mothers and fathers: The effects of infant temperament and parent factors

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The development of self-regulatory skills is essential to the promotion of positive socioemotional outcomes (Stifter et al., 2010). Adaptive respiratory sinus arrhythmia

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(RSA), a measure of regulatory capacity, has been associated with better emotion regulation and lower rates of behavior problems (Qin & Leerkes, 2018). Parent factors, such as parenting and personality, differentially affect how they interact with their infants and influence subsequent regulatory abilities (Braungart-Rieker et al., 2014; Casalin et al., 2014). Infant temperament might interact with parent factors, for better or worse, to influence subsequent infant regulation (Bates et al., 2012). However, research examining the associations between parenting, infant temperament, and physiological regulation has only included one time-point and mothers; longitudinal associations and fathers are largely unexamined. Previous research has also mostly focused on negative reactivity; additional temperament traits may make some infants more susceptible to parent influences (Slagt et al., 2016). The present study examined parent factors (parental sensitivity/intrusiveness, personality) and infant temperament as predictors of infant RSA suppression across early infancy with mothers and fathers. The study includes mothers, fathers, and their infants at 4-, 6-, and 8-months of age. Parents completed questionnaires assessing parent personality (Behavioral Inhibition System/Behavioral Activation System (BIS/BAS) Scales; Carver & White, 1994) and infant temperament (Infant Behavior Questionnaire-Revised; Gartstein & Rothbart, 2003). Mother/father report of infant temperament were averaged within time-point to create overall measures of infant negativity and surgency. Parents participated in a baseline task and the Still-Face Paradigm (SFP) with their infant (Tronick et al., 1978; parent order counterbalanced). Infant RSA suppression was calculated by subtracting the still-face episode RSA score from the mean baseline RSA score. Larger change scores reflect greater infant RSA suppression with mothers and fathers (Stifter et al., 2010). Trained, reliable coders rated parental sensitivity/intrusiveness in 10-s intervals during the SFP play/reunion episodes (Braungart-Rieker et al., 2014). Scores were averaged across play/reunion to create an overall parental sensitivity score. Higher scores indicate greater sensitivity and lower intrusiveness. Preliminary regression models using a portion of the current sample (n= 51 families) examined infant temperament, parent personality, and parental sensitivity at 4-months predicting infant RSA suppression at 8-months (controlling for SFP parent order at 8-months and prior infant RSA suppression). For fathers, significant infant negativity X BAS (B=-4.34, SE= 1.21, p=.001; Figure 1) and sensitivity X BAS (B= -4.14, SE= 1.59, p= .013; Figure 2), interactions were found. Follow-up analyses revealed that for fathers low in BAS, as infant negativity (B= 2.03, SE= .55, t= 3.66, p= .001) and paternal sensitivity increased (B=2.60, SE= .87, t= 2.98, p= .005), RSA suppression increased. No significant results were revealed for mothers. Subsequent analyses will examine longitudinal associations with additional dyads. Findings stress the importance of examining individual differences in infant and parent factors as predictors of infant RSA suppression with mothers and fathers.

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S19: Fair's fair?: Intentions and relationships impact infants' expectations about fairness and preferences for fair individuals

S19.1: Preverbal infants' intention-based evaluations of fairness

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Classic developmental theories suggest that mentalistic moral evaluations emerge during childhood and are the result of an experience dependent learning process (Piaget, 1932). By contrast, recent evidence revealed that by 8 months of age infants incorporate intentions in their social evaluations (Hamlin, 2011). Previous research demonstrated that 18-month-old infants attend to the outcomes of distributive actions to evaluate distributors' actions. These results were interpreted as evidence that a sense of fairness guides social evaluations early in infancy (Geraci & Surian, 2011; Sloane, Baillargeon, & Premack, 2012; for a review see Sommerville, 2018). The current study investigates whether 9-month-olds incorporate intentions in their social evaluation of distributive actions. Preferential manual choice and preferential looking methods were employed. In Experiment 1 infants were exposed to four familiarization events. In two familiarization events a distributor failed to divide equally two apples between two receivers (fair event). In the other two familiarization events another distributor failed to divide unequally two apples (unfair event). Preliminary data provided evidence that 9-month-old infants on the manual choice test reliably prefer the fair distributor rather than the unfair distributor. Looking times, by contrast, show that their visual attention is reliably shifted towards the unfair rather than the fair distributing agent. These results support the hypothesis that a sense of fairness guides social evaluation and show that the ability to take into account agents' distributive intentions is present at 9 - month of age. In addition, the comparison between data on visual preferences and data on manual choices suggests that the negative social evaluation affects visual attentional processes. In contrast the positive social evaluation affects manual choices. In Experiment 2, infants saw movies that were very similar to those used in Experiment 1, but the two receivers were replaced by two physical objects to assess the hypothesis that the preferences found in Experiment 1 were due to attentional cues or perceptual factors unrelated to the fairness principle. These results extend the recent literature on the early development of negativity bias (Vaish, Grossman, & Woodward, 2008; Hamlin, Wynn, & Bloom, 2010). The findings provide further evidence for an abstract and an early-emerging fairness principle and for the richness of moral cognition 'first draft'.

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S19.2: Infants' reactions to resource distribution outcomes as a function of ingroup/outgroup manipulations and language status

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The ability to evaluate events on the basis of whether or not they adhere to norms or principles of fairness is a key aspect of mature moral reasoning. By the start of the second year of life infants pay greater attention to the unequal outcome (versus equal outcomes) after watching resource distributions (Ziv & Sommerville, 2017), preferentially interact with fair distributors (Lucca et al., 2018), and associate positive stimuli with fair distributors and negative stimuli with unfair distributors (DesChamps et al., 2015). These findings suggest that infants possess an awareness of distributive fairness norms based on equality. An outstanding question is whether infants are treating violations to equality norms as moral transgressions, or whether they might more broadly construe them as violations to social conventions. One hallmark of moral responses is the belief that moral norms or principles transcend different situations or cultures. In the current study, we asked whether infants would expect both ingroup and outgroup members, as defined by the distributor's language spoken, to adhere to equality norms. We also asked whether bilingual infants would show similar or different responses to violations these violations. We tested 24-month old bilingual and monolingual English infants (N = 71) on a violation-of-expectancy paradigm. During familiarization, infants watched an actor read them excerpts from Brown bear, During the test trial, infants watched the actor distribute cookies to the two other individuals either fairly (3:3) or unfairly (5:1) and infants' looking times were measured. To assess infant's language status, parents filled out a questionnaire; infants were categorized as bilingual based on being exposed to a language other than English 25% of the time or more. Our question of interest was whether infants would vary their attention to the unfair versus fair outcome as a function of both the language spoken by the distributor, and their own language status. A 2 X 2 X 2 between-subjects ANOVA with test type outcome (fair vs. unfair), condition (English or Spanish), and infants' language status (bilingual vs. monolingual) revealed a main effect of test type outcome (fair/unfair) ($F(1,71) = 7.054$, $p = 0.012$; see Figure 1); indicating that overall infants looked longer to the unfair outcome. The interaction between distribution type and infant language status was also significant ($F(1,71) = 9.049$, $p = 0.005$); bilingual infants showed a stronger preference for the unfair versus the fair event than did monolingual infants (see Figure 2). Our findings raise the possibility that infants expect both ingroup and outgroup members to abide by equality norms in resource distributions, providing evidence that infants' reactions are moral in nature. In ongoing work, we are testing infants' responses to violations to social conventions as a function of ingroup/outgroup status. Because social conventions are culture specific our prediction is that infants will only expect ingroup members to follow social

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conventions. Our results are also in keeping with recent findings that bilingual infants are precocious in their social sensitivities, and perhaps more broadly cognitive advanced. Future work can seek to disentangle these two possibilities.

S19.3: Do 4-month-olds take into account group membership when judging fair outcomes?

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Our research asked whether 4-month-old infants would expect a distributor to divide two items fairly between an ingroup and an outgroup recipient, or whether they would expect the distributor to give both items to the ingroup recipient. This research built on three prior findings. First, infants in the first two years of life are sensitive to fairness and expect equal allocations of windfall resources between two similar recipients. Second, infants in the first two years are also sensitive to ingroup support and expect individuals to act in ways that support their ingroup members. Third, there is evidence that 19-month-old infants, like older children, expect ingroup support to trump fairness in resource-allocation situations where resources are limited. For example, when a monkey distributor with two items to allocate faced two potential recipients, another monkey and a giraffe, infants expected the distributor to give both items to the monkey recipient: Because there were only enough items for the monkeys, infants expected the items to be reserved for the monkeys' group. These and other results suggested that by 19 months, infants expect ingroup support to trump fairness when resources are limited. Is this rank-ordering one that infants learn from their social environments, or is it one that they naturally expect from a young age? To find out, we examined whether 4-month-olds would prioritize fairness or ingroup support in a resource-allocation task. Infants in Experiment 1 were first introduced to two groups of puppets, cats and foxes (older infants spontaneously assign different animal puppets to different groups, but young infants need additional cues to do so). In one trial, three cats stood next to each other and moved (e.g., clapped) and spoke (e.g. "Fun, fun!") in unison. In the other trial, three foxes again moved (e.g., tilted) and spoke (e.g., "Dance, dance!") in unison. Next, infants received a test trial in which a puppet from one group (e.g., a cat) divided two items between a cat recipient and a fox recipient in one of three ways: The distributor gave one item to each recipient (equal event), gave both items to the ingroup recipient (favors-ingroup event), or gave both items to the outgroup recipient (favors-outgroup event). Infants looked significantly longer if shown the equal or favors-outgroup event as opposed to the favors-ingroup event, suggesting that they expected ingroup loyalty to trump fairness. An alternative interpretation of our results was that these young infants simply expected no items at all to be given to the outgroup recipient, so that no rank-ordering of fairness and ingroup support was needed. To examine this possibility, infants in Experiment 2 saw a distributor

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(e.g., a cat) divide two items either equally (equal event) or unequally (unequal event) between two outgroup recipients. In line with prior studies, infants looked significantly longer if shown the unequal as opposed to the equal event. These results suggest that infants in Experiment 1 did consider fairness as well as ingroup support and expected the distributor to prioritize the latter over the former.

S19.4: Infants predict that distributors will act partially towards their friends

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Starting in the first two years of life, infants expect distributors to share resources equally across recipients, and look longer at unequal distributions (e.g., Schmidt & Sommerville, 2011). In a first study, we directly replicated this effect and added a second measure: predictions about how the distributor would share. Specifically, (N= 24) 13- to 16-month-olds were shown events featuring a distributor and two recipients. The distributor brought out a bowl with two apples, and each recipient indicated interested (by saying, "I want some!," and, "I want some too!"). In the prediction trial, the distributor gave out one apple, and then picked up the second and held it in mid air between the recipients (Figure 1). We used head turns as measure of who infants predicted the second apple would be shared with: the recipient of the first apple (predicting favoritism) or the other recipient (predicting equality). 75% of infants predicted equality (binomial p = .023; Figure 2). Infants also viewed six test trials which depicted two types of outcomes: equality (the distributor gave each recipient one apple) or favoritism (the distributor gave two apples to one recipient). In line with previous research, infants looked significantly longer at favoritism (M= 11.4 seconds) than at equality (M= 8.4 seconds; paired t-test p = .009). Thus, infants both predict and expect a distributor to give out resources equally. In a second study, we included information about the distributor's social relationships with the recipients. Children expect people to share more with their friends (e.g., Liberman & Shaw, 2017) and infants expect distributors to favor members of their own group (e.g., Bian et al., 2018). Therefore, we tested whether infants' predictions of sharing also vary based on relationships. Specifically, we were interested in whether infants are more likely to predict favoritism (over equality) when a friend (rather than a non-friend) is advantaged. To ask this, we replicated Study 1, but included a phase where the distributor interacted with each recipient. She smiled and waved at one (indicating friendship), and turned away from the other (indicating a lack of friendship). Then, infants (N=48) watched a prediction trial, and 6 trials measuring looking to each outcome. Infants were randomly assigned to one of two conditions that varied in terms of who the distributor gave the first apple to: the Friend or the Non-Friend. Infants were marginally more likely to predict equality (71%) than to predict that the distributor would favor the Non-Friend (29%, binomial p=.062; Figure 2). But, infants did not always predict equality.

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Instead, infants who saw the distributor give the first apple to her friend were more likely to predict favoritism (79%) than to predict equality (21%, binomial p =.006; Figure 2). We did not find any differences in infants' looking times to the trials depicting outcomes. Overall, this set of studies introduced a new measure of infants' predictive looking in a resource distribution task, and provided preliminary evidence that infants predict that distributors will demonstrate partiality towards their friends.

S20: Enhancing our understanding of social cognition in infancy through cutting-edge technology and individualized approaches

S20.1: Spatially resolved measures of cytochrome-c-oxidase during functional activation in infants

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Brain regions in adults have specialization of function. Whether humans are born with this or whether it develops through interactive specialization (Johnson, 2005) for example, is less clear. To investigate this, neuroimaging techniques are being increasingly employed in neurodevelopmental research. Functional near-infrared spectroscopy (fNIRS) measures of changes in blood oxygenation, related to underlying neural activity, that are spatially specific but are indirect markers of brain activity. Currently, little is known about coupling of neural activity and blood flow in infancy and studies have demonstrated that cerebral vasculature matures alongside neural circuitry during development (Zehendner et al., 2013). Broadband NIRS (bNIRS) provides the opportunity to investigate this relationship by measuring changes in cellular energy metabolism alongside haemodynamics (Siddiqui et al., 2017) through measurement of changes in the oxidation state of mitochondrial respiratory chain enzyme cytochrome-c-oxidase (oxCCO). bNIRS enables the investigation of the neurometabolic pathways underlying brain function and hence improve our understanding of mechanisms in neurodevelopment. Recent adult studies have demonstrated the possibility of acquiring spatially resolved measures of oxCCO (Phan et al., 2016). The aim of this study was to use multi-channel bNIRS to measure changes in mitochondrial activity, alongside haemodynamic changes, in the social brain regions in infants. Studies were performed with 42 typically

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developing (TD) infants aged between 4-7 months. Infants wore custom-built headgear containing 9 channels over the right temporal cortex. The bNIRS system was developed at UCL (Phan et al., 2016). Changes in concentration of HbO2 (Δ[HbO2]), HHb (Δ[HHb]) and oxCCO (Δ[oxCCO]) were calculated using attenuation of light at 120 wavelengths between 780-900nm using the UCLn algorithm. The experimental condition consisted of social and non-social visual and auditory stimuli to target the superior temporal sulcus temporo-parietal junction (STS-TPJ) region (Lloyd-Fox et al., 2009). The maximum response was identified in the time window of 10-18s post-stimulus onset and used to test for statistically significant differences between the social and non-social conditions. The maximum response was also averaged across participants to obtain a mean maximum response which was interpolated and rendered onto a 3-D mesh of a 5-7-month-old infant brain template (Richards, 2009). Data from 32 infants were included. A significant difference was found between the social and non-social conditions for Δ[oxCCO] and Δ[HbO2] in the channels located over the STS-TPJ region, in accordance with results from previous studies (Lloyd-Fox et al., 2009). Figure 1 shows the mean maximum response to the social and non-social conditions for HbO2 (top) and HHb (bottom). Figure 2 shows the oxCCO mean maximum response for (a) social and (b) non-social conditions. Both oxCCO and HbO2 have a stronger response to the social condition over the STS-TPJ region. response contained to the STS-TPJ region. The results from this study provide the first spatially resolved measures of mitochondrial activity during functional activation in infants. This study sheds light on neurometabolic pathways in early infancy, thereby aiding our understanding of brain development.

S20.2: Efficiency of scanning in infancy in the presence and absence of faces differentially predicts expressive and receptive language in toddlers

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Background: Efficient visual exploration in infancy is essential for cognitive and language development, as it facilitates adaptation to an ever-changing environment (Sokolov, 1963). It allows infants to participate in social interactions by attending to faces and learning about objects of interest (e.g., Yoshida & Smith, 2008; Frank, Vul & Johnson, 2009). Early differences in the efficiency of visual scanning are likely contributing to differences in learning and language development during subsequent years. Identifying how these early differences in visual exploration lead to later outcomes may help to better understand different pathways in cognitive

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development. Thus, we tested how the complexity of visual scanning in the presence or absence of a face at 6-7 months of age is related to language development at 2 years of age in a multi-ethnic and predominantly bilingual sample from diverse socio-economic backgrounds. Methods: The final sample analysed longitudinally included 45 children (18 girls and 27 boys) tested as infants around the age of 6-7 months (T1 M = 205.4 days, SD = 20.1), and followed-up around the age of 24 months (T2 M = 757.6 days SD=48.4). To capture individual differences in visual scanning, we used newly developed dynamical measures that account for the temporal and spatial distribution of recurrences of fixations in the same area of an image (Anderson et al., 2012). In our study, we checked how often infants' fixations recurred in the same area (RR, Recurrence Rate - Faces) and the temporal distribution of re-fixations (CORM, Centre of Recurrence Mass - Chairs) in presence and absence of face. Finally, we conducted hierarchical regression analyses separately for receptive and expressive language scores of PLS-4, using as dependent variables RR-Faces and CORM-Chairs and controlling for socio-demographic data. Results: For receptive language raw scores, the model with family income, RR-Faces and CORM-Chairs explained nearly 45% of variance with all three variables showing significant effects ($R2 = .444$, Adj. $R2 = .401$, $F[3,39] = 10.38$, $p < .001$). For expressive language, the final model significantly explained nearly 30% of variance, with income and CORM-Chairs being significant predictors ($R2 = .303$, Adj. $R2 = .240$, $F[3,36] = 4.79$, $p = .007$). Discussion: Our results demonstrate that dynamic measures of visual scanning at 6-7 months of age provide a powerful tool for quantifying infant attention to both social and non-social stimuli and can reliably and robustly predict language development in highly diverse samples. We also show that measures of the efficiency of visual scanning likely predict language development independently of attention to faces. This may suggest a potential mechanism linking early selectivity in attention to objects of interest with receptive and productive language development on the eve of preschool age. Finally, our results re-iterate the utility of mobile eye-tracking in combination with well-defined experimental tasks for developing potential early screening tools for infants and children at risk of developmental difficulties.

S20.3: An individual approach to understand the nature of face processing in early autism

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Atypical face processing is characteristic of Autism Spectrum Disorder (ASD) in its prodrome(Mayada Elsabbagh et al., 2012). According to 'social-first' theories of ASD, atypicalities in social information processing early in life result in cascading effects leading to the social-communication symptoms characteristic of ASD(M. Elsabbagh & Johnson, 2016). Prospective longitudinal studies of infants at risk for ASD enable us to investigate the mechanisms underlying symptom emergence. However, developmental studies often make use of traditional group-level comparisons, which may disguise inter-individual variations and may not inform on the different mechanisms underlying ASD development(Loth et al., 2017). To examine the domain of face processing in emerging ASD, we explored analytic approaches for translation of group-level findings to the level of the individual. We used an event-related potentials (ERPs) task with static faces, dynamic gaze shifts and visual noise, in a cohort of 8-month-old infants with familial risk for ASD (n=144), and investigated the association with ASD at 36 months (n=32 of 144). Machine-learning techniques were employed to uncover sources of informative variance in individual-level data. First, supervised classification was performed to predict individual status, as indicated by clinical outcome at 36 months. Specifically, we used support vector machine classifiers, with feature selection performed stochastically through a genetic algorithm to inform on the most relevant signals for prediction of ASD at 36 months. Next, Bayesian hierarchical clustering was used to investigate whether atypical face processing at 8 months defines meaningful subtypes in infants who meet criteria for ASD at 36 months. A broad pattern of alterations across the time-course of neural processing of faces at 8 months predicted 3-years ASD diagnosis with an estimated accuracy of 77.1% (confidence interval, CI=[61.1%; 90.5%]). Furthermore, we identified two different clusters among infants with later ASD diagnosis. Cluster one (n=13) was characterized by higher levels of ASD symptoms than cluster two (n=19), as indexed by the total score of the Autism Diagnostic Observation Schedule ($t(27)=2.06$, $p=0.049$), and higher levels of restricted repetitive behaviours, although difference was only marginally significant ($t(25)=1.89$, $p=0.07$). There were also significant differences between clusters in ERPs, with increased P1 and N290 amplitude in response to faces, and in particular to faces with averted gaze, in infants from cluster one compared to cluster two (see Figure 1). This study shows the use of novel tools to investigate the domain of face processing transdiagnostically. A diffuse pattern of alterations in early sensory and later cortical stages of face processing in the first year of life could predict individual ASD outcome at 3 years. Furthermore, atypical face processing defined two different subgroups among ASD infants. This suggests that the diffuse pattern of alterations identified through pattern recognition is not common to all infants who go on to develop ASD, but rather different subgroups show different alterations in neural processing of faces resulting in widespread atypicalities as predictive of ASD in infancy. Overall, this study shows how pattern recognition techniques help to improve early prediction of status, while

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stratification into subgroups allows understanding and reducing heterogeneity in clinical cohorts.

S20.4: Neuroadaptive optimization to study how neural signatures of attention to faces in infants relate to later autism

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Background Early difficulties in attention in social settings could affect learning and have cascading effects on social development. We first investigated this possibility at a group-level using electroencephalography (EEG) during a face/non-face paradigm in 8-month-old infants with (elevated-likelihood/EL, n=91) and without (typical-likelihood/TL, n=40) an older sibling with ASD (Study 1). An event-related potential (ERP) component reflecting attention engagement (Richards et al, 2010), the Nc, was compared in relation to categorical clinical outcome at three years of age. In Study 2 we apply a novel approach based on neuroadaptive optimization to investigate which characteristics of faces elicit the strongest Nc response in individual infants. We combine real-time neuroimaging with a Bayesian Optimization algorithm that identifies the optimal stimulus characteristics among hundreds of possibilities by refining its search based on individual responses to a limited subset of stimuli (Lorenz et al., 2017). Methods Study 1: The Nc mean amplitude was extracted over the left, central and right frontal regions of the scalp for three conditions: face with direct gaze, face with averted gaze and Noise (a control non-face stimulus matched in visual properties). This ERP feature in response to each of the face stimuli and the Noise stimuli were compared between TL infants, EL infants who later received diagnosis of ASD (EL-ASD; n=19), EL infants with typical development (EL-TD; n=48) and EL infants with other developmental profiles at 3 years (EL-Other; n=24). Study 2: In this ongoing study, we aim to recruit 50 eight-month-old TL infants. EEG is recorded while infants are presented with images of faces with different characteristics (i.e., gaze directions, facial expressions...) including the face of the infant's parent. The Nc mean amplitude is extracted in real time and used by the optimization algorithm to select the next presented stimulus until the stimulus producing the strongest Nc (optimal solution) is identified for each individual infant. The Vineland Adaptive Behavior Scales (VABS) and Infant Behavior Questionnaire (IBQ) parent-report questionnaires are collected as continuous measures of emerging social and temperament traits. Results Study 1: Different profiles of the Nc were observed based on later

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neurodevelopmental outcome (F(6,254)=2.354, p=0.031), with weaker Nc to faces with direct gaze in EL-TD and EL-ASD infants (Figure 1). Study 2: For each individual infant, a search space including artificially-created faces and the mother's face is created (Figure 2). We will present results of the relationship between VABS and IBQ scores and spatial similarity between the position of the optimal solution identified by the algorithm and the position of the mother's face in the search-space calculated for each infant. Discussion Replicating previous research (Jones et al., 2016), Study 1 revealed that neural signatures of attention engagement to faces with direct gaze are atypical in infants with later ASD. Study 2 applies for the first time neuroadaptive optimization in infancy to identify what characteristics of faces are more engaging at the individual level. This will help us evaluate individual differences in attention to social cues and plan personalized interventions in infants at elevated likelihood of neurodevelopmental disorders.

S21: Not just the linguistic factor! Associations between maternal child-directed speech on cognitive and socio-emotional competences

S21.1: Parent language stimulation, parent sensitivity and socioeconomic status: Associations with curiosity

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BACKGROUND: Curiosity is characterized by the drive to seek out new information, desire to explore, and joy in learning. Higher curiosity has been associated with higher kindergarten academic achievement, with a greater magnitude of benefit for children with socioeconomic disadvantage. To date, little is known regarding the modifiable caregiving contexts which may promote or inhibit the expression of curiosity, especially for children with lower socioeconomic status (SES). One potential modifiable factor previously associated with differences in early childhood outcomes is the quality of the early linguistic environment. Both parent language stimulation (e.g. quantity of language input) and sensitivity (e.g. quality of dyadic interactions) have been associated with early language and learning outcomes, but associations with curiosity are unknown. Parent-child conversation is thought to facilitate children's thinking, learning and exploration (i.e., behavioral indicators of curiosity) through pedagogical exchanges, however the associations between other forms of language stimulation in infancy (e.g. reading, telling stories, singing) and the development of curiosity have not been explored. OBJECTIVE: To examine the

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main and interactive effects of frequency of parent language stimulation in infancy, parent sensitivity and socioeconomic status (SES), with parent ratings of curiosity at kindergarten. METHODS: Sample included 4750 children from the Early Childhood Longitudinal Study, Birth Cohort, a nationally representative, population-based longitudinal study sponsored by the US Department of Education's National Center for Education Statistics (NCES). Measures included parent reports of language stimulation at 24 months (frequency of reading, telling stories, singing, dichotomized as < 3 times/ week vs. ≥ 3 times/ week); observations of parent sensitivity at 24 months; a composite measure of SES; and a measure of early childhood curiosity at kindergarten derived from a parent child behavior questionnaire (4-items, $\alpha = 0.70$). Multivariate linear regression examined the main and interactive effects of parent language stimulation, parent sensitivity and socioeconomic status with curiosity. RESULTS: The frequency of parent language stimulation varied by higher and lower SES families. At 24 months, families of lower socioeconomic status reported less frequent (< 3x/ week) reading ($p < .001$), telling stories ($p = .002$) and singing ($p < .001$) with their children compared with higher SES families. In adjusted models, more frequent reading ($B = 0.11$, $p = .02$), telling stories ($B = 0.10$, $p = .005$), and singing ($B = 0.13$, $p<.001$) at 24 months was associated with higher curiosity at kindergarten. SES moderated the association between more sensitive parenting at 24 months and curiosity (Table 1), with magnified effects in children from lower SES environments, compared to higher SES: (SES ≤ median): $B = 0.11$, $p < .001$; (SES > median): $B = 0.03$, $p = .25$ (Figure 1). CONCLUSIONS: Higher curiosity at kindergarten was associated with more language stimulation and greater parental sensitivity in infancy, with magnified effects of sensitivity in lower SES families. Anticipatory guidance to foster early curiosity should emphasize parent language stimulation and sensitive interactions, especially in low-income children.

S21.2: The role of maternal verbal input in the emergence of mental lexicon in early childhood

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Introduction: In children, the use of words to refer to mental states is a developmental competence which bridges the development of language and theory of mind (TOM). The reference to emotions, feelings, thoughts, and desires (i.e., mental lexicon) presupposes an early comprehension of the existence of these inner states, and it is thought to be a precursor of TOM. Concurrently, the ability to label these feeling states also requires the presence of early lexical skills. The way parental child-directed speech (CDS) might scaffold the emergence of mental lexicon in early childhood is twofold. Firstly, a complex and rich verbal input promotes children's linguistic abilities. Secondly, parents might provide their

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children with a corpus of mental state terms that can help them to identify and label mental states. Hypotheses: this study aims at analyzing how these two components of parental verbal input can foster the emergence of mental state lexicon during the second year, hypothesizing an interactional effect between these components. Methods: Thirty-five mother-child dyads were assessed at 18 and 24 months. At 18 months, dyads were observed during a play session and maternal utterances directed to the child were transcribed and analyzed in terms of quantity (verbal tokens), variety (verbal types), and complexity (mean length of utterance - MLU). The maternal lexicon describing inner mental states was also assessed by calculating the types and tokens referring to these states. At 18 and 24 months, children's vocabulary size and mental lexicon size were assessed with the Italian version of the MacArthur-Bates Communicative Development Inventory (MCDI). Results: Findings indicated that maternal MLU was positively associated with children's vocabulary size at 18 months ($r = .44$, $p<.01$) and with the number of children mental state terms at 24 months, controlling for their vocabulary size at the same age ($r = .47$, $p<.01$). The association between maternal MLU and children's mental lexicon size resulted moderated by the maternal use of word types related to mental states ($F(1,31) = 3,82$ $p<.05$). Addressing the children with more complex utterances was positively related to the children's early mental lexicon, only at a medium or high use of mental state language by mothers. No associations between other measures of maternal input (types and tokens referred to global production and inner mental states) and the amount of children's mental lexicon were found. Syntactically complex sentences, including mental lexicon, appear to be the best way to foster mental lexicon acquisition, probably because this kind of input can provide an adequate frame to facilitate the identification and, further on, the acquisition of labels for abstract concepts.

S21.3: Talk to me mum! The longitudinal effects of prosodic and linguistic characteristics of infant directed speech on the development of child attention and emotion regulation

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Introduction. The dynamic interactions between an infant and its caregiver are the primary contexts where the infant learns to develop and regulate emotional and cognitive abilities. During early infancy, the most prominent maternal interactive behaviours are maternal vocalizations directed toward the infant, or infant directed speech (IDS). IDS is characterized by specific linguistic and prosodic characteristics, with more elaborative IDS being associated with more optimal early language development. While the benefits of IDS on language development are well described, it is possible that vocal stimulation directed to prelinguistic infants may

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also be positively associated with non-linguistic infant competencies, such as emotion regulation and attention. While the prosody of the maternal voice has been associated with higher infant attention towards the mother, greater expressions of positive affect, and higher joint attention, there are relatively few longitudinal studies which have examined these processes in at-risk populations, including infants born preterm. Aim and hypotheses. The aim of the present study is to examine the longitudinal associations of linguistic and prosodic IDS, and maternal interactive quality at 3-months on infant attention and emotion regulation at 24 months, and to test for the possible moderating role of prematurity on these associations. We hypothesize that preterm birth would moderate the association of the quality and quantity of IDS and quality of dyadic interactions on infant attention and emotion regulation. Methods. Participants were 50 preterm (< 36 weeks g.a.) and 50 full-term infants and their mothers. Mother-infant interaction during free-play were video-recorded at 3 months age. Maternal IDS linguistic complexity (MLU) was calculated. IDS prosody was analysed with PRAAT and the variability of the voice in semitone (F0 variability) was calculated. The quality of dyadic co-regulation was evaluated with Fogel's RCS system. At 24 months, mothers completed the Child Behavior Checklist to assess Attentional abilities and Externalizing behaviours. Generalized models were used to examine the main and interactive effects of preterm birth, MLU and IDS on attention and behavior outcomes. Results. We found evidence of interactive effects between IDS syntactic complexity and F0 variability at 3-months, on infant attentional abilities at 24-months. Children whose mothers spoke with higher complexity and wider prosodic variability at 3 months showed better attentional competences at 24 months. We also found that preterm birth moderated the association between F0 variability, unilateral co-regulation and 24-month externalizing behaviour. Preterm infants whose mothers spoke with wider semitones (i.e. greater prosodic variability), and who demonstrated more unilateral dyadic interactions (i.e. lower co-regulation) showed more externalizing symptoms at 24 months, whereas this association was not observed in infants born full term. Conclusion. The quality of communicative linguistic and prosodic input of mothers predicted later attentional and emotion regulation, however outcomes vary by preterm birth status, and the level of affective co-regulation. This highlights the importance of considering the role of infant biological risk (e.g. preterm birth status) and pattern of co-regulation to determine the effect of maternal IDS on infant emotional outcomes. Implications for preventive interventions are discussed.

S21.4: Fluid, back-and-forth conversation sets a foundation for infant executive function skills

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Interactions with caregivers are critical to development in infancy. Many studies have shown that fluid, back-and-forth conversations between caregivers and infants build a foundation for language development (Hirsh-Pasek et al., 2015), predicting child language skills up to a decade later (Gilkerson et al., 2018). While extant research has classically looked at how these conversations shape infants' language development, these interactions may shape infants' cognitive systems more broadly. Recent research has begun to examine how other cognitive capacities, such as attention and behavioral inhibition, both build and are supported by fluid conversations. In this study we examine how the quality of the conversation between parents and infants relates to the infant's emerging executive function skills by examining how fluency and connectedness, a holistic measure of the balance and flow of conversation between infant and caregiver, relates to three aspects of emerging executive function: set-reversal, behavioral regulation, and working memory. 68 participants were recruited as part of a larger longitudinal study. Fluency and connectedness (FC) was assessed at 14 months during a 5-minute book-sharing interaction between infants and their mother. FC was evaluated on a 7-point Likert scale, with 1-point indicating no conversation occurred, 4-points indicating the conversation was unbalanced (e.g. dominated by one partner) or lacked smoothness (e.g. long gaps between conversational turns), and 7-points indicating the conversation was fluid and balanced through the interaction. Executive function at 14 months was measured using the Prohibition Task which tapped emerging behavioral regulation, the Ball Run Task which tapped emerging reversal learning, and the three boxes task which tapped working memory (Devine, Ribner, & Hughes, 2019). Executive function at 24 months was measured using the Baby Stroop task which tapped set shifting, the five boxes task which tapped working memory, and the Ball Run Task that was also completed at 14 months (Hughes, Devine, Mesman, & Blair, under review). We found significant concurrent associations between FC and infant's working memory [$F(4, 64) = 3.81$, $p = .008$)]. FC at 14 months was marginally related to reversal learning [$F(4, 24) = 2.79$, $p = .056$] and significantly related to set shifting [$F(4,24) = 4.19$, $p = .013$] at 24 months, controlling for 14 month EF measures. Pairwise comparisons revealed significant differences on infant's reversal learning between dyads rated as a 3, indicating a conversation that is low quality with few bouts of high quality interaction, and dyads rated as a 4-6. Infants in dyads rated as a 6, indicating a sustained back-and-forth interaction, had significantly higher set-shifting scores than dyads with lower scores. Further analyses will break down the interaction by analyzing the language and specific behaviors used by mothers and infants in order to further understand how the co-construction of high-quality interactions promotes optimal child outcomes. Altogether, these results indicate that fluid and connected conversations with caregivers relate to infant cognitive development beyond language, and in fact might support emerging executive function skills.

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S22: Tips, tricks, and statistics: Recommendations for improving infant research methods

S22.1: Tools for transparency: Practical tips for sharing your research

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With the replication crisis and subsequent reckoning in psychology to improve research practices (Nelson, Simmons, & Simonsohn, 2018), researchers are more inclined to share their materials, data, and analysis scripts. Sharing data provides multiple benefits (Klein et al., 2018), including making it easier for researchers to undertake direct replications (i.e., by using original stimuli and detailed protocols available), conduct re-analysis or meta-analysis of existing datasets, and to reproduce analyses in order to detect and avoid errors in analysis. However, despite these benefits, and despite increasing recognition of the value of transparency, sharing remains relatively rare in infant research. This talk aims to address the gap between researchers' desire to share and their actual sharing practices. We provide practical tips on what to share and where to share, focusing on how to efficiently integrate sharing into research workflows. We also address common questions and concerns that researchers have about sharing, by providing examples from our own work. What to share. In general, study materials such as stimuli, instructions, video recordings of test sessions, raw data, and analysis scripts are important to share. Including additional meta-data is helpful to contextualize materials. For example, datasets can be explained by including a "codebook" describing the variables included in the raw dataset. We will show examples of codebooks and discuss tips for preparing them. We will also provide tips to guarantee that analysis scripts will run on different computers and discuss options for sharing data analysis in a self-contained platform (https://mybinder.org/), where scripts can be executed error-free on a server and are more easily accessible by other researchers. How to share. There are multiple platforms for sharing, and a commonly used platform is the Open Science Framework. OSF has many features useful for research, such as the possibility to send anonymized links for the review process and the creation of DOI to be able to cite datasets. Sharing workflow. In our experience, sharing is easiest and most efficient when a study is set up with data sharing in mind. That way, at each point in the research process, the relevant materials can be prepared for sharing. Some researchers adopt a "template" such that shared folder structures are similar across studies and labs, for example with different folders for study materials and documentation, raw data, results including processed data files, analysis scripts, and a readme file explaining the folders' contents. We will provide examples of templates that can be adapted for use. Concerns about sharing. Several concerns might prevent researchers from sharing. For example, participant privacy may be a

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concern, and we will provide resources for how consent forms can be amended to allow sharing. Researchers might also be concerned about errors in their code or limited programming skills. However, errors happen, and the field as a whole will be better off for finding them. Finally, researchers might be concerned that sharing data is time-consuming, but we will argue that data sharing mostly redistributes workload to earlier timepoints, compared to sharing on-demand after publication.

S22.2: Let the data do the talking: Optimizing visualizations for transparency and readability

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Communicating results accurately and effectively is a key component of the research process. Data visualization is one way to communicate results while helping readers understand the main findings of a study (Pastore, Lionetti, & Altoè, 2017). Creating visualizations is very accessible with today's technology, but these automatically-generated graphs are not optimal for visualizing infant data, which has small sample sizes and large variability. For example, bar plots hide larger trends and can lead to misinterpretations of the data (Saxon, 2015). As a result, there has been a push in infant research to move towards visualizations showing the underlying distribution of the data and individual data points, such as pirate plots ("#barbarplots," 2016; Tsuji, 2018). Despite the improvements such changes make in communicating data and results, visualizations of infant data can be further enhanced by incorporating knowledge from the fields of human perception and cognition. Accounting for pre-existing perceptual biases can improve visualizations, and make them easier to interpret. For example, groups can be depicted by incorporating Gestalt principles, like proximity and color, into the visualization (Kobourov, Mchedlidze, & Vonessen, 2015). Color is a particularly important element in visualizations. When choosing what colors to use, researchers should consider the underlying structure of their data (i.e., continuous, ordinal, or nominal; Levkowitz, 1996; Silva, Sousa Santos, & Madeira, 2011). For instance, when depicting nominal data, the colors representing each group should be perceived as discrete and lacking an inherent order. When choosing a color scheme, researchers can turn to several online tools that accommodate data structure and perceptual biases (e.g. ColorBrewer; Brewer & Harrower, 2013). Second, taking the limitations on a reader's memory into account can lead to visualizations that enhance the reader's understanding. The cognitive system can only process a limited amount at any one time, so it is important to draw the reader's attention to the most relevant information. The use of cues such as color, arrows, and text can reduce the load on a reader's working memory (McCrudden & Rapp, 2017), allowing them to focus on interpreting the findings instead of trying to remember what elements in the graph are important. For an example of how to incorporate

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these suggestions, see Figures 1 and 2, which visualize the same data. Figure 1 was created in Microsoft Excel. It is uninformative about individual infants' performance, and there are no cues to direct the reader's attention. Figure 2 was made in R and is more transparent about the underlying structure of the data. It shows individual data points, the distribution, and the 95% confidence interval around the mean. While this graph shows more information, it is not difficult to read, because perceptual and cognitive biases were considered in its design. Data points are grouped together using Gestalt principles, and the use of color emphasizes the shape of the data's distribution, directing the reader to the most important components of the visualization. By utilizing perceptual biases in the design of data visualizations, infant researchers can overcome challenges around cognitive limits and ultimately better communicate their findings.

S22.3: Bayesian sequential testing in developmental research

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Developmental research frequently involves investigation of the extent to which support for one of two alternative hypotheses can be obtained from a given sample of data. There is increasing interest in the possibility of using a Sequential Bayesian Testing design (SBT) in studies investigating support for competing hypotheses (Schönbrodt et al., 2017). In SBT, researchers collect data from an initial prespecified sample of participants and compute a Bayes Factor (BF), which is interpreted based on previously specified heuristics as providing evidence in favour of the null or the alternative hypothesis. The sample size can then be optionally increased until the researcher is confident - based on their chosen heuristics - that they have sufficient evidence in favour of one or the other hypothesis. Such a design comes with many benefits, including that one can conclude in favour of the null hypothesis, continue or stop collecting data on the basis of sequentially computed BF, and report confidence in an interpretation in support of a particular hypothesis. Especially given issues of variability and limited sample size in studies involving infants, SBT may, therefore, hit the sweet-spot in terms of "informativeness and efficiency" in developmental research (Stefan et al., 2019, p. 1042). To explore the suitability of SBT in developmental research, we chose three well-established studies in developmental research, namely, the mispronunciation sensitivity task (Swingley & Aslin, 1998), the mutual exclusivity task (Markman & Wachtel, 1988), and the cross-situational learning task (Smith & Yu, 2008) and replicated them using a SBT approach. Following an initial sample of 20 participants each, we sequentially collected data until we had at least moderate evidence in favour of either the null or the alternative hypothesis (BF < 1/3 or > 3, c.f., Lee & Wagenmakers, 2014). In a first step, we calculated the BF objectively using two uninformed priors, while analysis is

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ongoing with regards to a subjective analysis of the data with informed priors. We successfully replicated the mispronunciation sensitivity task and the mutual exclusivity task in our initial sample of 20 participants. Regardless of the prior used, we obtained BFs ranging from providing moderate to very strong evidence in favour of the alternative hypothesis in the mispronunciation sensitivity, e.g., r=sqrt(2)/2: BF10=8.13, and mutual exclusivity task, e.g., r=sqrt(2)/2: BF10=98.33. In contrast, we consistently found moderate evidence in favour of the null hypothesis in the cross-situational learning task following testing of between 20 to 42 participants, r=sqrt(2)/2: BF10Range: .19 to .31. We compare this to the BF obtained in the literature, following our calculation of the BF for all studies examining similar effects in the literature. The results highlight the "efficiency" of SBT allowing us to be more confident about our interpretation of the data despite a smaller sample size. With regards to the cross-situational learning task, the results highlight the "informativeness" of BFDA, providing moderate evidence for the null hypothesis, i.e., that children did not learn the word-object associations presented. Both these findings highlight the potential advantages of SBT in developmental research.

S22.4: Using long-form recordings to study infants' speech input and outcomes: Opportunities and challenges

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A new age dawned when the LENA© Foundation started using very long audiorecordings, analyzed automatically with their patented software. Not only did LENA© make accessible to many technology previously available only to a select few (Roy et al., 2015), but also early results from the Foundation and its early adopters suggested LENA© measures were informative in the study of early diagnosis, individual variation, and even interventions for reducing socio-economic inequality in language opportunities (to mention just a few, Greenwood et al., 2017; Warlaumont et al., 2014; Weisleder & Fernald, 2013). Since 2014, a self-organized network of researchers working with DAylong Audio-Recordings of Children's Language Environments (darcle.org) has started evaluating the opportunities and challenges that such long-form recordings provide infant researchers. This talk will first introduce briefly LENA© technology and current alternatives for hardware and automatized software. These options will be compared in terms of cost and time investment, reliability, and ease of use. LENA© technology is unique in its ease of use, and although it requires a significant monetary investment, it is also the best studied in terms of reliability. Previous validation studies suggest that LENA©'s Adult Word Counts and Child Vocalization Counts are quite reliable, whereas Conversational Turn Counts and automated analyses of child vocalization quality are not. Additional analyses suggest that individual speaker categories (such as key

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child and female adult) can have a precision and recall below 45%. There is no statistical evidence that LENA© performs any better or worse in American English than other languages, or with typically-developing children compared to children at risk. There are numerous alternatives to LENA© in terms of hardware, with widely varying costs. None of these have software that is as easy to use nor as well studied as LENA©, but researchers with some programming skills can find solutions that are as reliable as LENA©, and which even have some tools that LENA© lacks (such as classification of adult speech as directed to the infant or not). The talk then turns to outstanding challenges that no software can currently resolve. The first is that it is impossible to predict accuracy on a new dataset, and thus it is important for users to be ready to invest some time annotating data to establish the level of accuracy obtained in their own data set. Second, the current level of accuracy for any automatic tool is sometimes low enough to raise questions about their use in specific studies, which has prompted some early adopters to go back to hand-annotation, either as a complement to or a replacement for automatized analyses. Third, long-form recordings pose unique ethical challenges. Current DARCLE recommendations will be introduced that facilitate making ethical choices when collecting, annotating, and sharing long-form recording data.

S23: Building contingency: How caregiver and child characteristics relate to interactions that support infant language

S23.1: Serve-and-return and infant language skills: Evidence from fathers and mothers in low-income, ethnically diverse families

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Through social interactions with their caregivers, children learn to communicate effectively and behave in culturally appropriate ways (Bruner, 2000; Vygotsky, 1978). Children learn that their actions have communicative powers when they receive responsive feedback from their parents (Messer, 1994). Specifically, social interactions that are sensitive to children's verbal and nonverbal cues (aka serve-and-return; Fisher et al., 2017) are beneficial for language development (Shneidman & Woodward, 2015). Infants serve through eye gaze, gestures, object exploration, and vocalizations, and when parents return those serves in a way that is contiguous (close in time) and contingent (meaningful), they are more likely to foster infants' language skills (Tamis-LeMonda et al., 2014). These types of social interactions are typically examined between children and mothers in white middle-

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class families (Hoff, 2003). Despite their significance, however, we know almost nothing about serve-and-return interactions among low-income families, and even less between fathers and children. Understanding the degree to which low-income fathers and mothers engage in serve-and-return interactions during infancy can help us identify how early interactions with caregivers set children in a trajectory of growth and development. To address these gaps, we ask: 1) How do low-income fathers' and mothers' engage in serve-and-return interactions with their infants at 9 months? 2) What are the sources of variation in serve-and-return among low-income families? 3) Does serve-and-return with mothers and fathers at 9 months predict children's language skills at 18 months? We use data (n = 82) from an ongoing parenting intervention that includes an ethnically diverse sample of first-time, low income mothers, fathers and their children (Cabrera & Reich, 2017). We videotaped parent-child toy play for 10 min and transcribed parent and child speech. Children's verbal (e.g., babbling) and nonverbal (e.g., eye gaze and hand movements) serves were coded as single events and parents' verbal returns to those serves were coded in terms of contiguity (i.e., how close in time to the serves) and contingency (i.e., whether the return was meaningful). Using a validated scale, we also measured parents' depressive symptoms, which have been associated with less responsive parenting (Goodman, 2007). We present three sets of preliminary findings. First, 14% of infants' serves were verbal and 86% were nonverbal during the 10 min interaction. Infants served with the same frequency to mothers and fathers. Fathers and mothers returned contiguously (within 2s) to 50% of verbal serves (see Figure 1) and 40% of nonverbal serves, but most returns were not meaningful to the object of the child's attention (see Figure 2). Second, mothers' and fathers' depressive symptoms were significantly correlated with children's language skills (r = -.62) but not with serve-and-return. Lastly, only fathers´ contiguous returns were significantly correlated with children's language skills at 18 months (r = .47). Using a larger sample (n = 200), we will further examine the associations among fathers' and mothers' depressive symptoms, serve-and-return, and infants' language skills, controlling for parents' education and quantity of speech.

S23.2: One is not enough: Understanding variability in early language interaction quality using parent self-efficacy and developmental knowledge profiles

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Introduction: Understanding variability sources in parent-child early language interaction quality is essential to improving it. Modifiable parent characteristics, such as developmental knowledge and self-efficacy, have been positively

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associated with child language skills and interaction quality (Anonymous, 2019a; Suskind et al., 2017). However, there has been little investigation of interactions between characteristics (Hess, Teti, & Hussey-Gardner, 2004). We examined child language, input quantity and diversity, and interaction reciprocity across three parent self-efficacy and developmental knowledge profiles: 1) concordant-high (n=10 dyads, high self-efficacy and knowledge), 2) discordant (n=11, high self-efficacy and low knowledge or vice versa), and 3) concordant-low (n=9, low self-efficacy and knowledge). Hypotheses: We hypothesized that high self-efficacy and developmental knowledge are most supportive when they co-occur. Specifically, we hypothesized that concordance would predict: 1) child language skills, 2) parent input quantity and diversity (i.e., total and different words), and 3) interaction reciprocity (i.e., conversational turns). Population: We conducted secondary analyses using baseline data from a longitudinal intervention study. Children (1;0-2;3, n=41) and their parents--English monolingual or English-Spanish bilingual--in low-income households were enrolled (Anonymous, 2019b). We included 30 dyads with complete baseline self-efficacy and knowledge data in this study. Methods: We assessed parent self-efficacy and knowledge using the Self-Efficacy for Parenting Tasks Index-Toddler Scale (Coleman & Karraker, 2003) and the Knowledge of Infant Development Inventory (MacPhee, 1981). We used a median split for self-efficacy and knowledge to generate concordance groups. We evaluated child language using the Preschool Language Scales--Fifth Edition (Zimmerman, Steiner, & Pond, 2011, 2012). We transcribed and coded interaction samples for parent number of different and total words as well as conversational turns. Results: There were no significant differences in child language or parent self-efficacy across parent education levels. However, parent education was positively associated with developmental knowledge. Child age was negatively associated with language standard scores. Child age and parent concordance significantly predicted language scores. Children whose parents were in the concordant-high group had the highest expressive scores followed by concordant-low and discordant. Tukey-adjusted comparisons revealed moderate, significant concordant-high-discordant ($t(26) = 4.29$, $p < .001$, $d = 1.88$, 95%CI [.83-2.92]) and concordant-high-concordant-low contrasts ($t(26) = 2.91$, $p = .02$, $d = 1.35$, 95%CI [.32-2.83]). Receptive language data will be presented. Concordance also significantly predicted input quantity. Parents in the concordant-high group produced the most words followed by concordant-low and discordant. Tukey-adjusted comparisons revealed a small, marginally significant concordant-high-discordant contrast ($t(24) = 2.44$, $p = .06$, $d = 1.10$, 95%CI [.11-2.08]). Preliminary analyses--to be presented--showed a similar pattern for conversational turns and input diversity. Conclusion: The findings support our hypothesis that co-occurring high self-efficacy and developmental knowledge are most positively associated with child language and interaction quality. Further research on profiles and causal mechanisms is needed.

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S23.3: Building fluid and connected conversation: How caregiver speech differentially relates to interaction quality

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The types of utterances caregivers use and the quality of caregiver-infant interactions relate to infant language development (Hirsh-Pasek et al., 2015; Tamis-LeMonda et al., 2012). Most studies examine these factors separately; however, they are not independent. One recent study suggests that responsive statements are positively related to infant language when they occur in the context of smooth, back-and-forth interactions and directive statements are negatively related to infant language when they occur in the context of interaction with little back-and-forth between caregiver and infant (Smith et al., 2018). Here, we examine how different types of utterances differentially relate to fluid and connected conversations to better understand what characterizes these high-quality interactions. Data from for this study was drawn from the NICHD Study of Early Child Care and Youth Development. One hundred and eighty mother-child dyads, selected to demonstrate a wide range of socioeconomic status backgrounds and child language skills, were observed during the three-box task. This task is a semi-structured play session in which mothers are instructed to let their child interact with the contents of three boxes--one contains a book ; two contain toys. From this task, ten types of mutually exclusive maternal utterances were identified: book text, didactic statements, didactic questions, directives, affirmations, corrections, attention-getting utterances, elicitations, imitations, and other utterances (see Table 1 for definitions, examples, and percent agreement). Proportions of each utterance type were calculated (e.g., proportion of didactic questions = # of didactic questions/ total number of maternal utterances). The quality of the interaction was rated for fluency and connectedness (the balance of the conversation and the flow of the turns; Adamson et al., 2016) on a scale from 1-7. Higher scores reflect greater interaction quality. Bivariate correlations between fluency and connectedness and types of utterances indicate significant positive relations with proportion of affirmations ($r = .404$, $p < .001$), imitations ($r = .264$, $p < .001$), didactic questions ($r = .224$, $p = .002$) and didactive statements ($r = .191$, $p = .010$) as well as negative relations with proportions of attention-getting utterances ($r = -.377$, $p < .001$), corrections ($r = -.177$, $p = .017$), and directives ($r = -.189$, $p = .011$). In a multiple regression examining all types of utterances simultaneously, fluency and connectedness was uniquely predicted by proportions of affirmations ($t(170) = 4.915$, $p < .001$, $R^2 = .099$), imitations ($t(170) = 2.209$, $p = .029$, $R^2 = .020$), and didactic statements ($t(170) = 2.269$, $p = .024$, $R^2 = .021$). These findings suggest that certain types of caregiver utterances may uniquely contribute to fluid and balanced conversations with infants. Children are immersed in language environments that

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vary by types of caregiver utterances as well as in quality of the interaction between caregiver and child. By understanding how different types of utterances relate to interaction quality, we can begin to uncover possible reasons why some types of utterances promote learning more than other.

S23.4: Maternal question use and child language outcomes: The moderating role of SES and children's concurrent vocabulary

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Maternal questions facilitate child language growth by offering children opportunities to practice their language skills (Mol et al., 2008). However, early interventions aiming to enhance question use, such as dialogic reading, are found to be less effective for children from low-SES background and for children at risk for language delay (Manz et al., 2010; Mol et al., 2008). It is unclear whether these discrepancies are due to differential effects of questions across diverse groups or difficulties in increasing parental questions use in certain groups. To address this issue, the current study examined whether the effect of questions vary by SES and children's language skills by asking: 1) How do different types of maternal questions relate to child language skills later? 2) Does SES moderate the effect of maternal questions? 3) Does children's concurrent vocabulary moderate the effect of maternal questions? Participants were 165 mother and their toddlers (M=25.21mon, SD=.87) from the NICHD study of Early Child Care and Youth Development. Mothers reported on their years of education (M=14.38, SD=2.44, range=7-21) and income-to-needs ratio (M=3.49, SD=3.40, range=0-23.88). We coded three types of maternal questions during a semi-structure mother-child interaction: Y/N questions (e.g., "Is this a doll?"), referential questions asking for description and labeling (e.g., "What's this?"), and advanced questions asking about behaviors, inferences, or internal states (e.g., "How do you feel?"; interrater agreement = 98.1%-99.4%). Proportions of each question type out of the total maternal utterances were calculated to account for mothers' talkativeness. Child vocabulary at age 2 and receptive language at age 3 were assessed using the MacArthur-Bates Communicative Development Inventories and the Reynell Developmental Language Scales, respectively. At the bivariate level, all three types of questions were associated with child language at age 3 (r's=.21-.40; p's < .01). Multiple regression suggested that referential questions (b=56.51, beta=.17, p=.016) uniquely contributed to later child language, controlling for other types of questions, maternal education, income, child age, and child vocabulary at age 2. Yet, the association between referential questions and child language skills was only significant for children whose mother had low (12 years) or medium (14 years) education but not for children whose mother had high education (Interaction: b=-22.72, beta=-1.08, p=.042; see Figure 1). Additionally, the positive effect of

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referential questions was only seen for those children with large or average vocabulary sizes at 24 months, but not for those with small vocabulary (b=1.58, beta=.43, p=.049; see Figure 2). Referential questions are especially beneficial during toddlerhood, probably because they offer children opportunities to learn and apply vocabulary knowledge. The effect of referential questions was stronger for children from lower SES backgrounds, highlighting the need for effectively increasing parental use of referential questions in low-SES families. The benefit of referential questions, however, does not generalize to children with small vocabularies. While children with large vocabularies might be ready to respond to referential questions, those with limited vocabularies might need to build on their vocabularies first before they can learn from referential questions.

S24: Novel technologies to assess language development in infants

S24.1: Using web-based platforms to expand the socioeconomic reach of parent report measures of vocabulary development

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Parent report is a mainstay of early vocabulary assessment. Parent reports are based on experiences with the child that are more extensive than a researcher or clinician can generally obtain. Moreover, they are less likely to be influenced by factors that may mask a child's true ability in the laboratory or clinic, such as shyness, or that can impact the validity of naturalistic sampling, such as word frequency (Frank et al., 2019). In the US, one widely used instrument is the MacArthur-Bates Communicative Development Inventories (MB-CDI), appropriate for children 8 to 30 months learning American English (Fenson et al., 2007). While the validity and reliability of these instruments are well-established, their clinical utility has been questioned because existing norming samples are skewed toward higher-educated families and the representation of non-Whites is limited. Moreover, representation generally has been restricted to US east and west coasts. To address these concerns, we have created an online version of MB-CDI called Web-CDI. In Web-CDI, parents are sent a link via email and complete the CDI either on a computer or mobile phone. Data are anonymized (e.g., birth dates are not stored). Parents provide information about the child's birth and health history, ethnicity, caregiver education, and exposure to non-English language(s). This method allows researchers to communicate with families electronically, facilitating access in remote areas and eliminating costly mailings or laboratory visits. Instructions are provided in picture form to increase participant understanding (Figure 1). Since 2018, ~3000 CDIs have been collected

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via 15 research groups throughout the US. A primary goal for Web-CDI is to obtain a nationally representative sample with increased participation of groups who have been underrepresented in earlier efforts (e.g., caregivers with less than 12 years of education; African Americans). While there have been several large-scale web-based efforts in Europe and the UK (Kristoffersen et al., 2013; Meints et al. 2016), evidence is limited regarding the feasibility for soliciting participation from diverse samples of families. Here, we report on ongoing efforts to apply Web-CDI in ways that increase the diversity of our respondent pool. Our strategy has been to use social media outlets, such as Facebook, to target families based on geographic location (e.g., identifying cities which have a higher than average representation of African Americans) or other profile features (e.g., members of parenting groups). We plan to conduct a series of waves of data collection, targeting 100-200 respondents per wave who meet inclusionary criteria (full term, monolingual English, normal hearing/vision). Results to date are promising (Figure 2): Yields for African Americans, mixed ethnicities, and High School only respondents were ~2x higher than in Fenson et al., however, rates of respondents with below High School remained small. Additional analyses suggest that ensuring compatibility with mobile devices is key to improving access to diverse populations. The development of cost-effective online parent report methodologies has greatly expanded researchers' tool-kit for assessing early vocabulary development. Such methodologies facilitate data collection for a broad range of research purposes and support efforts to increase representativeness of normative samples.

S24.2: BabyLex-IRT: Estimating early vocabulary sizes using a Bayesian-inspired item-response theory approach

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The MacArthur-Bates Communicative Development Inventories (CDIs) are among the most widely used evaluation tools for early language development. CDIs are completed by the parents or caregivers of young children by indicating which of a prespecified list of words and/or sentences their child understands and/or produces. Despite the success of these instruments, their administration is time-consuming and can be of limited use in clinical settings, multilingual environments, or when parents possess low literacy skills. To develop a shorter version of the American English CDI-WS that maintains the accuracy and precision of the full CDI, Makransky, Dale, Havmose, and Bleses (2016) conducted real-data simulations using Computerised Adaptive Test (CAT; van der Linden & Glas, 2010) based on Item Response Theory (IRT; Embretson & Reise, 2000). In their approach, the CAT algorithm selects items based on the dynamic estimation of the child's ability. Real-data simulations established that with just 50 items, the CDI-CATs had correlations

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of .95 with the full CDI, and average SEs below .20. Empirical validation was not reported. Mayor & Mani (2019) presented a different method (henceforth, BabyLex) where an estimation of the full-CDI score was obtained by combining parental responses on a limited set of words randomly sampled from the full CDI with vocabulary information from age-, gender-, and language-matched participants (extracted from the WordBank database). Real-data simulations using versions of the CDI-WS for American English, German, and Norwegian revealed the high validity and reliability of the instrument, even for tests sampling only 25 words, effectively cutting administration time to a couple of minutes. Empirical validations with new German-speaking participants confirmed the robustness of the test (correlation of .96 and SE of .14). The BabyLex app was released subsequently. However, this approach requires large samples of data on WordBank and it is unclear how BabyLex performs with smaller samples. Furthermore, the random sampling of words is suboptimal, since sampled items may by chance be too easy (e.g., for a toddler with large vocabulary) or too difficult for the participant. We, therefore, supplemented BabyLex with a principled selection of items (IRT-based CAT, as in Makransky et al., 2016) in place of the random selection. We validated our approach using four CDI-WS with different sample sizes on Wordbank: American English (over 200 samples per age, in months; Fenson et al., 2000), Danish (100 to 200 samples per age; Bleses, Vach, Jørgensen, & Worm, 2010), Beijing Mandarin (50 to 100 samples per age; Soli, Zheng, Meng, & Li, 2012), and Italian (less than 50 samples per age; Rinaldi, Pasqualetti, Stefanini, Bello, & Caselli, 2019). Further improvements were observed for BabyLex-IRT over BabyLex across the age range and gender. Comparisons to existing CDI short-forms in American English, Danish, Italian and Mandarin revealed significant improvement; SEs were reduced by factors of two to four, albeit with certain limitations with regards to the necessary number of items presented at test in smaller datasets, e.g., Italian. In sum, BabyLex-IRT offers a promising approach for evaluating infant vocabulary sizes that is efficient, reliable and valid.

S24.3: Socio-economic status and word comprehension in early childhood: A study in a low inequality setting and a meta-analytic review

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Numerous previous studies suggest that socio-economic status (SES, often indexed by maternal education) affects word comprehension (e.g., Fernald & Marchman, 2013). Much of this previous work is done in countries with high levels of childhood poverty and low levels of access to public daycare, two factors that may increase the socio-economic gradient. Additionally, there is relatively little work putting this

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effect in the context of other factors affecting performance, such as age. In Study 1, we report on a test of SES-word comprehension links carried out in France, where childhood poverty is close to the mean for OECD countries (and lower than in the USA and Mexico). Complete data was available for 95 Parisian 2- to 3-year-olds attending daycare for at least 6 months, who were tested with a paired forced-choice task built on iPad© and inspired on the Computerized Comprehension Task (CCT, used recently by Friend et al., 2016, among others). Three practice trials, in which feedback was provided, were followed by up to 38 test trials, which portrayed words varying in frequency and lexical category (nouns, verbs, adjectives). Mixed effect models and correlation analyses (see Figure 1) revealed that effects associated with maternal education were smaller than (and did not interact with) those of age, and effects were greater for accuracy (r=.33) than response times (r=0). To integrate those results with previous literature, we report a meta-analysis (Study 2). A systematic review revealed 458 potentially relevant references, of which 11 articles (N children = 965) reported a statistical test of association between SES and a measure of word comprehension based on overt choice (PPVT, CCT). First, we estimate the strength of the correlation between SES and comprehension scores: the overall effect size was z-transformed r=0.36 [95% CI 0.23-0.48; p-value <.0001]. This indicates a medium effect of SES on vocabulary in young children, with SES explaining about 13% of the variance. Second, we establish the moderators explaining heterogeneity. These analyses suggested SES effects increased with age (Figure 2). There was no significant effect of additional factors tested: type of vocabulary assessment, type of SES measure (education, income, composite), nor whether the main aim of the study was to characterize SES. There was no sign of selective data collection or reporting. These findings represent an important step toward resolving discrepancies in the literature, by suggesting that some of the heterogeneity observed may be within the range of possible variation given the overall effect size and the precision allowed by typical sample sizes (median N=73). Our two studies concur that SES effects on word comprehension appear sizable, but disagree on whether they increase with child age. More research with a wider coverage of participants' location and age would be desirable to assess the extent to which SES-comprehension links vary across countries and across ages. To conclude, we discuss discrepancies with a mega-analysis of SES-word comprehension based on parental reports, which shows unstable and sometimes inverted effects.

S24.4: The development of canonical babble in a crosslinguistic and cross-cultural corpus

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Canonical babble development is predictive of later language outcomes (Oller et al., 1998; 1999) and delayed emergence of canonical babble is often found in children who go on to develop speech and language disorders (e.g., Fasolo et al., 2008; Lang et al., 2019; Patten et al., 2014). However, these findings have been garnered from a limited set of languages and cultures leading to a potentially biased sample. Biased sampling may make it difficult to use such measures to reliably detect delays and disorders in all populations. We explore change in the canonical babbling ratio (ratio between canonical syllables and other speech-like sounds; CBR) with age in a large, diverse, and naturalistic, dataset. This dataset may draw a clearer picture of canonical babble emergence world-wide. Using two different audio recording systems, carried out in six different cultures and five different languages, we gathered daylong naturalistic recordings of 52 infants' vocal productions in their home environments (Table 1 shows exposure language, age, and demographic information from all infants). After recordings were gathered and processed, we randomly extracted 100 utterances per child. These utterances were then segmented into smaller clips (<499 ms) in order to filter out potentially identifying information. Clips were then uploaded to a website (iHEARu-play) where, after brief training, citizen scientists annotated the clips as canonical syllables, non-canonical syllables, laughing, crying, or other (see Figure 1 for full annotation pipeline). Results revealed that CBR increased throughout development (Figure 2). A regression model predicting canonical babbling ratio by child age (in months) demonstrates that for each month of development, CBR increased by (β=0.01, t=5.88,p<.001; adjusted R2=0.4). CBR also increased with age in each of the four language corpora with a cross-sectional age sample, though with slightly different slopes: English (R=0.29, [CI=-0.42, 0.78],p=0.42, 7-17 months), Tsimane (R=0.14, [CI=-0.38, 0.59],p=0.612, spanning 7-32 months),Tseltal (R=0.95, [CI=0.79, 0.99],p<.001, 2-36 months), Yélî Dnye (R=0.9, [CI=0.61, 0.98],p<.001, 1-36 months). Overall, we found a high degree of consistency in babbling emergence within our culturally and linguistically diverse dataset which is shareable with other research groups. Our results align with what has been reported in previous work. Namely, a canonical babbling ratio of .15 was reached by about 7 months across the corpora, replicating previous reports (Oller et al., 1998, 1999), which found this ratio was reached by 0;10. This finding not only increases confidence about the universality of canonical babble development, but also helps validate automatic extraction and crowdsourced labeling as viable methods for data processing and annotation of daylong audio recordings of children's language environments. We did, however, also find some differences between corpora which may be attributed to a variety of causes including how recordings were processed and the linguistic environment (e.g., the amount speech heard, the complexity of a language's syllable structure). Possible reasons underlying differences between corpora are discussed as well as future directions for this work.

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S25: Embracing new technologies to quantify early learning environments

S25.1: Hands-on learning: Toddler's multimodal attention at naming moments leads to successful word learning

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Learning a new word requires the coordination of behaviors between parents and children and across different modalities. Traditional views of word learning suggest that infants need to be looking at the right object at the right time in order to form the correct object-label mapping. To study these in-the-moment behaviors that drive early word learning, we identified instances when parents named objects during free play and examined whether dyadic behavior during naming could predict if the infant learned the object's name. Unlike prior work studying parent-child interactions at the micro-level, dyads did not play in a sterile, "white room" laboratory environment (e.g.,Yu & Smith, 2012). To better capture naturalistic behavior, an apartment-like lab was furnished with a dining area, kitchenette, couch, and tv-stand. The space was equipped with wireless head-mounted eye-trackers, numerous third-person view cameras, and motion tracking to still collect the high-density behavioral data that is needed for analyzing interactions frame-by-frame. 21 12-to-24-month-old toddlers and parents played for 10min with 10 toys that were selected to be outside of toddlers' vocabulary (e.g., bison, kettle, mango). Parents were asked to refer to each object with a specific name. In addition to measuring visual attention, object handling and parent speech were coded (Figure 1). After the play session, toddlers' knowledge of object-label mappings was then measured with a screen-based test. If the toddler looked more at the target after hearing its label during both of its testing trials it was considered "learned" and it was "unlearned" if the toddler looked more at the distractor during both trials. Across all subjects, 42 objects were unlearned and 49 learned. An event-level dataset was created by finding all parent utterances in which they named an object their child learned or did not learn (learned=198, unlearned=194). To determine what creates a successful naming event, we defined three temporal windows: 1) a "before" window, the 3s before the onset of the naming utterance; 2) "during" the naming utterance; and 3) the 3s "after" the offset of the naming utterance. Within each window, we extracted three sensorimotor properties: 1) looking only: the proportion of time the toddler looked at the named target but did not hold it; 2) holding only; and 3) hand-eye coordination: simultaneously holding and looking at the named object. As shown in Figure 2, we found that hand-eye coordination during and surrounding a naming utterance was a significant predictor of learning. There were no meaningful differences in the amount of time spent only holding or

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only looking at learned and unlearned objects, suggesting that sustained, multimodal attention is the biggest predictor of whether a labeling event was "successful." Crucially, parent's eyes were also more coordinated with their toddler's hands during and after successful labeling events (ps<=0.011). We argue that visual attention alone is not sufficient for early word learning. Rather, multimodal attention is critical for linking seen objects to heard words. Including hands in our definitions of infants' information processing will change the way we conceptualize both the ambiguity and quality of naming events.

S25.2: Automatically detecting children's visual access to social information in egocentric videos

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Young children learn via social information, gathered in part by attending to the faces and hands of their caregivers. Although infants have near-constant companions in their caregivers, young children's visual access and attention to social information has been found to vary meaningfully over time as they develop control over their own posture and locomotion (Sanchez, Long, Kraus & Frank, 2018), as well as the capability to deploy their attention and process social information. Egocentric views collected from infants and toddlers wearing head-mounted cameras make it possible for researchers to now quantify the amount and types of social information available to young learners, but annotation of the frames extracted from these videos is prohibitively time-consuming for large datasets, meaning that many of the frames are not inspected. For example, Fausey, Jayaraman & Smith (2016), a cross-sectional study of 34 infants aged 1-24 months, collected a total of 143 hours of head-mounted camera footage (15.5 million frames), of which one frame every five seconds was hand annotated (by four coders), totalling 103,383 frames (per coder)--an impressive number of annotations but nonetheless only 0.67% of the collected footage. Using these annotations, Fausey et al. found that infants aged less than 12 months received face-dense input, relative to 1- to 2-year-olds who received more hand-dense input. The present research aims to test the generality of these findings using the SAYcam dataset (Sullivan, Mei, Perfors, Wojcik, & Frank, under review), a longitudinal collection of over 1700 headcam videos collected from three children along a span of 6 to 32 months of age. Children wore headcams at least twice weekly, for approximately one hour per recording session. One weekly session was on the same day each week at a roughly constant time of day, while the other(s) were chosen arbitrarily at the participating family's discretion. With many hundreds of hours of footage (>100M frames), this large dataset truly necessitates a shift to an automated annotation strategy. Here, we test the validity of several modern computer vision models optimized for detecting social information in natural scenes. In particular,

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we focus on OpenPose (Cao et al., 2017), a model optimized for jointly detecting human face, body, hand, and foot keypoints (135 in total) that operates well on scenes including multiple people even if they are partially-occluded (see Figure 1). We discuss the detection accuracy of multiple models using a manually-annotated sample of 24,000 frames, and present our full, publicly-available analysis pipeline. Our preliminary findings of over 30 million frames tagged by OpenPose indicate some consistency in the prevalence of hands and faces in children's early visual environment, but also surprising variability over time and across children.

S25.3: The linguistic landscapes of learning in two small-scale societies

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We present findings from a comparative study of language development in two small-scale societies--Tseltal (Mayan) and Rossel (Papuan)--focusing on how much speech children hear, who they hear it from, and how their linguistic landscapes relate to caregiving practices. Based on prior ethnographic work, we expected these communities to differ radically in their talk to infants: Tseltal caregivers reportedly rarely use child-directed speech (CDS), and infants are carried by their mother until age one; Rossel caregivers reportedly more widely share caregiving responsibilities from earlier on and engage infants in face-to-face, affective interactions. Children in both groups are raised in extended families, with many cousins, and with caregivers working as subsistence farmers. 55 children (0;0-4;0) wore an audio recorder (Olympus) and wearable photo camera (Narrative Clip) in a vest for most of a waking day at home; photos were taken two (Tseltal) or four (Rossel) times per minute. We transcribed a random selection of short clips from the recordings of 10 children in each site (0;0-3;0) and, separately, annotated most of the photo collection (>110K images) for the number of adults and children present and whether the child was holding an object. While the rate of CDS in Tseltal was indeed low (3.6 min/hr), it was actually lower for Rossel children (3.1 min/hr; Figure 1). Children in both sites more speech before and after daily farming work. While Tseltal children's CDS was stable with age, Rossel children experienced an increase in CDS, mostly coming from other children. These differences may derive from the multi-caregiver Rossel context, which includes play-groups of older children. All results were confirmed ($p < .05$) using negative binomial mixed-effects regressions. The photo data, from 84 children, concord with the audio-based findings: children consistently display a dip in number of speakers present from late morning to midday, during which farming is typically done. Second, Tseltal infants only begin to hold objects after 0;10, when they start spending less time being carried; in comparison, Rossel infants show a more level trajectory, with more early object handling (Figure 2). These patterns bear out as effects of child age and an interaction of child age and community (both $p < .001$) in a mixed-effects regression

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of the proportion of photos showing child object handling. Notably, despite these low input rates, both groups of children reached linguistic milestones--canonical babble, first words, and multi-word utterances--around the same age as expected for Western children. This minimal use of CDS paired with typical linguistic development underscores the importance of other sources of linguistic information (e.g., visual cues, overheard talk) and mechanisms for capitalizing on brief interactions (e.g., bursty learning). These data also give us a birds-eye view of how economic lifestyle interacts with caregiving practices in shaping daily talk. Finally, the Rossel data demonstrate an intriguing dissociation between child-centric interactional ideologies and actual rate of input. We will discuss these issues with respect to the role of CDS in language learning more generally.

S25.4: Analyzing emotion in language input: Caregivers' cues to valence support toddlers' learning of emotion words

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Research linking young children's language input to word learning has predominantly focused on nouns and verbs (and their corresponding objects and actions) (e.g., Bergelson & Aslin, 2017; Roy et al., 2014). However, less is known about learning abstract words, such as emotions, whose meanings encompass complex continuous dimensions, such as the degree of positivity or negativity (valence; Russell 1980; Thornton & Tamir, 2019). Here we seek to understand how valence cues in caregivers' input support children's emotion label acquisition. Two studies apply sentiment analyses to quantify the representation of valence, both in children's emerging vocabulary and in caregivers' language. In Study 1, we assessed the link between toddlers' production of emotion labels and the representation of valence in their early vocabulary. First, we explored toddlers' use of valenced words. Toddlers started producing valenced words (e.g., smile, better, help, bad, dirty, cry) at an older age than non-valenced words (e.g., airplane, napkin, buy), controlling for frequency in caregiver input (Figure 1a; Beta regression: $\beta = 0.25$, $p<0.0001$). This indicates that children's production of valenced words lags behind that of neutral (or less valenced) words. Next, we evaluated children's production of valenced words through a sentiment analysis (Thornton & Tamir, 2019) of the word tokens in Wordbank (Frank et al., 2017). Children's expressive vocabulary increasingly represented the full continuum of valence with age, as measured by the variance of valence of words, controlling for vocabulary size (Figure 1b; $\beta=0.0007$, $p<0.0001$). Finally, we assessed how the valence range of a child's vocabulary relates to their emotion label (e.g., happy) production. Children whose vocabularies (excluding emotion labels) covered a wider range of valence produced more emotion labels, controlling for overall vocabulary size (Figure 1c; Poisson regression: $\beta=36.5$, $p<0.0001$). This suggests a link between toddlers'

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network of valence-related words and their ability to label emotional states. In Study 2, we assessed the hypothesis that caregivers' cues to the valence of emotion labels supports this link. Within 18 CHILDES corpora of North American English (ages 0-5; Sanchez et al. 2019), we assessed the valenced context in which emotion labels are used by computing the valence of words surrounding an emotion label uttered by each child and parent. This sentiment analysis technique revealed that caregivers provided increasingly rich valenced information at least three utterances preceding an emotion label; caregivers provided the most scaffolding for younger infants (Figure 2a). The more scaffolding a parent provided, the better their child was at producing appropriate emotion labels: controlling for age, mean length of utterance, and overall use of valence, caregiver cues to valence predicted children's production of emotion labels in valenced semantic contexts (Figure 2b; Gamma regression: $\beta=0.21$, $p<0.05$). The quality of caregiver cues to valence supports children's own successful production of emotion labels. This investigation provides a new technique for defining the 'quality' of infant-directed speech through complex patterns of words and contexts to trace the emergence of emotion words. Our approach will enable other researchers to quantify how caregivers dynamically select words that help children move from producing concrete nouns to constructing complex, abstract meanings.

S26: Updates from the ManyBabies Consortium: Four Collaborative Replications of Important Findings in Infancy Research

S26.1: ManyBabies 1B: Testing bilinguals' preference for infant-directed speech

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From the earliest months of life, infants prefer listening to infant-directed speech (IDS) over adult-directed speech (ADS; Dunst, et al., 2012; ManyBabies Consortium, 2019). Yet, IDS differs across languages, individuals, and cultures, both in form and in prevalence. Further, the vast majority of research on infants' IDS preferences has been conducted in North America, using English speech typically directed at North American, monolingual, English-hearing infants (Dunst et al., 2012). Infants growing up bilingual provide a particularly useful wedge in understanding experiential influences on infants' attention to IDS. Bilingual infants are exposed to IDS in two languages, in which the form, prevalence, and function of IDS may vary. This unique aspect of their experience can allow researchers to investigate how exposure to IDS

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in particular languages affects infants' preferences for this key information signal in their environment. Examining bilingual infants' preference for IDS can also yield insights about the nature of bilingual development itself. Several lines of research suggest that early exposure to two or more languages changes some aspects of early development (Byers-Heinlein & Fennell, 2014): bilinguals maintain sensitivity to non-native consonant contrasts (García-Sierra et al., 2016; Ramírez et al., 2017), tone contrasts (Graf-Estes & Hay, 2015; Liu & Kager, 2016a), and visual differences between languages (Sebastián-Gallés et al., 2012) until a later age than monolinguals. This raises the possibility that preference for IDS versus ADS could have a different developmental course for bilingual versus monolingual infants. ManyBabies 1 Bilingual is a large-scale, multi-lab, pre-registered attempt to understand how bilingualism affects infants' preference for IDS over ADS. All labs measured infants' relative looking time to speech in North American English (NAE) IDS versus ADS as an indicator of infants' preference for IDS. Because infants vary widely in their experience with NAE IDS, our multi-site approach gives us precision in estimating the effect size of bilingual infants' preference for IDS in comparison to monolingual infants, allowing us to disentangle how experience with specific languages moderates this preference. We collected data from two age groups: 6-9 month-olds and 12-15 month-olds, which we compared to those from monolingual infants from the same communities collected in ManyBabies 1 Monolingual sample (ManyBabies Consortium, 2019). Seventeen labs from 7 countries contributed data, yielding a final bilingual sample size of 148 6-9 month-olds, and 185 12-15 month-olds. Using meta-analysis and mixed-level models, we found no difference between monolinguals and bilinguals in their IDS preference. Like monolinguals, older bilinguals showed stronger IDS preference. Importantly, bilinguals who had more exposure to NAE showed stronger IDS preference, suggesting a dose-response relationship between exposure to NAE and preference for IDS (Figure 1). Together, our findings suggest that both bilinguals and monolinguals show IDS preference but that language input (i.e., percentage exposure to NAE) changes the magnitude of infants' IDS preference. Our project not only reveals a precise measurement of how experiential factors moderate infants' preference for IDS, but also a model for how bilingualism researchers can collaborate to better understand language development in this variable, under-studied population.

S26.2: ManyBabies 2: Theory of mind in infancy

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A fundamental feature of human social cognition is the ability to ascribe mental states to others (termed Theory of Mind; ToM). False belief tasks are a classic way to assess this ability, where children are asked to predict an agent's action based on

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that agent's (mis)representation of the state of affairs (Wellman et al., 2001). While verbal tasks are typically passed around age 4, a variety of spontaneous response tasks have found success in similar scenarios in infancy (Southgate et al., 2007; Onishi & Baillargeon, 2005; Buttelmann et al., 2009). This wave of findings pointed to the possibility that even young infants may represent others' false beliefs, and has given rise to new theories of the development of ToM (e.g., Apperly & Butterfill, 2009; Perner & Roessler, 2012; Scott & Baillargeon, 2017). However, a number of partial or failed replications have called the robustness of these paradigms into question (Barone et al., 2019; Kulke & Rakoczy, 2018). The current empirical situation is complex and puzzling, and has led to debate about the replicability of infant ToM findings (Baillargeon et al., 2018; Poulin-Dubois et al., 2018). Against this background, ManyBabies2, a group consisting of authors of the original studies and of previous replication attempts, is pursuing a multi-lab initiative to study infant ToM. This group is conducting a large-scale conceptual replication of anticipatory looking-based false belief tasks in 18-36-month-olds and adults (based on Southgate et al., 2007; Surian & Geraci, 2012; Schneider et al., 2011). We designed a set of engaging, 3D-animated video sequences. Participants are shown chasing events, where first in a familiarization phase it is conveyed that a chaser's goal is to reach a chasee. Then, in various scenarios the chaser will have a true or false belief regarding the location of the chasee. We will explore whether infants and adults correctly anticipate the chaser's action based on their belief about the location of the chasee. In a pilot study in spring-summer 2019, seven labs from Europe and North America collected data on gaze behavior in the familiarization phase. A key desideratum of this paradigm is that it should produce sufficient anticipatory looks, as a low rate of anticipatory looking has been found in previous studies, leading to high exclusion rates. Analyses based on data of n=68 infants of the pilot study suggest that the stimuli are engaging and elicit a relatively high proportion of goal-directed action anticipations in familiarization: Overall, 70% infants' first looks were in the correct area of interest (AOI). The average proportion of looking towards the correct AOI was around 75% (S.E. = 0.034 ; Figure 1). Additionally, we identified an element in the scene that is potentially distracting and will thus likely be revised in the following studies (Figure 2). We will discuss theoretical and methodological implications of these results, as well as future steps for the project. We hope to receive feedback and encourage other potential interested labs to join ManyBabies2.

S26.3: ManyBabies 3: Infant rule learning: a multi-lab replication study

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The ability to learn and apply rules lies at the heart of cognition. Rules are essential in all core cognitive abilities, from using language to causal inference, from

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reasoning to social interactions, from concept learning to problem solving. The study of rule-learning in infancy tries to uncover whether and to what extent this core cognitive ability is available in infants and how this ability varies across different developmental circumstances. In their seminal study, Marcus et al. (1999) showed that 7-month-old infants were able to abstract ABB/ABA patterns from a 2-minute stream of speech syllables and to generalize these patterns to sequences of novel syllables. Since then, many studies have followed this paradigm to answer questions about the human-, or domain-specificity of rule-learning, and about the nature of the rule-learning mechanism, albeit with mixed results (Rabagliati, Ferguson & Lew-Williams, 2019). The goal of the ManyBabies 3 (MB3) project is to establish the robustness of the rule-learning effect in this paradigm, by studying it in a large and diverse sample of infants across laboratories. There are many reasons to study rule learning within the ManyBabies framework (e.g., ManyBabies Consortium, in press). Under some views, rule learning is a building block of the human cognitive architecture (Chomsky, 1981; Fodor, 1981), and so should be a universal human ability. Even so, studies of rule-learning have mostly been with infants from Western cultural backgrounds, often English (see Rabagliati et al., 2019). This limits our understanding of whether rule learning is truly universal. Second, although abundant research shows evidence for rule learning, there are also quite a few null results, and there is large variability in published effect sizes. Rabagliati et al. (2019) have shown that the residual heterogeneity even when controlling for other variables (e.g., infants' age, experimental design factors) is very high. As such, studying rule-learning in a large-scale replication study in infants from a large age range (5-12 months) can help us find previously unidentified factors that drive this variability. Third, large-scale infancy research provides another opportunity to study how different experimental paradigms can influence infants' performance. Marcus et al. (1999) used the head-turn preference paradigm whereas other studies used different paradigms such as central fixation (Schonberg, Marcus, & Johnson, 2018). In ManyBabies 1, which investigated infants' preference for infant-directed speech, different experimental paradigms (head-turn, eye-tracking, and central fixation) yielded different effect sizes. By allowing labs to choose their methods, MB3 provides another test of the influence of paradigm on effect size. In MB3, our research questions are the following. 1) What is the magnitude of the rule-learning effect in infancy? 2) How does rule-learning vary by age? 3) How does rule-learning vary with different linguistic backgrounds? 4) How does the effect vary with experimental paradigm? Testing the development, scope, and limits of abstract rule-learning is of considerable theoretical importance for understanding cognitive development in general and the human ability to acquire language in particular, and MB 3 is positioned to provide unique contributions toward these goals.

S26.4: ManyBabies 4: A large-scale, multi-lab, coordinated replication study of infants' social evaluations

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Kelsey Lucca(1), Arthur Capelier-Mourguy(2), Krista Byers-Heinlein(3), Michael Frank(4), Annette Henderson(5), Siobhan Kennedy-Costantini(5), Jonathan Kominksy(6), Zoe Liberman(7), Peter Reschke(8), Laura Schlingloff(9), Melanie Soderstrom(10), Jessica Sommerville(11), Denis Tatone(9), Francis Yuen(12), J. Kiley Hamlin(12)

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Evaluating others and their actions as praiseworthy or blameworthy is a fundamental aspect of human nature. In recent years, evidence has emerged to suggest that the ability to form social evaluations based on third party interactions emerges within the first year of life, much earlier than previously thought. By six months, infants prefer agents who aid another individual by helping them achieve their goal of climbing to the top of a hill, as opposed to hindering them by pushing them down a hill [1]. In recent years, with the rise in attention to the importance of reproducibility in scientific research, numerous studies have assessed the replicability of findings on infants' social evaluations. Although some of these replications have been successful, others have not [2,3]. As with all replication failures, failures to replicate infant social evaluation studies may reflect that the original studies overestimated the true size of the effect, and/or may stem from methodological differences between the replication attempts and the original studies. In this talk, we will present an update on the ManyBabies 4 project, a multi-laboratory, standardized, and highly structured study aimed at replicating infants' preference for prosocial (helping) agents, over antisocial (hindering) agents. We will provide an overview of the experimental design (Figure 1) and results from pilot data (N = 19, Figure 2). This talk will provide an opportunity for researchers interested in participating in the project to meet with the project leads, ask questions, and acquire information needed to join the project. In ManyBabies 4, we aim to measure both the strength of infants' preference for prosocial individuals, as well as laboratory- and participant-level moderators of this preference. We are examining this preference developmentally in infants between 5.5 and 10.5 months of age. In addition to providing more precise estimates of these quantities, this large-scale replication study, combined with a recent meta-analysis on the topic [4], also aims to provide an empirically sound assessment of the effects of publication bias on this literature. We selected helping and hindering actions as representative examples of prosocial and antisocial behaviors. In a series of videos, infants are shown a climber character, a wooden circle with googly eyes, repeatedly attempting to climb a hill. Infants then are shown in alternating order an antisocial character hinder the climber's goal by pushing the climber down the hill, or a prosocial character help the climber by pushing it up the hill. At test, infants are

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presented with real-world replicas of the helping and hindering characters and prompted to choose (i.e., reach for) one of the two. Filmed stimuli rather than a live puppet show were used during the familiarization/habituation phase to ensure standardization, minimize the training burden across laboratories, and to adapt the design for our target age group. The findings from ManyBabies 4 will not only provide new insights into the nature and strength of infants' sociomoral evaluation, but will also contribute to our growing understanding of the best practices for running large-scale studies with infants.

S27: Real-world interactions in Real Time: moment-to-moment dynamics of parent-infant joint engagement in naturalistic contexts

S27.1: Multiple sensorimotor pathways to parent-infant coordinated attention in naturalistic toy play

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Joint attention in early development has been extensively studied because of overwhelming evidence that the ability to socially coordinate visual attention is essential to healthy developmental outcomes, including language learning. Many previous studies on joint attention presented well-controlled and repetitious social signals in discrete trials to measure the infant's responses to those joint attention bids. Those studies fall short of capturing the essence of real-time everyday interactions which requires infants to keep track of rapid changes in action and to deal with potentially noisy environments. The goal of the present study is to examine how parents and infants establish coordinated attention in naturalistic everyday contexts.

 Method. We decorated a lab environment to be home-like which consists of everyday furniture, including a couch, chairs, lamps, an eating area, and a play area. As shown in Figure 1A, 43 parents and infants (M=19.5mo, SD=2.56mo) were asked to play a set with of 10 everyday toys in the home-like environment just as what they would do at home. Both participants wore head-mounted eye trackers. There were approximately 279 minutes of joint play in total, yielding roughly 803,500 gaze data points (at the rate of 30 frames per second) from both participants.

 Results. As shown in Figure 1B, we first aligned the two gaze streams from each parent and infant in a dyad, yielding a series of events in which the two partners fixated on the same object. For each joint attention bout, either parent or child needs to be the initiator, fixating on the object ahead of the other person who is thus the follower responding to the behavior of the initiator to

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create coordinated attention. Hence, we determined which partner was first in time to enter our definition of coordinated attention and categorized the coordinated attention bout as either child-led or parent-led. As shown in Figure 2A, infants were the initiator of 3.05 child-led coordinated attention bouts per minute (with parents as the follower), and parents were initiators (with infants as the follower) of more than 2.52 parent-led coordinated attention bouts per minute. Thus, parents and infants were equal contributors to establishing coordinated attention bouts. To understand how they established coordinated attention, we operationally defined three pathways to coordinated attention: 1) gaze pathway: there was a face look by the follower before the follower joined the initiator; 2) parent-hand pathway: the parent manually handled an object to attract both partners' attention to that object; and 3) child-hand pathway: the infant manually handled the object of interest to attract both partners' attention. As shown in Figure 2B, both child-led and parent-led bouts may be created through the gaze pathway and the two hand pathways. However, the frequency of these pathways differs as a function of who is leading and who is following, with hand following being much more likely by the infant than the parent overall.

 Conclusion. Coordinated visual attention between parents and infants can be viewed primarily as a sensory-motor behavior. Hence, skill in achieving coordinated visual attention in social settings, just like other sensory-motor skills, emerges from the multiple pathways to the same functional end.

S27.2: Infant vocalizations and maternal speech in naturalistic play: Contingencies from 4 to 12 months

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Infant language learning depends on temporal and sequential contingencies between speech and other joint actions and events in shared social environments. These contingencies can ostensibly be optimized by responsive caregivers during joint engagement. For example, different aspects of maternal responsiveness predict child language milestones (LeMonda et al. 2001), and maternal responsiveness across the first year structures dyadic interactions in such a way as to scaffold the development of turn-taking behavior (Leonardi et al. 2016). Such findings suggest that reciprocal, responsive actions and signals between parents and infants might create opportunities for social feedback and learning. For instance, contingent responses might increase infants' vocalizations, which have been related to positive language outcomes (Warlaumont et al. 2014). The current project addresses reciprocal contingencies between infant vocalizations and maternal speech and manual actions, recorded in homes for a longitudinal study of 41 dyads. Micro-behavioral analyses of action contingencies are used to identify

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non-random sequential dependencies that could promote learning. Recently, Chang and Deák (2018) showed that shifts in gaze and manual object-handling at 12 months were related to the content of mothers' recent utterances. We extend this framework to examine (1) whether infants' vocal responses differ in frequency or latency contingent on maternal verbal content or object-manipulating actions (Deák et al., 2017); and (2) whether mothers produce selective verbal responses to infant vocalizations, and whether such selectivity predicts infants' later language skills. Finally, we will extend Chang and Deák's (2018) analyses by comparing contingency statistics between maternal speech and manual actions, and infant visual attention and vocalizations, at 4-, 6-, and 9-months as well as 12 months. This comparison will characterize changes in reciprocal contingencies with development. In the current study, speech and vocalizations were transcribed during a 10- minute home session composed of free play and a pointing game. Results show that half of infants' vocalizations occur within 1.8 (median) seconds after a mother's utterance begins; as infants mature, latency increases (Figure 1: 4 months: 1.42 sec; 6 mo: 1.50; 9 mo: 2.04; 12 mo: 2.07) and the rate of infant vocalizations increases. The frequency of particular content types in maternal utterances changes with age (Figure 2). This points to reciprocal changes in the mother-infant dyads' interactions across development. Ongoing work has two goals: first, we are examining not just the content type of maternal utterance, but also acoustic signal, characterizing the prosody of these infant-directed speech acts to determine whether prosodic information or semantic/discourse variables are the best predictors of infant vocalizations. Second, to examine reciprocal influences in vocal interactions we are deriving contingencies between infant vocalizations and maternal verbalizations and maternal object-directed actions (coded for 3 min. of each session), conditional on infants' gaze (i.e., looking at maternal actions). Thus, we will characterize how, from 4 to 12 months, parental speech potentiates infant vocalizations, and how those vocalizations then promote further verbalizations from parents. Finally, we will relate these patterns to standardized language test outcomes (MBCDI, BSID-3, LUI) at 22 months.

S27.3: Everyday joint engagement: Coupling of the mothers body with the infants manual actions

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Joint engagement between infants and a more mature partner supports learning in the moment and predicts language and cognitive skills over time (e.g, Tomasello & Farrar, 1986). Previous work on joint engagement focused on how parents and infants coordinate eye gaze with one another during shared tasks (e.g., Yu & Smith, 2013; 2017). Nonetheless, eye-gaze is only one modality through which infants and parents share interest (Suarez-Rivera, Smith & Yu, 2019). Furthermore, the lab-

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based structure of most studies may overrepresent the prevalence of joint engagement relative to real-world interactions. We thus extend research on joint engagement in two key ways. We conceptualize joint engagement as a phenomenon of the whole body, asking how mothers coordinate talk, manual actions, gestures and bodily physical proximity with their infants' manual actions. Second, we describe the ebb and flow of joint engagement over extended periods (2 hours) in the home environment. How do mothers coordinate multiple behaviors with infants' manual actions in real time during everyday home activities? We video recorded 36 mothers and their 13-to-23-month-old infants during two hours as they went about their day, and coded the frequency and duration of infants' interactions with toys and household objects. Infant object interaction was defined as the manual displacement of an object with the onset marked by contact with any object and the offset marked by three or more seconds off an object. For each bout of infant object interaction, we coded mothers' proximity to the object, manual contact with the object, gesture towards the object (e.g., point), and speech referencing the object. Results on 23 dyads thus far showed that, on average, infants engaged in 202 object bouts during the 2-hour visit (Range 130 to 293). Mothers referenced and touched objects of infant action in nearly half of bouts (Ms=44% and 45%, respectively); they gestured during 10% of infant bouts. Mothers were twice as likely to coordinate manual and verbal references to objects (multimodal behaviors) than to display either modality alone (Figure 1a). Mother proximity did not always lead to verbal and manual engagement but did so 70% of the time. Figure 1b shows that of the times that mothers were proximal to infants, they were more likely to coordinate manual and verbal behaviors than to not engage or engage through either modality alone. The regularities in the co-occurrence of mother behaviors and infant object bouts are illustrated in Figure 2. We are currently examining latencies between behaviors as well as transitions between different object bouts to describe the ebb and flow of joint engagement at home. The social and sensorimotor dynamics of infant-mother joint engagement at home extends findings in laboratory-based contexts. Despite the complexity of home environments, mother-infant dyads coordinated behavior to the same degree as seen in controlled lab settings. Furthermore, mothers were highly likely to provide multimodal engagement towards the objects of infant manual engagement (Suarez-Rivera et al., 2019). The ebb and flow of everyday joint engagement may support infants' interactions with the people and objects of their environments.

S27.4: Playing and learning together: Spontaneous joint engagement scaffolds infant play at home

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When infants and adults interact with objects - commonly referred to as joint engagement (JE) - infants can capitalize on the knowledge of their expert social partners. During JE, adults and infants coordinate multiple behaviors, including visual attention, gestures, touch, and language. As infants develop their abilities to engage with others, their object play progresses as well - from sensory exploration to complex play involving designed and pretend actions. These overlapping trajectories likely indicate a developmental cascade, in which infants' interactions with social partners support increasingly complex play and complex play allows for increasingly rich social interactions. Although joint attention in lab-based studies is found to scaffold infant visual attention, whether JE scaffolds infants' actions with objects in real-time, naturalistic settings remains unexamined. We video-recorded 36 mothers with their 13-, 18-, and 23-month-old infants (n=12 per age; 50% female) for two hours during their everyday routines. Videos were coded for frequency and duration of infants' manual displacement of objects, and infant "playforms" during object interactions - simple touch versus complex play (i.e., using objects functionally or symbolically). Within each object interaction "bout" we coded mothers' proximity, manual touch/gesture, object-directed language references - three dimensions of "multimodal" JE. Preliminary analyses of 16 dyads revealed that infants displayed simple touch (Mcount=135.63 bouts, SD=40.34), more frequently than complex play (M=61.38, SD=18.56) (Figure 1), $p<0.001$. Notably, however, bouts of complex play were nearly 3 times as long (M=39.93s, SD=11.60) as simple touch (M=14.57s, SD=4.52), $p<0.001$. We next compared proportions and durations of simple and complex bouts in which mothers offered no input versus all three dimensions of input (i.e., "full JE"; Figures 2a-2b; bouts with 1 or 2 modes of input are included in Figures 2a-2b). Infants were more likely to display complex play when mothers displayed full JE than no engagement, whereas infants were just as likely to engage in simple touch with no input as with full JE. Specifically, mothers provided no input in 22.45% of simple touch bouts and full JE in 19.57% of simple touch bouts ($p=0.593$). By contrast, infants' complex play largely occurred with full multimodal engagement (50% of complex play bouts) relative to no maternal input (14.3%; $p<0.001$). Mothers' full JE also corresponded to longer bouts of simple touch and complex play. Bouts of simple touch lasted 22.47 seconds when mothers were fully engaged (SD=14.64), but only 7.45 seconds (SD=2.83) when mothers did nothing, $p<0.01$. Bouts of complex play lasted 51.66 seconds (SD=16.72) during full JE, but lasted only 27.67 seconds (SD=26.11) when mothers did nothing, $p<0.01$. We are currently examining how infant play and maternal input change with infant age, and will leverage our time-locked coding to test the sequencing and latencies of infant and mother behaviors--whether infant object interactions elicit maternal engagement and/or whether maternal input supports complex infant play. This first investigation of joint engagement at home advances an understanding of how infant learning is scaffolded in real-time.

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S28: Exploring the circumstances in which infants attribute dispositions to agents

S28.1: Three-month-old infants' understanding of a human agent's preference

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Understanding people's preferences is important for interpreting and predicting their behavior. A preference is defined as a dispositional state that helps explain why an individual chooses one object over another option. There is ample evidence that infants attribute preferences to agents based on choice information (Baillargeon et al., 2015). That is, an agent's unvarying choice of one object between two options signals her preference for the target over the non-target object. Recent research also suggests that infants attribute to agents preferences based on effort information (Liu, Ullman, Tenenbaum, & Spelke, 2017). That is, after seeing an agent make varying efforts to reach two targets individually, infants expect the agent to prefer the harder-to-access target than the easier-to-access one. The present study examines whether 3-month-old infants can use both choice information (Experiment 1) and effort information (Experiment 2) to attribute preferences to a human agent. In Experiment 1, 3-month-olds watched an agent consistently reach for and grasp one of two toys, toy-A but not toy-B, during familiarization. Both toys were on a same fronto-parallel plane and equidistant to the agent. During test, the positions of the two toys were switched. Infants expected the agent to reach for A again and responded with heightened interest when she reached for B. If toy-B was not an option for the agent during familiarization because it was absent or hidden from her (but not from the infants), infants seemed to realize that the agent's actions toward toy-A did not signal her preference for A over B. In Experiment 2, both toys were present and the agent again consistently chose A but not B during familiarization. If the two toys were on a same fronto-parallel plane and equidistant to the agent, infants again attributed to the agent a preference for A over B. If the two toys were of varying distances to the agent because they were on two different fronto-parallel planes, infants did not interpret the agent's actions toward A as evidence for her preference, regardless of whether A was closer to or farther from the agent than B. Ongoing research is examining whether keeping the two toys on the same fronto-parallel plane but still varying their distances to the agent would render it possible for infants to attribute a preference to her. For instance, similar to Liu et al. (2017), infants might attribute to the agent a preference for toy-A over B if A was farther from the agent and hence harder to access than B. Together, the

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present study provides evidence for an early-emerging system of psychological understanding. Infants as young as three months can interpret a human agent's actions in terms of preferences when she consistently chooses one object over another, at least when the two options were similarly accessible to the agent.

S28.2: Self-experience scaffolds infants' reasoning about preference

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Preference for a type of objects can be challenging for infants to infer because preference-related actions tend to be variable. A person's preference for corns over broccoli would be easier to deduce than preference for vegetables over other types of food. Prior research showed that infants at 14 months, but not younger, attributed to a person a preference for objects from an abstract category (i.e., tall objects) after seeing three examples. The present research examined whether 11-month-olds can succeed in the same task with additional visual experience and self-experience. Infants' reasoning about action patterns across situations can benefit from seeing more examples (e.g., Song & Baillargeon, 2007). Experiment 1 examined whether observing more examples would also facilitate infants' reasoning about a person's preference. Eleven-month-olds watched an experimenter choose tall over short objects across three or six different object pairs (Three- or Six-Example Condition) during familiarization. Next, they saw the experimenter choose either the tall object (old-choice test event) or the short object (new-choice test event) from a new object pair. Results showed that infants in both conditions looked about equally at the two test events (ps > .75), suggesting that they did not form any expectation about the actor's choice in test. Thus, the increase from three to six examples was not sufficient to enable 11-month-olds to detect the preference. This finding implied that reasoning about others' preference for a type of objects may be challenging for infants at this age. Past research has shown that infants' own experience with intentional actions affects their reasoning of intentional actions in others (e.g., Sommerville, Hildebrand, & Crane, 2008). Experiment 2 examined whether self-experience of making a choice would facilitate 11-month-olds' reasoning about others' preference. Prior to familiarization, a new group of 11-month-olds completed an action task in which they had an opportunity to choose an object from two identical objects or from two objects that differed in color. Next they saw three examples of the experimenter's choosing tall over short objects. Infants who made a choice in the action task looked significantly longer at the new-choice than the old-choice test event, whether they had a pair of different objects ($p = .007$) or identical objects ($p = .008$) to choose from. In contrast, infants who did not make a clear choice (i.e., switching choices, choosing neither, or choosing both objects) looked about equally at the two test events ($p = .71$). The benefits of self-experience were not contingent to whether the two objects were different or not; as long as

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infants made a choice in the action task, they were more likely to detect others' preference in the subsequent task. Together, the present results showed that doubling the amount of observation had little impact on 11-month-olds' success in detecting others' preference for a type of objects. In contrast, self-experience of making one choice was sufficient to potentiate the reasoning process, making preference detection at the abstract level a less daunting task for infants.

S28.3: 8-month-olds attribute, and expect others to attribute, strong preferences to agents

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Prior research indicates that infants attribute preferences for particular objects or activities to agents. For example, if an agent repeatedly chooses a doll over a truck, infants attribute to the agent a preference for the doll. If the toys' locations are switched, infants expect the agent to continue acting on her preference and to reach for the doll in its new location. The present research built on these findings and asked two questions. First, how strong or general are the preferences that young infants attribute to agents? After seeing that an agent prefers toy-A over toy-B, would infants expect the agent to also prefer toy-A over an entirely new toy, toy-C? Second, would young infants expect a bystander who witnessed the agent's actions to form the same expectation about the agent? In Experiment 1, 8-month-olds received four familiarization trials and four test trials. In the familiarization trials, a female agent, E1, reached consistently for toy-A over toy-B (e.g., a toy fish over a truck). Next, the toys' positions were switched, and toy-B was replaced by a toy from a new category, toy-C (e.g., a toy apple). In the test trials, E1 reached either for toy-A (old-object event) or toy-C (new-object event). Infants looked reliably longer at the new-object than the old-object event, suggesting that they attributed to E1 a strong preference for toy-A: they expected this preference to be maintained even when an entirely new toy was introduced. This effect was eliminated when toy-A was the only toy present in the familiarization trials: infants could then no longer gauge E1's disposition toward toy-A (did she reach for it because she liked it or because it was the only toy present?), and they looked equally at the two test events. In Experiment 2, 8-month-olds were tested using a similar procedure, with two exceptions. First, another agent, E2, was also present in the familiarization trials and watched E1's actions. In the test trials, a barrier blocked part of E1's window, preventing her from accessing the toys. E1 tried in vein to reach for the toys. She looked at E2, who then grasped either toy-A (old-object event) or toy-C (new-object event) and held it up to E1 for her inspection. Infants looked reliably longer at the new-object than the old-object event, suggesting that they expected E2 to attribute to E1 a strong preference for toy-A, just as they did themselves. As in Experiment 1, this effect was eliminated when toy-A was the only toy present in the familiarization

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trials or when E2 was absent in the familiarization trials. In sum, 8-month-olds who see an agent repeatedly choose toy-A over toy-B attribute to the agent a strong preference for toy-A: they expect this preference to be maintained even when new toys are introduced. Moreover, infants expect a bystander who watches the agent's actions to make the same attribution.

S28.4: 20-month-old infants' attribution of behavioral dispositions to agents

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Infants attribute to agents positive dispositions for categories of objects, colors, and object-directed actions. Can infants attribute to agents dispositions to behave in particular ways in social situations - to be friendly, mean, etc? Although infants are attentive to prosocial and antisocial behaviors early in development (Hamlin et al., 2011), direct tests of this question have found mixed results. For instance, 17-month-old infants who saw an agent steal another agent's toy anticipated she would steal again but infants who saw her give a toy also anticipated she would later steal, making it unclear whether infants expected consistent behavior (Koch et al., 2015). Here we sought to clarify whether 20-month-old infants attribute stable behavioral dispositions to agents and, if so, whether they generalize these dispositions across contexts? Infants were randomly assigned to one of four combinations of familiarization-valence (prosocial, antisocial) and test-condition (same-context, different-context) and tested in a violation-of-expectation task. All infants first received three familiarization trials in which two agents sat a table with Legos between them (Fig-1). Agent-B stacked four Legos of the same color while Agent-A made a multi-colored stack. In each trial, Agent-B then sought another Lego of the same color. In the prosocial-valence version, Agent-A assisted Agent-B each time by pointing out a Lego for her (trial-1), moving a Lego within her reach (trial-2), or helping her open a container to retrieve a Lego (trial-3). In contrast, in the antisocial-valence version Agent-A snatched the Lego before Agent-B located it (trial-1), moved the Lego out of Agent-B's reach (trial-2), or slammed the container shut (trial-3). Infants thus saw Agent-A either behave antisocially three times or prosocially three times. Infants then received two test trials that differed across conditions. In the same-context condition, Agent-A and Agent-B again played with Legos. Agent-B reached for a block but accidentally knocked it off the table (Fig-2). Agent-A retrieved the block and either handed it to Agent-B (prosocial event) or kept it for herself (antisocial event; order counterbalanced). In the different-context condition, Agent-A and B again sat at a table but no Legos were present. Agent-B rolled a ball to Agent-A and then gestured for Agent-A to return it. Agent-A either rolled the ball back to Agent-B (prosocial event) or aggressively hid the ball in her lap under the table (antisocial event). Each test trial was categorized as either consistent or inconsistent with the valence of Agent-A's actions in the familiarization trials. In the

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same-context condition, infants looked significantly longer at the inconsistent (M = 14.2, SE = 1.8) than the consistent event (M = 9.0, SE = 2.0), F(1, 22) = 4.23, p = .05. In contrast, infants in the different-context condition looked significantly longer at the consistent (M = 16.6, SE = 2.0) than the inconsistent event (M = 10.3, SE = 1.8), F(1, 22) = 5.87, p = .024. These results suggest that infants attribute behavioral dispositions to agents and expect them to be consistent within a given context, but they do not yet generalize this expectation across social contexts.

S29: Integrating computational and neuroimaging methods to investigate infant cognitive development

S29.1: Decoding representations of familiar objects in young infants using fNIRS

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Uncovering object representations in infancy is necessary to understand the organization and limits of mental representations early in life, and how these representations change with development and across populations. However, measuring the representation of multiple objects within a single infant is very difficult and substantially limits investigations in this area. Most methods to date have relied on habituation and other looking time measures to make inferences about small numbers of objects and at the group level rather than for a single infant. We describe how the combination of fNIRS and computational methods (decoding and representation similarity analysis) will substantially increase our ability to quantify object representations in individual infants. We summarize recent advances using this approach and present the progress of an ongoing, large-scale, multi-site data collection effort. Several recent findings have established the potential of using fNIRS and computational methods to uncover object representations with young infants (Figure 1). Emberson, Zinszer, Raizada and Aslin (2017) successfully applied machine-learning methods to extract patterns of activity in multi-channel fNIRS recordings of 6-month-old infants. Two different audiovisual stimuli were reliably decoded in the absence of univariate magnitude differences in any region of interest. Reuter, Robertson, Lew-Williams, Zinszer and Emberson (in prep) have extended these findings to decode 4 familiar objects paired with early learned words in infants (15-18 month olds: cookie, shoe, ball, cup) and are using these neural signatures to determine whether infants activate these representations

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during sentence comprehension even when these specific words are not spoken. Zinszer, Bayet, Emberson, Raizada, and Aslin (2018) found that, in adults, fNIRS could be used to decode 8 familiar objects (e.g., kitty, foot) and uncover these objects' representational structure through a representational similarity analysis (RSA). Building on these findings, an ongoing, pre-registered multi-site, large-scale data collection project is substantially expanding the methodological boundaries of decoding object representations in infancy using 74 fNIRS channels. Over 4-5 sessions, infants (8-10 months) will view 8 familiar objects (animate: baby, hand, dog, cat; inanimate: bottle, book, spoon, shoe). Each object is instantiated by two exemplars presented in different view-points (Figure 2). Objects were chosen to be highly familiar to young infants based on previous empirical findings, parental report, and headcam analyses of infant visual experience. Stimuli were normed for their low-level visual properties (e.g., brightness, colorfulness) using computer-vision algorithms and human reports. This project will overcome many of the limitations faced by previous work including allowing us to determine whether larger numbers of objects (8 vs. 4) can be decoded and mapped representationally in young infants and establishing measures of representations for each infant (vs. at the group level). The convergence of fNIRS and computational methods has proven to be a powerful approach to uncovering object representations in young infants. Ongoing work is substantially expanding this approach methodologically. In the near future, the combination of fNIRS and computational methods hold the promise of answering fundamental developmental questions regarding object representations in infancy.

S29.2: Time-course and properties of higher-order visual representations in the infant brain

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Neural representations of visual objects are robustly organized in the adult visual brain along domains and categories (e.g. animal versus human body), supporting quick and efficient identification of visual objects. The infant visual brain exhibits some functional specificity to object domains such as faces. However, whether the specificity of high-level visual activations early in life is sufficient to support robust, fast, category-specific representations of visual objects and kinds is currently unknown. To address this question, we used time-resolved multivariate pattern analysis (MVPA) of electro-encephalography (EEG) data to probe the timing of neural representations of animate visual images in 12-15-month-old toddlers. A group of 12-15-month-olds (N=22) watched pictures of animals (cat, dog, bunny,

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teddy) or parts of the human body (hand, foot, mouth, nose), while EEG data were recorded at 1000Hz from 128-channels (EGI). Stimuli were presented in random order for 500 ms with a jittered ITI of 1-1.5 s. A subsample (N=10) contributed 80 valid trials or more out of 160, providing sufficient data for within-subject MVPA. EEG data from a group of adults (N=8), recorded from 32-channels (BrainVision), was obtained to validate the paradigm and form a basis of comparison. Linear SVMs classified trials across pairs of visual stimuli (e.g., cat vs. dog) at each time-point within-subject with 4-fold cross-validation. Within-subject classification accuracy rose above chance level in toddlers (Fig. 1AC) and adults (Fig.1DF), demonstrating that neural representations significantly support the pairwise discrimination of visual images in both age groups. Neural representations were significantly maintained over time in adults (Fig. 1E), and marginally so in toddlers (Fig. 1B). Classification accuracies were higher when classifying trials across pairs of images belonging to different (e.g. dog vs. hand) rather than the same (e.g. nose vs. hand) domain category in adults, replicating earlier findings (Fig. 1D); no such effect was evident in toddlers (Fig. 1A) suggesting that neural representations did not robustly support linearly discriminating these domain categories within the first 500 ms of processing in this age group. Neural representations in toddlers may be organized differently than in adults. Pairwise classification accuracies were averaged to form group Representational Dissimilarity Matrices (group-RDMs), representing how similar or different stimuli were to one another on average. We first asked how reliably these group-RDMs could be estimated in our dataset (split-half noise ceiling; Fig. 2A, diagonal values); next, we examined how similar these group-RDMs were to one another (Pearson's correlations; Fig. 2A, lower-triangle value). All p-values were FDR corrected. All adult group-RDMs and one toddler group-RDM exhibited above-chance reliability. Group-RDMs were similar between two later time-windows in toddlers and adults, but not between these two age groups (Fig.2A & inset). We next tested whether group-RDMs were similar to those predicted by two existing computational models of vision or a control index of low-level image similarity; none of the group-model similarities were significant after FDR correction (Fig. 2B). Taken together, these findings highlight the scientific promise and technical challenges of integrating computational tools with electrophysiology to probe neural representations in preverbal infants.

S29.3: Deep neural networks as a model of learning during the helpless period of infancy

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Humans are helpless for a long time during infancy, compared with many other species. The classic explanations for this attribute the helpless period to brain immaturity. For example, the "obstetrical dilemma" theory notes that because

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humans walk upright on two legs, this places a limit on the size of the pelvis, and so on the birth canal. When combined with the large size of the human brain, the theory argues that we must be born early, while our brains are immature, leading to a delay in the emergence of behaviour. I will present neuroimaging data that counters these classic explanations. Rather than being immature, we have found that even higher-order brain systems such as the frontoparietal network underlying executive control are functioning in the first months after birth. I will present converging evidence from ethology, which is also inconsistent with the classic explanations. Instead, I highlight a neuroconstructivist explanation for helplessness, that our complex brains require an extended period of experience-driven development before behaviour can emerge. According to this view, a cognitive function does not just "switch on" as its brain substrate matures; rather it will develop from some basic innate building blocks through experience with the environment. A challenge posed by this perspective is how to conceptualise this gradual development of cognitive functions. How do we begin to imagine what the precursors of any given cognitive function are? Many concepts in cognitive science still follow their origins in folk psychology or intuition, but this method is ill-suited for insight into the minds of young infants, where we do not have a sense of the phenomenology. We propose therefore that it will be necessary to develop computational models of the development of cognitive functions. I propose that deep neural networks (DNNs) provide a framework for modelling infant learning. The last decade has seen rapid development in artificial intelligence, driven by deep neural networks (DNNs). DNNs have proven surprisingly effective as a model of the brain, and in some systems, such as the ventral visual stream, are the best predictors of neural activity to a novel stimulus. Given the success of DNNs in emulating adult behaviour and brain representations, DNNs are promising candidates as models of infant development. I will describe three modelling projects from my group that aim to shed light on why human infants are helpless for so long and to make testable predictions for the development of brain and behaviour.

S29.4: Adult-grade cognitive neuroscience in infants

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(1)Yale University

The study of infant cognition is a story about dependent measures. The inability of infants to understand or follow instructions restricts which tasks are possible. Their inability to speak or control fine movements restricts behavioral outputs. As a result, infant cognition has relied heavily on indirect measures such as looking time. The study of adult cognition is not shackled in this way, with access to the full complement of human tasks and behaviors. Yet, even in this best-case scenario, behavior has not proven sufficient to fully understand the mind. Behavior is the

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output of a complex brain that employs diverse representations, over multiple stages of processing, along competitive pathways. Such was the promise of functional magnetic resonance imaging (fMRI), to unpack the mind into building blocks in the brain. Early days of fMRI focused on mapping components of cognition onto different brain regions. This localization approach assumed a one-to-one mapping, that brain regions could be treated as modules subserving specific functions. The last 15 years of fMRI have pursued a different theoretical agenda. Rather than being localized, the mind arises from the coordination of distributed representations across networks of interacting brain regions. Linking mind and brain in this way requires a new statistical language, built on computational models, machine learning, and graph theory. Such analysis approaches can identify computational principles of how the mind works and extract the information contents of the mind. These techniques have caused a revolution in adult cognitive neuroscience. However, given the challenges above in infant cognition, they hold potentially greater value for understanding the pre-verbal mind. If applied to infants, it might eventually be possible to infer how they perceive and attend to the world, what they learn and remember, and even how they think. The key bottleneck has been the difficulty of obtaining fMRI data from infants while they are awake, performing tasks, and having their behavior monitored. In this talk, we will describe our work over the past five years to re-imagine the scanning environment and acquisition protocols for infants. These efforts have culminated in a robust system for large-scale infant fMRI data collection, with over 150 sessions completed from more than 60 unique participants, resulting in almost 1000 minutes of usable functional data and over 250 anatomical scans. We retain the majority of our functional data after motion and other exclusions, and on average obtain one experiment's worth of fMRI data per scheduled session. We will present examples of what can be learned by coupling infant fMRI with classic and cutting-edge analyses from adult cognitive neuroscience. These projects include using retinotopy to understand the organization of the infant visual system, using functional alignment to project adult cognition into the developing brain, using hidden Markov models to infer how infants segment events, and using deep neural networks to characterize the selectivity and tuning of infant visual representations. Our hope is that these findings serve as a proof of concept for the potential of adult-grade fMRI to enable new progress in infant cognition.

S30: The reciprocal roles of parents and children in organizing learning opportunities in dyadic interaction

S30.1: Are you like me? Contingent adult-infant interactions in a naturalistic dual-EEG paradigm

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Miriam Langeloh(1), Christine Michel(1), Daniel Matthes(1), Stefanie Hoehl(2)

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Infants prefer contingent interactions. This preference is indicated by behavioral (more smiling and testing behavior) and neuronal responses (reduced mu power) towards contingently imitating adults compared to non-contingent, non-imitating adults (Agnetta & Rochat, 2004; Reid et al., 2011). Recent research has started considering reciprocal influences and dynamic exchanges within dyads: In adults, imitation is associated with increased brain-to-brain coupling in the mu frequency (Dumas et al., 2010). Brain-to-brain coupling might be one mechanism underlying behavioral attunement in adult-infant-dyads. Here, we established a dual-EEG procedure to measure 16-month-old infants´ (N=29, Mage=16 months 19 days, 14 girls) and female adult experimenters´ (N=5) brain activities simultaneously during social interactions (Figure 1A). In a within-subjects design, experimenters either contingently imitated infants´ actions (contingent imitation condition), performed different actions (contingent other action condition), played with the infants in a natural way (warm-up phase) or observed a non-biological movement without social interaction (EEG baseline; see Figure 1B). On a behavioral level, we expected infants to smile more at and show more testing behavior in response to a contingently imitating adult experimenter. On a neural level, we expected stronger reduction in mu power (6-9 Hz) in infants´ brains as well as increased brain-to-brain coupling between adults and infants during contingent imitation compared to contingent other actions and a non-social baseline. Behavioral results revealed that infants smiled more at the experimenter during the contingent imitation compared to the contingent other action condition, $t(28)=3.05$, $p=.005$. This indicates that infants perceive contingent imitation in social interactions as rewarding. Furthermore, infants performed more testing behavior in the contingent imitation condition, suggesting that they recognized the functional link between their own and others´ actions, $Z=-4.37$, $p<.001$. Whenever infants were not imitated, they actively took the opportunity and imitated the adults´ actions themselves. Infants were more likely to imitate adult experimenters in the other action condition, $t(28)=5.90$, $p<.001$, and in the warm-up phase, $t(28)=5.82$, $p<.001$, compared to the contingent imitation condition. Analysis of infants´ mu power across fronto-central channels (F3,F4,C3,C4) demonstrated a significant main effect of condition, $F(1.12,31.29)=7.06$, $p=.010$. Unexpectedly, post-hoc comparisons revealed that infants´ brains responded with stronger reduction in mu power towards contingent other actions compared to contingent imitation, $t(28)=2.96$, $p=.006$. Thus, the match between own and another person´s actions did not influence mu power beyond being engaged in a temporally contingent interaction. This effect cannot be explained by low-level differences in movement, measured by brightness-pixel-changes within the scenario, $t(28)=6.11$, $p=.948$. Preliminary results indicate that brain-to-brain coupling in the mu frequency across central channels (C3,C4) did not

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differ between conditions. Further analyses will test whether the amount of imitation is related to brain-to-brain coupling on the dyadic level. Together, our results show that 16-month-olds enjoy being imitated by adults and that their brains require less activation to process interactions involving contingent imitation.

S30.2: The development of prelinguistic vocal sequences: implications for early communication and language

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What is the function of babbling in infants' language learning? Recent findings suggest that infants' immature vocalizations elicit contingent speech from caregivers which is simplified in its linguistic structure (The Authors, 2019). The contributions of parental speech are well established; individual differences in the number of words in infants' ambient language environment predict infants' communicative development (Newman, Rowe, & Ratner, 2016). At present, it is unknown whether caregiver speech elicited by infant babble changes in statistical structure over the course of infants' development. The present research investigates the statistical structure of parental speech that is contingent on babbling. We longitudinally compare parents' speech to 5- and 10-month-old infants to examine whether babbling elicits different structural patterns in parents' infant-directed speech as a function of age. Fifteen parent-infant dyads participated when infants were 5 (M infant age = 5.30mo) and 10 months of age (M infant age = 10.02mo). Dyads engaged in 15-minute unstructured free-play sessions. Parents were asked to play like they normally would at home. Recordings of infants' vocalizations and parents' speech during free-play were obtained. Parents' speech during play was transcribed in full. Utterances from parents were categorized as contingent if they occurred within 2 seconds after infants' vocalizations; all other parent utterances were categorized as non-contingent. We found that parents simplified their speech in response to babbling compared to non-contingent speech (Figure 1A; 1B). During play sessions with both 5- and 10-month-olds, contingent parental speech was less lexically diverse and shorter in utterance length than non-contingent speech. Contingent speech also contained a higher proportion of single-word utterances than non-contingent speech when infants were 5 and 10 months of age. Our data also suggest that parents may incrementally introduce more complex speech to infants as they develop. The degree to which parents' contingent and non-contingent talk differed in the number of unique words decreased over developmental time. Differences in the degree to which parents' contingent and non-contingent utterances contain only a single word trended towards decreasing over development. Future analyses will examine the degree to which 5-month-old infants expect their babbling to elicit a caregiver response. We will analyze whether infants' strength of expectation for babbling to change their parent's behavior is

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related to the statistical structure of parents' contingent speech. Our findings suggest that infants' babbling may function to elicit changes in the structure of parents' speech which in turn may facilitate infant communicative development. The higher proportion of single-word utterances in contingent speech may benefit infants. Single-word utterances simplify the task of finding word boundaries, facilitating statistical learning (Lew-Williams, Pelucchi & Saffran, 2011). In addition, the tendency for repetition of words in contingent speech may facilitate infants' mapping of seen objects to heard words (Schwab & Lew-Williams, 2016). By vocalizing, infants catalyze the production of simplified, more easily learnable language from caregivers. Parents may scaffold infants' early language and communicative development by incrementally reducing the difference between contingent and non-contingent speech.

S30.3: Toddler vocalizations shape the structure of parent-child interactions

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(1)Indiana University

Young children play an active role in shaping the multimodal dynamics of parent-child interactions. One effective way to do so is through vocalization (e.g., Elmlinger, Schwade, & Goldstein, 2019). Previous research on child vocalizations has focused on young infants under 12 months of age and little is known about the potential effects of vocalization in the second year of life. Here we examined three specific hypotheses on how toddler vocalizations may shape the structure of parent-child interactions to create rich opportunities for early learning: 1) on the parent side - changing the content of parent speech; 2) on the child side - supporting tight hand-eye coordination between toddlers' visual attention and manual action; and 3) on the dyadic side - supporting joint attention between toddlers and their parents. 31 12-to-24-month-old toddlers and their parents played with 24 toys for an average of 7min, while wearing head-mounted eye trackers. A suite of fine-grained behaviors from the toddlers and their parents were measured, including momentary gaze direction, manual action on objects, parent speech, and toddler vocalization. Hand-Eye coordination was measured as when the toddler was attending to an object held by their own hands. Joint attention was defined as the parent and child attending to the same object at the same time (Figure 1). Parent speech. Parent utterances were categorized as contingent speech (CS) if they began within 2s of a vocalization or non-contingent (NC) otherwise. For each parent's CS and NC utterances, both the total number of words spoken across the experiment (tokens) and the number of unique words used (types) were calculated. A comparison between the CS and NC utterances showed that parents produced more NC utterances overall - resulting in a higher number of both tokens and types in NC speech (CS tokens=152.74, NC tokens=438.32; CS types=68.42, NC types=134.39). Type/Token ratios were calculated to capture the quality of linguistic

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input. The higher ratio in CS utterances (CS mean=0.55, NC mean=0.34; p<0.001) suggests that vocalizations elicit less repetitive and more lexically diverse speech, which is more prototypical of child-directed speech used in toddler's second year of life. Hand-Eye (H-E) Coordination. H-E coordination instances co-occurring with a vocalization lasted longer than H-E instances that did not (With mean=4.00s, Without mean=2.20s; p<0.001). Further, the duration of H-E coordination after the onset of a vocalization was longer than the duration before, suggesting that vocalizations affected the toddler's own behaviors by extending toddler hand-eye coordination (Figure 2) which has been shown to be critical for early learning. Joint Attention (JA). Vocalizations also shape dyadic interaction, extending the duration of joint attention between toddlers and their parents. JA co-occurring with vocalizations lasted longer than JA without (With mean=4.21s, Without mean=2.30s; p<0.001). In summary, toddler vocalizations have real-time multimodal effects on the structure of parent-child interactions. Vocalizations elicit more diverse speech from parents, extend hand-eye coordination within a toddler and joint attention between a toddler and the parent, suggesting multiple pathways through which toddlers actively shape social interactions to create rich opportunities for learning.

S30.4: Do maternal vocalizations scaffold children to take up an active role in peekaboo routine?

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What drives infants to become active participants in an interaction? One possibility is that it is the structure of a routine that infants increasingly recognize and learn to regulate their behavior accordingly. Another possibility is that caregivers' actions guide them along the structure. The first possibility was proposed in Nomikou et al. (2017), who found that infants at the age of 4 months vocalized significantly more or less often during specific phases rather than their vocalizations being evenly distributed across the whole interaction. More specifically the authors found that infants vocalized more before and after being covered and uncovered and less during transitional phases of the peek a boo game. This modulation of vocalization was interpreted in terms of infants' early agentivity. Against this background, in this study, we tested the other possibility, i.e., that infants' vocalizations occur during specific phases, because through contingent vocal behavior, their caregivers guide them to it. For our purpose, we performed new analyses on the data of the same sample as Nomikou et al (2017). 18 Polish mother-infant dyads were filmed playing peekaboo when the infants were 4 months of age. We coded the entire routine into six phases reflecting the structure of the routine. The occurrence of mothers' and infants' vocalizations within these phases served as our independent variables in analyzing infants' participation in the interaction. Our results revealed correlations

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between caregivers' and infants' number of vocalizations within the individual phases of the peekaboo game: Preparation r = .720 , n = 17 , p = .001; Cover r = .552 , n = 16 , p = .027 ; Waiting r = .546 , n = 18 , p = .0190 ; Uncover r = .606 , n = 17 , p = .010 Acknowledgment r = .857 , n = 19 , p □ .001 ; Topic Change r = .738 , n = 17 , p = .001. This provides evidence for the second possibility outlined above according to which infants become active participants in a routine through responding to their mothers, who, in turn, vocalize more in specific phases and thus eliciting responses of their infants (see also Goldstein & Schwade, 2008). This way, caregivers might scaffold their infants into perception of particular phases that are more appropriate for taking turns than others, thus shaping infants' agentivity in routines/ interaction. In future research, we aim to analyze the guiding role (whether the mother or the child is leading) in these interactions. Goldstein, M. H., & Schwade, J. A. (2008). Social feedback to infants' babbling facilitates rapid phonological learning. Psychological Science, 19(5), 515-523. Nomikou, I., Leonardi, G., Radkowska, A., Rączaszek-Leonardi, J., & Rohlfing, K. J. (2017). Taking up an active role: emerging participation in early mother-infant interaction during peekaboo routines. Frontiers in Psychology, 8, 1656.

S31: Fine-grained environmental data illuminate the process of language learning

S31.1: How learning word-forms could guide infants to phonetic categories: New evidence from English

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The conventional explanation of how infants learn speech sound categories holds that infants project speech sounds into an innate multidimensional phonetic space, and cluster together same-category sounds using innate distributional learning abilities. This account is supported by laboratory demonstrations of very rapid stimulus-driven category attunement, showing an in-principle capacity for auditory distributional learning (e.g., Maye et al.). For infants to learn that a set of sounds comes from two different categories on this account of distributional learning, the categories should present a bimodal distribution in phonetic space. Yet most attempts to find bimodally distributed phones in real infant-directed speech have failed (work by Bion, Cristia, Feldman, Swingley, and others). Instead, spoken tokens of speech sounds describe overlapping categories, foiling correct separation by distributions alone. Some researchers (e.g., Feldman, Swingley, Thiessen, Yeung & Werker) have suggested that the phonetic forms of words could guide infants to better categorization. For example, infants uncertain whether /l/ and /i/ differ

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phonologically might detect that /i/ occurs in the context "cheese" but there's no "chizz"; that /I/ occurs in "chin" but there's no "cheen". This could guide infants' learning even before they know many word meanings. Here, we implemented a word-form-supplemented distributional learning model on speech samples from running English conversation. Starting from two hand-annotated moms' speech from the Brent corpus of infant-directed speech, and four women from the Buckeye corpus of adult-directed speech, we measured formant values for about 35,000 vowels. Clustering algorithms were applied over tokens for each speaker, modeling traditional token-based category-finding. The alternative word-based model started from frequent word-forms infants might infer given very limited knowledge of vowels. Median formant values over these hypothesized protolexical items were entered into clustering algorithms, modeling the idea that infants learn phonetics from types rather than tokens. For both infant-directed speech and adult-directed speech, type-based learning, though imperfect, was superior to token-based learning (see Figure), replicating similar results over a smaller Spanish sample (Swingley & Alarcon, 2018). Subsequent analyses compared infant-directed and adult-directed speech in the impact of exaggerated prosodic focus, and examined quantitatively the clarifying effect of semantic knowledge in distinguishing minimal pairs. The results suggest that it is unlikely that infants can discover their language's vowels purely from "bottom-up" distributions over all experienced tokens. However, given that infants start learning word-forms at least as early as they show evidence of native-language phonetic tuning, they might use these word-forms to guide phonetic learning, and if so, this heuristic would lead to more accurate categorization. This result suggests that prior correlational results showing links between vocabulary size and phonetic categorization may run in both directions causally: categorization of sounds helps in learning words, but learning words also helps categorize sounds in infancy.

S31.2: The food for thought: Unpacking the everyday language experiences of infants

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Typically, researchers of infant language development design studies that involve pre-specified stimuli and procedures--the objects for play, the setting for testing, the placement of infant and adult, the timing of sessions, and (sometimes) the precise sounds and words directed to infants. The rigor and value of controlled experiments remain fundamental to advancing science. Yet, an exciting, complementary approach to infant language learning delves deeply into the weeds of the input: What words and phrases comprise infant language experiences at home; what social and contextual cues accompany everyday words and phrases; where do inputs take place; and what is the temporal structure of speech to infants?

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By understanding the natural inputs to learning--words, gestures, locations, and timing of language exchanges--researchers come many steps closer to identifying the "food for infant thought".
 In 4 studies, we describe infant language experiences in the home setting. We video-recorded 100+ first-born infants (12 to 24 months) during home routines for one to two hours, with only mother present. We transcribed speech to infants, time-locked to videos, and coded the content of language (i.e., action verbs and concrete nouns directed to infants); the behaviors that accompanied specific words (e.g., infant and mother looks, gestures, and touch of objects; infant manual and whole-body actions); the locations of inputs (e.g., rooms and places); and the infant activities that framed language (e.g., mealtime, dressing). Finally, our time-locked transcriptions allowed us to assess which words "hung together" in temporal proximity.
 Study 1 (N=40) tested the behavioral cues surrounding 3,000 "naming events" (nouns to infants), and revealed that over 90% of named objects were within view of infants; and that mothers or infants looked, touched, and/or gestured toward over 80% of named objects, offering salient behavioral cues to the referents of words. Study 2 (N=40, same sample) tested the real-time routines and locations surrounding noun and verb input. Words corresponded in highly specific ways to what infants were doing and where they were, such as body words (hands, legs), clothing items (shirt, diaper), and grooming verbs (wash, splash) occurring while infants were bathed and dressed, in the bathroom or bedroom, on a changing table, etc. Study 3 (N=32) investigated the infant actions that correspond to verb inputs. Infants were exposed to manual action verbs (push, stir) as they manipulated objects, and whole body verbs (walk, go) as they locomoted through space. Study 4 (N=91) used a similarity-based analytic approach to uncover the temporal structure of language inputs, modeling which words occurred with which other words. We found that taxonomic and functional relatedness frame word "closeness". Taxonomic closeness was seen when words within a semantic category occurred within minutes of one another, for example when food words (banana, cereal) co-occurred but were temporally distant from words for toys. Functional closeness was seen when words from different but related categories (foods, utensils, eating-verbs) hung together in time.
 In summary, naturalistic contexts contain systematic regularities in behavioral, temporal, spatial, and semantic/functional features of language, which may help infants disambiguate word meaning.

S31.3: Rethinking input: The infant's view challenges the problem of referential uncertainty in early word learning

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(1)Indiana University

The success of early word learning relies on solving the problem of referential uncertainty - selecting the correct referent of a heard name from many potential

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candidates in an everyday context. Competing accounts on early word learning begin with different assumptions about the referent uncertainty problem. By one view, referential uncertainty in the real world is rampant and therefore intractable without strong internal perceptual, cognitive, and linguistic constraints on nameable categories. By the second view, certainty rather than uncertainty characterizes the input because parents use social cues (points, gaze, etc.) to make the intended referent transparent. By the third view, the learning environment contains a mix of some more uncertainty and some less uncertainty naming events. There are many laboratory experiments and compelling results consistent with each of these alternative counts. However, there are also disagreements about the relevance of those experiments given that different underlying assumptions used to design the experiments may not match the uncertainty of everyday learning experiences. The solution to this impasse is to directly measure and quantify the uncertainty in the real-world learning environment.

 Method. We arranged a home-like environment and recruited 36 infants (M=19.3, SD=1.8) and their parents to play with a set of 24 unfamiliar toys in the environment (Figure 1A). To capture the spontaneous incidental object naming that occurs in everyday interactions, parents were not told to name the objects nor that we were interested in object name learning or language. We used head-mounted eye tracking to measure infant gaze (Figure 1B) and quantified the uncertainty by measuring the distribution of infant attention to the parent-intended referent when parents named an unfamiliar object. In a 3-sec window beginning at the onset of a parent naming event, the proportion of time that gaze was directed to the parent-intended referent was measured.

 Results. There were 1245 naming events embedded in a total of 224-min toy play. Unexpectedly, infant attention across those name events forms a bimodal distribution (Figure 2) which fits none of the previous assumptions. For much of the 3-second window after a naming event, infants either looked to the intended referent or, equally often, looked to some other object. On 82% of the naming events that fell into bin 0% (no gaze directed to the intended referent), infants spent twice as much time on a single wrong object than on the second most attended object (M=63.5%, SD=10.2%). The two extremes - looking 100% to the intended referent or 100% to competitors (and mostly to a single competitor)- accounted for 65% of all parent naming events. For the remaining 35% of naming events, infants distributed gaze to multiple objects in ways that included at least some visual attention to the intended referent.

 The data for learning first object names are co-occurrences of heard names and seen things. The infant experienced co-occurrences measured in the present study consist of many correct co-occurrences but just as many wrong pairings. The unique bimodal distribution is unexpected which clarifies and redefines the uncertainty problem in early word learning.

S31.4: Reverse engineering early language acquisition: Can machine learning help?

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Emmanuel Dupoux(1)

(1)EHESS

Machine learning models trained on large datasets have enjoyed considerable success in practical applications involving adult cognitive functions (e.g., vision, speech, language, planning) and are currently used as quantitative models for analyzing brain activity in humans and animals [1]. Can the same kind of connection happen with infant development [2]? Here, we review three recent lines of work that attempt to apply machine learning models to issues of language acquisition.
 The first line concerns early phonetic learning. Through mere immersion in a linguistic environment, infants become attuned to the phonetic categories of the surrounding language(s). Here, we look at state-of-the-art unsupervised representation learning models. This work shows that exposed to speech of a particular language, such models learn phonetic properties which mimic infant learning in native-language sound discrimination and categorization, but do so without discovering linguistically interpretable units. This suggests that infants' phonetic learning has been mischaracterized in prior research.
 The second line concerns the hypothesis that parents talk to their infants in a way that facilitates language learning. Here, we review studies applying machine learning algorithms to speech addressed to infants or adults and show that this effect is not found consistently across linguistic levels. Such facilitation is found in prosodic boundary learning, an opposite effect is found in phonetic learning, and there is virtually no measurable effect on word segmentation [3].
 The third line concerns language emergence. Contrary to most current machine learning systems, infant learners do not use a lot of training data; in some instances, they have very little data and invent a new rudimentary expressive system. We consider recent work on language emergence, where two agents create their own communication channels. We show that while some properties of human language are found quite systematically (iconicity, minimization of long distance dependencies), others (redundancy avoidance, efficiency, compositionality) require special architectures to emerge [4].
 We conclude that machine learning can help infant development research by pointing out gaps in our theorizing about early language acquisition (line 1), helping us to better characterize the language input from the learner's point of view (line 2); and vice versa, language development can point to particular properties of the learner that need to be incorporated in an artificial learning architecture to match human performance (line 3).
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S32: What can video coding tell us about infant development? Methodological examples and new results from two preterm infant cohorts

S32.1: Longitudinal assessment of social cognition in infants born preterm using eye-tracking and parent-child play

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Introduction Preterm birth is associated with cognitive impairment and social difficulties in childhood. This study draws on a well-characterised preterm cohort in whom we have previously demonstrated a group difference in attentional preference for social information, measured from multiple eye-tracking tasks in infancy. However, the same eye-tracking battery administered at 5 years old revealed no group level differences. Here, we assess whether early differences are apparent at 5 years in a more ecologically-valid context. Hypotheses We hypothesised that children born preterm would spend less time in complex engagement states than children born at term, and that this would be related to gestational age at birth. In addition, we hypothesised a correlation between social attentional preference in infancy and engagement state profile at 5 years, envisioning that children with a smaller social preference score would spend less time in more complex joint engagement states during parent-child play. Study population A cohort of 50 preterm and 50 term infants, with mean (range) gestational age at birth 29+2 (23+2 - 33+0) and 40+1 (37+0-42+0) respectively, were recruited in infancy from the Royal Infirmary of Edinburgh neonatal intensive care unit or postnatal wards, and from community groups. Methods A period of parent-child play was recorded in a specialist lab at 5 years of age and subsequently video-coded for joint engagement. The Bakeman and Adamson states of engagement scheme (1984) was used, with extensions for the purposes of this study. All infants had completed eye-tracking assessment in infancy, comprising three free-viewing social tasks of increasing complexity, from which a social attentional preference score was computed. Results 36 preterm and 31 term infants had a complete set of video-coding and eye-tracking data (Table 1). There were no statistically significant differences between children born preterm or at term in the

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percentage of time spent in the more complex coordinated states of engagement during parent-child play at 5 years of age (Table 2). In addition, there was no evidence of individual differences in joint engagement being related to gestational age. Although preterm infants demonstrated reduced social attentional profiles using eye-tracking in infancy, a lower social preference score did not correlate with a reduction in time spent in the more complex states of engagement at 5 years. Conclusion Children born preterm were observed to have equivalent profiles of complex social interaction with their parents during parent-child play compared with children born at term. Infant eye-tracking measures of social attentional preference were not reliable early identifiers of those children that had less complex social interaction in parent-child play at 5 years. The role of atypical infant social attentional preference in the development of parent child play and the broader preterm phenotype is uncertain, and the optimal method for modelling the social problems experienced by children born preterm remains a challenge.

S32.2: Frequency and type of parental gesture during parent-child play is influenced by socioeconomic status and gestational age at birth

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Preterm birth is closely associated with language impairment. This may be driven by differences in exposure to words and gestures, which are known to influence language development. Socio-economic deprivation is linked to lower language exposure, and is a risk factor for early delivery. Hypotheses: We aimed to investigate relationships between gestational age at birth, socioeconomic deprivation, and language exposure, operationalised by coding parental gesture type and frequency, as well as parental speech, during play in infancy. Study Population: 39 parent-preterm infant dyads and 46 parent-term infant dyads from the Theirworld Edinburgh Birth Cohort were studied (www.tebc.ed.ac.uk). The projected sample available for analysis at June 2020 is 100 infants equally distributed between preterm and term groups. Methods: Parents were video recorded for 10 minutes interacting with their child during play. Videos were coded for parental language and gesture count in the following categories: giving, manipulating infant, manipulating object, pointing, other. The Scottish Index of Multiple Deprivation (SIMD) was used to describe deprivation. Between group comparisons in parental gesture frequency were made using Student's t-test, and the relationship between parental gesture and SIMD was evaluated using Pearson correlation. In a sub-set of infants who have also returned for a follow-up appointment at 24 months, a one-tailed correlation will be used to investigate whether maternal communication has a positive effect on infant language outcomes (MacArthur Bates CDI). These longitudinal data are not currently sufficient for analysis, but will be available in June

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2020. Results: Mean gestational age at birth was: preterm 29.57 (26.71-31.86) weeks; term 39.28 (38.00-41.57) weeks. Parent-infant dyads were assessed at 9 months corrected (range 8-10 months) for the preterm group and 9 months (range 8-11 months) for the controls (p=0.187). Parental mean length of utterance is significantly correlated with SIMD rank in both term born (r=0.349, p=0.022) and preterm infants (r=0.435, p=0.009). SIMD quintile was also correlated with an increase in parental word types in both terms (r=0.345, p=0.024) and preterms (r=0.349, p=0.40). Additionally parents with a higher SIMD quintile also showed an increase in word tokens in both term controls (r=0.375, p=0.013) and preterms (r=0.366, p=0.031). There was no significant mean difference in frequency of any parental gesture between preterm and term groups. Collapsed we found that: Frequency of pointing gestures correlated with SIMD rank (r=0.289, p=0.10) and mean length of utterance (r=0.232, p=0.033). Conclusions: The data suggest that parental vocabulary and gesture frequency during infant play are affected by socio-economic deprivation. Given increased rates of socio-economic deprivation in preterm infants, it is important to investigate the longitudinal impact of this early language profile on outcome in our sample. Poor language outcomes in preterm infants may be largely attributable to differences in linguistic environment governed by socio-economic status.

S32.3: Reduced emotional response to the still-face paradigm in preterm infants

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Background Preterm birth has been associated with emotional dysregulation in childhood, though it is unknown at what point during development this arises. The Still-Face paradigm has been widely used in the study of infant emotional regulation and typical responses are well characterised. Objective To investigate emotional response to the still-face paradigm in preterm infants versus term born controls. Method Participants included 23 preterm and 23 term infants enrolled in the Theirworld Edinburgh Birth Cohort study (www.tebc.ed.ac.uk). The projected sample available for analysis at June 2020 is 160 infants equally distributed between preterm and term groups. Ethical approval was granted from the UK National Research Ethics Committee and all participants gave written informed consent. At 9 months of age (corrected for preterm group) infants and a care giver took part in the repeated Still-Face paradigm. The mother plays and interacts with the infant for 2 minutes, becomes still and unresponsive for 2 minutes, before resuming play for a further 2 minutes. The episodes are repeated, resulting in five episodes in total (two still-face and three play). A video recording of the interaction was coded using

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the Infant Caregiver Engagement Phases (ICEP) coding scheme (Reck, Noe, Cenciotti, Tronick, & Weinberg, 2009). The ICEP includes a set of mutually exclusive codes for infant negative and positive affect and additional codes for self-comforting behaviours. Emotional response is indicative of emotional reactivity while emotional regulation can be examined by investigating the self-regulatory behaviours employed by the infant during the paradigm. ELAN video coding software was used. Group differences in time spent in a negative engagement state overall and during "still-face" episodes were tested using Wilcoxon rank sum tests. Results Demographic characteristics are presented in Table 1. Term infants spent significantly more time in a negative affective state throughout compared to preterm infants (Mdn (IQR) 149.67 (129.31) vs 67.28(131.31), w=172, p=0.04). Term infants also spent more time in a negative affective state during the first "still-face" episode (Mdn (IQR) 13.82 (26.89) vs 0 (7.89), w=181, p = 0.05). There was no difference between term and preterm infants in time spent in a negative affective state during the second "still-face" episode (Mdn (IQR) 57.01 (70.74) vs 23.03 (49.06), w=187, p=0.09). There was no significant difference in time spent engaged in self-comforting behaviours overall (w=238, p =0.57) or during the first (w=225.5, p=0.38) or second (w=274.5, p=0.83) "still-face" episode. Conclusion Findings of reduced negative affect in the preterm group indicate atypical emotional response to the still-face paradigm in preterm infants. This suggests that difficulties with emotional regulation observed later in childhood and adolescence may arise within the first year of life. This opens up the possibility of a potential beneficial role for early intervention. Lack of group differences in self-comforting behaviours suggest comparable regulatory mechanisms in term and preterm infants. Replication with a larger sample is needed to confirm this finding.

S33: Parent-infant interaction styles in diverse populations and their impact on infant development

S33.1: Mother-infant interactions, maternal mental health and infant cognitive outcomes in The Gambia

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Introduction: Environmental risk factors can have important consequences for infant health and development in low- and middle-income countries (LMICS). Stimulating early interactions with caregivers are posited to promote improved cognitive and motor development. While these associations have been demonstrated widely in high income settings, the nature the of association between parent-infant interactions and infant development in LMICs is less well understood. The Brain Imaging for Global Health (BRIGHT) project is delivering longitudinal measures of brain and cognitive development from birth to 24 months in Gambian and UK infants. Here we examine characteristics of early mother-infant interactions, when infants are 1-month of age in The Gambia. We seek to (i) understand the early interaction styles of mothers in The Gambia, (ii) explore the association between maternal interactive characteristics and infant developmental outcomes at 12-months in The Gambia.

Method: Mother-infant interactions were assessed when infants were 1-month of age in The Gambia (N=182) using video recorded play sessions, designed to be as natural as possible. Sessions were then rated by experimenters for maternal, infant and interactive characteristics. Maternal factors focused on the level of contingency in maternal responsiveness, whereas infant scales related primarily to levels of active social engagement and overall alertness. For analyses, infants were split into two groups – those with high and low levels of active social engagement. The Mullen Scales of Early Learning (MSEL) were used to assess infant cognitive and gross motor skills at 12 months of age. The association between maternal contingency at 1m and infant cognitive and gross motor skills was assessed separately in the high and low socially engaged infant groups.

Results: Higher levels of maternal contingency during the play session at 1-month were associated with better infant gross motor skills at 12-months in the group of infants with lower levels of active social engagement. On the other hand, there was no significant association between maternal contingency and gross motor skills in the group of infants with high levels of social engagement. There were no associations between the maternal characteristics and infant cognitive performance in either group.

Discussion: Our findings suggest that higher levels of contingent feedback from mothers can promote better gross motor skills among infants. However, this association was specific to infants that are less active and socially engaged. This suggests that infants who are less active may need additional stimulation from caregivers and that parental input can serve as a protective factor in their motor development. Future work will assess (i) how parent infant dynamics change over infancy, (ii) how they contribute to emerging cognitive ability during the first 24-

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months of life and (iii) how specific poverty associated risk factors impact on interactions between parents and infants.

S33.2: The communication of deaf infants with hearing parents

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The development of social communicative skills during infancy paves the way for later language, and there is strong evidence that the development of these skills occurs through interaction with caregivers. Approximately 95% of deaf infants are born to parents who typically are not fluent sign language users, and who face challenges in scaffolding communicative development regardless of modality. Consequently, the majority of deaf infants tend to experience limited access to rich communicative interaction, and are at significant risk of delays in later language development. Recent research has identified specific early communicative behaviours that predict later language development; however, it is not clear whether deaf infants are delayed in these key early communicative skills. We tested whether deaf infants who were at risk of reduced access to rich communicative interaction in infancy were less likely to engage in the precise types of early communication that predict later language relative to their typically-hearing peers. Participants were 8 deaf infants with moderate-to-profound bilateral hearing loss, who had no additional needs, who were not preterm or low birth weight, whose parents were hearing, monolingual English speakers, and who had spoken English as their primary target language. A further 8 typically-hearing infants were matched to the deaf infants for age in days, gender, and SES. Infants' naturalistic communication was coded using ELAN for the frequency of use of five types of infant communication known to positively predict later language development: show gestures, give gestures, index-finger pointing, gaze-coordinated vocalizations, and early word use. Table 1 presents descriptive statistics for these communicative acts. Hearing loss had a significant negative effect on the frequency with which infants engaged in these behaviours ($b = -0.853$, 95% CI [-1.602, -0.125], $p = .01$). Findings suggest that deaf infants are at significant risk of communicative delay from infancy in the specific types of early communication known to be important for later language development. Future research should focus on early interventions to support infant-parent interaction in order to limit developmental delay. In a step towards this goal, we will briefly report on a follow-up pilot intervention study exploring the feasibility and acceptability of video materials to support parents in adapting to their child, scaffolding communicative development, and making communication accessible. Findings suggest video materials were acceptable and generally effective in promoting infant-parent interaction. Future research needs to test the effectiveness of such interventions and explore the best

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means of laying a strong social-communicative foundation for later language in deaf infants.

S33.3: Deaf mothers and their hearing infants: Social interaction, maternal sensitivity and language development

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Hearing infants with deaf mothers (HoD) have a very different experience of speech, language and communication than hearing infants with hearing mothers (HoH). Despite having full hearing, HoD infants, whose mothers use sign language as their preferred mode of communication, are likely to experience a reduced amount of auditory spoken language. Many deaf signing individuals use speech to communicate with hearing people, but the extent to which they actually 'voice' their speech and produce sound, as opposed to silently mouth, is extremely variable (Bishop & Hicks, 2005). When addressing her infant, a deaf mother may use sign and/or spoken language, though spoken utterances by deaf mothers tend to be reduced in length and frequency compared to that of hearing mothers (Woll & Kyle, 1989). On the other hand, HoD infants experience a very special case of bilingualism in which they acquire one spoken language (e.g. English) and one sign language (e.g. British Sign Language). Previous literature on language development and parent-child interaction in this population is scarce and often based on very few cases. In studies of parent-child interaction, it has been observed that dyads who are mismatched for hearing status (HoD or deaf infants of hearing mothers) are significantly less likely to be rated positively for maternal sensitivity than dyads matched for hearing status (HoH or deaf infants of deaf mothers) (Meadow-Orlans & Spencer, 1996). These findings suggest that maternal sensitivity can be disrupted when the communicative needs of the infant are different from those of the mother. In theory, these patterns of interaction could be associated with poorer language development in this population. Prior literature suggest that when compared with monolingual norms of language development, some bimodal bilingual children show deficits in phonology, comprehension, vocabulary and grammar (Schiff-Meyers 1993; Hofmann & Chilla 2015). But bimodal bilinguals achieve the early linguistic milestones in each of their languages at the same time as children learning two spoken languages (unimodal bilinguals) (Petitto, Katerelos et al., 2001; Hofmann & Chilla, 2015). This presentation aims to clarify parent-child interaction and language development in a large sample of hearing infants with deaf mothers. Videos of 28 deaf mothers and 32 hearing mothers playing with their hearing infants (4-8-month old) were coded for maternal sensitivity using CARE-Index (Crittenden, 2010). Language development measures were collected longitudinally with the Mullen Scales of Early Learning at 4-to-8-months and the English and BSL Communication Development Inventory at 14 and 24 months. HoD dyads displayed

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increased variability in dyadic synchrony, with some deaf mothers displaying increased controlling behaviour, especially in their language and vocal tone. Interestingly, HoD infants presented better receptive language skills than HoH infants at 4-to-8-months and similar English vocabulary to unimodal bilingual infants at 14 and 24 months. These findings suggest that parent-child interactions in HoD dyads may be adapted to the communicative needs of the partners and efficiently promote language development.

S33.4: Development of social attention and communication in infants of blind parents

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Infants of parents who are blind experiences unique forms of communications, because the parents' use of visual forms of communications, such as eye gaze and pointing, is different from sighted parents due to access to visual information. Our research group has investigated how sighted infants of blind parents develop visual social attention and socio-communicative behaviour, with the focus on the use of eye gaze. The results showed that infants of blind parents allocate less amount of visual attention to the information conveyed by adults' eyes than, but nonetheless shows similar overall development of social communication as, infants of sighted parents. Our study also revealed unique characteristics of cognitive and communicative development in infants of blind parents, suggesting that they are developing in a 'non-verbal bi-communicative' environment, in which infants switch between two distinct forms of non-verbal communication between blind parents and sighted adults. Need for further comparisons with infants developing in multilingual environment will be discussed.

S34: Parent-infant interactions and language development in infants with communication disorders

S34.1: The effects of hearing loss on the social feedback loop in infants with cochlear implants

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Previous theoretical and empirical work has suggested that typical language development in hearing children depends heavily on the contingency between child vocalizations and caregivers' responses to vocalizations (McGillion et al., 2017; Oller, 2000). According to the transactional model of language development, child vocalizations can elicit developmentally appropriate responses from the caregiver, which in turn leads to greater child vocal skills that subsequently receive more complex language input from the caregiver. This dynamic interplay provides a scaffold for subsequent language development (Sameroff & Chandler, 1974; Tamis-LeMonda, Kuchirko, & Song, 2014). However, this reciprocal relationship might be affected by auditory and communicative characteristics of children with hearing loss, such as early auditory deprivation, reduced audibility, and a lower rate of communication (Vohr et al., 2008). The primary objectives of this research were to determine (1) whether hearing loss affects the quantity of child vocalizations, and (2) whether the contingency between child vocalizations and adult responses differ as a function of child hearing status. To answer these questions, we collected and analyzed the microstructure of caregiver-child interaction from 184 naturalistic recordings using the Language ENvironment Analysis (LENA) system. Thirty-eight children with NH and 17 children with CIs participated in the study. Detailed information about the participants and the LENA recordings is available in Table 1. Three measures were extracted from each LENA recording: (1) the total number of child vocalizations (CV) normalized by the duration of the recordings, (2) the proportion of child vocalizations receiving adult response (adult response rate, ARR), and (3) the proportion of adult responses followed by child vocalizations (child response rate, CRR). For each measure, we fitted a mixed-effects model with Hearing status (NH, CI) and Age as the fixed factors, and Participant as a random intercept using the lmer function (Bates et al., 2015) in the R environment (R Core Team, 2014). No significant main effect of Hearing status was found for the measure of CV, $F(1,63) = .05$, $p = .824$, suggesting that children with CIs produced similar number of vocalizations as children with NH; ARR was significantly higher in the NH group than in the CI group, $F(1,59) = 8.30$, $p = 0.006$; similarly, CRR was significantly higher in the NH group than in the CI group, $F(1,61) = 6.63$, $p = 0.012$. These findings suggest that although hearing loss does not affect the quantity of child vocalizations, it affects the contingency between child vocalizations and adult responses. Reduced contingency leads to fewer iterations of the social feedback loop, reducing the number of opportunities for the children with CIs to learn from their caregivers, which may negatively impact their later language development. These findings have important clinical implications because they support a focus on promoting caregiver-child interaction in developing intervention strategies to mitigate the effects of hearing loss on child language development.

S34.2: Caregiver touch-speech communication and infant responses in 12-month-olds at high risk for autism spectrum disorder

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Background: Multimodal input facilitates attention and learning in infants. Therefore, differences in the presentation of multimodal information, as well as deficits in multi-sensory integration may impact early communicative skills. Children with autism spectrum disorder (ASD) show hyper- and/or hypo-responsiveness to single and multisensory cues in their surroundings. Since caregivers show sensitivity to their child's sensory experiences, atypical sensory responsivity in ASD may impact caregivers' use of multimodal cues during social interactions. Touch is of particular interest, since it plays a vital role in human interactions and facilitates early caregiver-infant communication. However, it remains unclear whether caregivers with infants at-risk for ASD use touch and associated speech in a different manner compared to controls. Therefore, in this study we examined the presentation of caregiver touch-only and touch+speech input to 12-month-olds at high (HRA) and low risk (LRC) for ASD, as well as infants' responsivity to touch-only and touch+speech input. Objective: To examine (1) the frequency of all caregiver touches, (2) the duration of touch that overlapped with speech and (3) the percentage of touch-only and touch+speech bouts presented to 12-month-olds at high and low risk for ASD. Exploratory analyses examined whether any differences in the presentation of touch-only and touch+speech bouts were related to infants' responsivity. Methods: Data for 58 (HRA=31, LRC=27) mother-infant dyads were selected from a larger sample obtained as a part of a longitudinal study. Dyads participated in 10-minute play sessions using identical sets of toys and were instructed to play as they would at home. Trained coders, blind to group membership, evaluated the frequency of caregiver-initiated touches to infants during play interactions along with maternal speech and infants' looking behaviors before, during, and after each touch. Results: Independent samples t-tests revealed marginal differences in the frequency of touch delivered to infants in the HRA (M=19.87, SD=9.30) and LRC (M=16.19, SD=6.36) groups, p=.08. Additionally, the duration of touch that overlapped with speech was significantly higher in the HRA (42.4%) compared to the LRC (34.6%, p=.03) group. However, infants in both the groups received a greater percentage of touch+speech bouts than touch-only bouts. Finally, HRA infants were less responsive to touch-only bouts compared to touch+speech bouts. Discussion: Infants in the HRA group received a greater percentage of touch input that overlapped with speech. A possible explanation for the greater overlap of touch with speech in the HRA group could be attributed to strategies that mothers draw from their experiences of interacting with their older child with ASD. Next, HRA infants responded less to touch-only compared to touch+speech bouts suggesting that their mothers may use more touch+speech communication in order to elicit infant responses. This reduced responsivity to

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touch-only bouts in the HRA group is consistent with past evidence suggesting hypo-responsivity to single sensory stimuli. These findings have broader implications for caregiver-infant interactions in ASD, since providing a richer multimodal input has been suggested to promote learning and attention in typical development.

S34.4: Parent-infant interactions and word-learning skills in deaf infants with cochlear implants

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The ability to associate the sound patterns of words to their referents is essential for word learning and has been found to be fragile in deaf infants even after cochlear implantation (Houston et al., 2012). Some deaf infants are able to rapidly learn associations after implantation while others have difficulty. Variability in word-learning skills is found even when accounting for differences in auditory and speech perception skills, suggesting that other mechanisms affected by early auditory experience may also play a role. One possible mechanism for why early auditory deprivation leads some infants to have difficulty associating words to referents is the quality of interactions with their parents. High-quality parent-infant interactions where reciprocal communication between parent and infant occurs frequently has been found to be associated with strong expressive language in typically developing infants (Hirsh-Pasek et al., 2015). High-quality interactions may be beneficial also for deaf infants after cochlear implantation and protective against poor development of word-referent association skills. To test this possibility, we assessed quality of parent-infant interactions using the Language ENvironment Analysis (LENA) system. Eight families were given LENA recording devices at several intervals 3 to 12 months after cochlear implantation (mean 4.6 recordings; range: 1 to 12). The devices were worn by the infants and recorded up to 16 hours of their auditory environment per recording (mean: 14.83 hours; range: 8.4 to 16 hours). LENA software was used to automatically generate an estimate of the number of conversational turns between the infant and an adult. The infants were also brought into the laboratory at several intervals 9 to 27 months after cochlear implantation to participate in a novel word-learning experiment using a variant of the Intermodal Preferential Looking Paradigm. Infants were presented with two novel objects one at a time on a television monitor. Each object was paired with a novel word that was presented in carrier sentences. After familiarization with the word-object pairings, infants' learning was tested by presenting both objects side-by-side as one of the words in carrier sentences was spoken across 16 test trials. Infants' looks to the target (i.e., named) object and non-target object were recorded and coded offline. For each trial, we calculated the duration of the longest look to the target and longest look to the non-target. Learning was operationally defined as the difference

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in mean longest look to the target and non-target. Analyses indicated no significant differences in interval after cochlear implantation on the measures of word learning and conversational turns; thus, both measures were averaged across intervals. A significant positive correlation was found between number of conversational turns per hour and performance on the word-learning task ($r = .71$, $p < .05$), which is consistent with the possibility that high-quality parent-infant interactions leads to robust word-learning skills in deaf infants after cochlear implantation. However, it is also possible that the direction of causality is in the opposite direction or that conversational turns and infants word-learning skills are mutually reinforcing. These possibilities and future directions will be discussed.

S35: Novel approaches to electroencephalogram (EEG) lateralization: Beyond traditional asymmetry

S35.1: EEG frontal asymmetry changes during emotion-eliciting tasks and parent-child interaction dynamics

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Mother-infant interactions are significant contributors to child social-emotional development and their links to brain activity are starting to be explored. Differences in hemispheric activation, important to understanding individual differences in temperament, can also be critical to parent-child interactions (Bernier, Calkins & Bell, 2016). Greater relative left activation is generally associated with approach emotions and motivation and positive affectivity, whereas greater relative right activation is liked with avoidance and negative emotionality (Fox et al., 1994). Neurophysiological responses during emotion-eliciting tasks have not been sufficiently examined, and their links with parent-child interactions largely neglected. The present study addresses this gap in research by examining associations between change in infant frontal electroencephalogram (EEG) asymmetry during positive and negative emotion-eliciting tasks relative to baseline, focusing on links with parent-child interaction factors: reciprocity/synchrony, directedness, and intensity. Mothers 6-12-month healthy infants (e.g., no medical or birth complications) participated (N=45). Parent-Child Interaction (Gartstein et al., 2018) factors were coded from play observations for reciprocity/synchrony, directedness (parent vs. child-directed), and intensity, and using 7-point Likert scale (1-7). EEG was recorded during baseline (Baby Mozart video), Laboratory Temperament Assessment Battery (Lab-TAB; Goldsmith & Rothbart, 1996) Peek-a-Boo, and the repeated Still-Face Paradigm (SFP; Haley & Stansbury, 2003; Tronick et al., 1978) at 16 left and right scalp sites, with power computed for the 6 to 9 Hz

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frequency band ("infant and child alpha"; Bell & Fox, 1994). Frontal asymmetry scores were computed by subtracting the natural log (ln) power at the left frontal (F3) site from ln power at the right frontal (F4) site to assess the differences in the 6-9 Hz alpha band (Fox, 1994). A positive frontal EEG asymmetry score (1 SD > Mean) reflects greater right frontal activation. ANCOVAs were conducted, with parent-child interaction factors as the dependent variables and Peek-a-boo/SFP asymmetry change from baseline as the predictor variables. Baseline asymmetry values were subtracted from the Peek-a-boo and 2nd SFP asymmetry scores, respectively. The resulting difference scores were dichotomized: one group with values > 0 and another group with asymmetry difference scores < 0. Infant age and sex were introduced as covariates. ANCOVA analyses showed that SFP asymmetry change score groups differed on reciprocity/synchrony [F(1, 23)=6.954, p=0.015]: infants who shifted toward greater left frontal activation experienced greater reciprocity interacting with mothers. The SFP asymmetry change score groups also differed on intensity [F(1, 23)=8.085, p=0.009], as well as directedness [F(1, 23)=5.897, p=0.023]. Mother-infant interactions among infants shifting toward greater right activation were more directive and intense, controlling for covariates. Peek-a-boo asymmetry change score groups produced trend level effects. Infants shifting to greater left activation during a mildly stressful task engaged in more synchronous/reciprocated play, whereas those shifting right were involved in more parent-directed interactions, also characterized as more intense, stimulating, and engaging. Results support the Capability Model of frontal alpha asymmetry (Coan, Allen, & McKnight, 2006).

S35.2: Individual differences in frontal asymmetry while viewing emotion faces: A capability model approach

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Research has established a link between profiles of resting electroencephalogram (EEG) activity and patterns of approach and withdrawal behaviors. Some have suggested these individual differences could be highlighted by task-related (as opposed to "resting") EEG (Coan et al., 2006). Using this approach, we sought to examine concurrent changes in frontal asymmetry while infants viewed with dynamic videos of women expressing positive and negative emotions. We employed a novel approach to assess the temporal changes in frontal asymmetry while infants viewed dynamic facial expressions. EEG was recorded while 34 7-month-olds viewed 2-second long videos of a female transitioning from a neutral expression into either a fearful grimace or a happy smile (Figure 1). Event-related alpha activity was computed over 250ms windows while the expressions unfolded and frontal asymmetry scores were calculated for each time window (Right - Left). Mothers completed the IBQ-rvsf (Putnam et al., 2014) and infants were median-split

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into high and low Negative Emotionality (NE). We hypothesized that high NE infants would show increasing right frontal activity (withdrawal) to emerging fear expressions relative to low NE. And high and low NE would show increasing left frontal (approach) to happy expressions. A 2 Emotion (Fear/Happy) x 4 Time (500-1000ms/1000-1500ms/1500-2000ms/2000-2250ms) x 2 NE Group repeated measures ANOVA revealed a significant Emotion x NE Group interaction ($F(1, 32) = 4.22$, $p = .048$, $\eta 2 = .116$) and a trend Time x NE Group linear contrast ($F(1, 32) = 3.82$, $p = .059$, $\eta 2 = .107$). The pattern of group means for fear expression showed high NE infants had right frontal activation ($M = -2.49$, $SD = 11.61$) relative to left frontal activation ($M = 2.32$, $SD = 11.61$) in the low NE infants, but the interaction was driven by greater right frontal activation to happy expressions ($M = -5.00$, $SD = 12.14$) in the low NE group (Figure 2A). The changes in frontal asymmetry over the duration of the stimuli provided partial confirmation of our hypotheses. High NE infants remained right frontal for the duration of the videos and changed to left frontal once the face disappeared; however, the low NE infants started left frontal and became increasingly right frontal even after the face disappeared (Figure 2B). Using this data analysis approach we were able to observe changes in frontal asymmetry online as the facial expression of the stimuli progressed. High NE infants showed a stable pattern of withdrawal while the expression was on the screen and shifted to approach once the social stimulus was removed. The initial approach orientation in low NE infants was expected but the increasing withdrawal may have resulted from boredom to the repetition of the stimuli in this design. Broadly, these results demonstrate unique neural responses to observing facial expressions of emotion that evolve as the stimuli change that are consistent with the capability model of individual differences and maternal reports of infant temperament. Figure 1. Example screenshots of the dynamic facial expression stimuli. Figure 2. Event-related changes in frontal asymmetry (F3/F4) for low and high negative emotional infants (A) by emotion and (B) over time.

S35.3: Predictors of level of negative affect after arm restraint at 5 months

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Early development of self-regulation involves biological processes, as well as socialization experiences (Kopp, 1989; Sameroff, 2010). Parents provide early external support for self-regulation by guiding infants in the use of attention to alleviate distress. Infants with higher attentional control are better equipped to regulate in distressing contexts by using their behavioral attention skills to distract themselves from a distressing event (Ruff & Rothbart, 1996). Attentional control can be assessed behaviorally and via measures of brain electrical activity. We observed young infants in two contexts: play with mother and mother-induced distress. We then observed the level of infant distress during presentation of a video that

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provided infants with the opportunity to use attentional skills to regulate their negative affect. Our goal was to examine maternal and infant contributors to the level of infant negative affect. Participants were 300 typically developing 5-month-old infants and their mothers. During the lab visit, infants and mothers engaged in two positive and two negative interaction tasks in standardized order, with the intent of capturing maternal interaction style during positive tasks and then using the negative interaction tasks to induce distress in the infants. Positive interaction tasks included toy play and peek-a-boo. Each lasted 2 min and we coded for maternal responsivity and maternal positive affect and averaged across tasks. Negative interaction tasks were designed to induce negative affect in infants and included mother removing a toy and mother restraining infant's arms (Lab-TAB prelocomotor version). Each task lasted 2 min or until 20 sec of hard crying. If the infant exhibited hard crying after toy removal, then arm restraint was not attempted. Most infants proceeded to the arm restraint procedure. Immediately after arm restraint, the experimenter presented a 45 sec Sesame Street video. We assessed infant attention-based regulation by coding for longest look to video and analyzing EEG frontal/parietal EEG coherence recorded during the video. We coded for level of infant negative affect during the Sesame Street video as an assessment of self-regulation after distress as our dependent variable. Prior to the lab visit, mothers completed the Infant Behavior Questionnaire-Revised. We focused on the distress to limitations scale. The six predictors (left frontal/parietal EEG coherence, right frontal/parietal EEG coherence, IBQ distress, maternal responsibility, maternal positive affect, infant attention to video) collectively accounted for 21% of the variance in infant negative affect during the video after the distress inducing tasks. IBQ distress, left hemisphere EEG coherence, and infant looking behavior contributed unique variance (see Table 1). Increased frontal-parietal EEG coherence is typically seen during effortful attention with adults, so our finding of less left hemisphere coherence associated with greater distress behaviors was not unexpected. It was also not surprising to see that shorter looks were associated with a greater level of distress, as less looking is indicative of lower levels of attentional control during distress. These data imply that maternal interaction style had little impact on the level of negative affectivity in early infancy. Perhaps 5 months is not sufficient time for mothers to affect self-regulatory behaviors.

S35.4: Infant neurophysiological patterns and temperament are linked to maternal depressive symptoms

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Infant brain electrical activity, measured via an electroencephalogram (EEG), has been used to study developmental processes and associated with individual differences in motivational outcomes (i.e., temperamental approach versus

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withdraw) as well as with social experiences and trajectories for risk. Numerous studies have shown that right frontal EEG asymmetry is a biomarker in infants of depressed mothers and these infants also show a greater tendency toward behavioral withdrawal during social interaction compared to infants of non-depressed mothers (Jones & Mize, 2016). However, shifts in the patterns of right and left hemispheric activation have been documented (Gartstein et al., 2019), and are likely aligned with alternations in socio-emotional experiences during development. Thus, a number of important questions surrounding related risk remain unanswered. The goal herein was to report on studies linking variation in infant EEG patterns, temperament, and behavioral/emotional responses with maternal depression. In two studies, EEG patterns were measured along with temperament, behavioral/emotional responding, and maternal depressive symptoms. In study 1, 189 mothers and infants were assessed at 1- and at 3-months and in study 2, 95 mothers and infants were evaluated in the lab at 6- and at 12-months. Measures of behavioral/emotional responding included dyadic interaction and social threat responses, respectively. Analyses were conducted to examine patterns of frontal to occipital region asymmetry (Ln(Right)-Ln(Left)) as well as left and right hemisphere alpha power and activation. In study 1, the findings demonstrated that infant frontal EEG asymmetry and temperament could be used to predict maternal depressive symptoms. Right frontal EEG asymmetry was related to maternal depression (more symptoms on the CES-D and EPDS); positive affect and regulation (IBQ smiling and soothing) predicted fewer depressive symptoms, together accounting for 10% of the variance. In addition, left and right hemisphere power scores also showed similar predictive ability (9.1% of the variance accounted for) but in opposite directions. Specifically, left hemisphere activation predicted lower depression scores whereas right hemisphere activation predicted greater depressive symptoms (Table 1). In study 2, findings revealed that temperament ratings and frontal EEG asymmetry predicted more infant adaptive gaze and affect toward their mother during a negative emotions task. Infants with left frontal asymmetry showed more approach-type gaze and distress when mothers attended to a social rival, with 17% of the variance explained. In addition, maternal depression was again predicted by a model with EEG power values in the expected direction, but only infant temperament scores reached significance. Infant temperament, left and right hemisphere EEG, collectively predicted 23% of the variance in maternal depressive symptoms (Table 2). Electrophysiological and behavioral patterns emerging as predictors of risk with respect to maternal depression are important, as the latter contributes significantly to infant socio-emotional development. Interventions can be expected to demonstrate greater effectiveness before behavioral patterns stabilize and while EEG patterns are likely to demonstrate higher plasticity - earlier in infancy.

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S36: Learning 'hard words': The role of conceptual representations when the tough gets tougher

S36.1: An investigation of the origins of logical quantification: Infant's (and adult's) representations of exhaustivity in collective or individual complex actions

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Universal quantifiers in natural language (e.g., "All", "Every", and "Each") can be used to express the exhaustivity of a property, relation, or action among a collection of objects (e.g., every student is drinking coffee). However, the universal quantifiers exhibit striking differences in their usage. While "Each" can only be used to describe individual actions (e.g., *Each of the wolves chased a sheep as a team / Each of the wolves chased a sheep alone), "All" can also be used to describe collective actions (e.g., All of the wolves chased a sheep as a team). Such a difference in the possible uses of quantifiers might reflect a difference in the thoughts that they express. Specifically, "Each" and "All" may express exhaustivity via two distinct logical relations (Knowlton et al., submitted). While "Each" might categorize individuals (e.g., for any individual wolf it is the case that it is a sheep-chaser), "All" might relate the members of a group or set to some predicate (e.g., without exception, the members of the group of wolfs are sheep-chasers). In order to shed light on the mental representations of the universal quantifiers and their developmental origins, we investigated adult's and infant's capacity to encode visual scenes displaying exhaustive-collective actions or exhaustive-individual actions. In Experiment1, adults were asked to describe movies in which chevron shapes were seen to "chase" moving balls (see Fig. 1). They spontaneously used the word "All" to describe movies where the chevrons all pursued a single ball together and "Each" for movies where each chevron chased its own ball. Crucially, the use of "Each", but not of "All", significantly decreased when there were more than three chasers. This suggests that "Each" piggybacked on the representation of multiple discrete individual events (within the capacity of working memory), while "All" piggybacked on the representation of a single collective event. In Experiment2, we asked if these representations are in place early in life, using visual habituation to test 10-month-olds (see Fig. 2). Infants who were habituated to the "All" movies with three chasers successfully dishabituated to the "Each" movies with three chasers, and vice versa. These findings begin to suggest that the representations of exhaustive-collective and exhaustive-individual actions that connect with natural language quantifiers are in place early in life. We are currently running a third experiment, in which infants are habituated to movies with five chevrons (beyond the capacity of working memory) that exhaustively act together or individually. At test, the chevrons perform

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the very same movements but they are no longer contingent with the balls' positions (i.e., the chevrons are targeting invisible balls). If infants attempt to quantify over the two types of 5-chevron events with computations similar to adults, we predict them to dishabituate only when habituated to collective actions (which they should represent at a single event). Such pattern of results will more strongly suggest the presence of two forms of early quantificational capacities that predate - and likely play a role in - the acquisition of natural language quantifiers.

S36.2: Spatial metaphor facilitates word learning

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Young children are excellent word learners. However, as demonstrated by the over-representation of concrete nouns in children's early lexicons, learning words that label abstract concepts is hard (Gleitman et al., 2005; Snedeker & Gletiman, 2004). One unexpected route that may help children circumvent this difficulty is metaphorical extension. Across languages, spatial words are commonly used metaphorically to describe more abstract domains, like time (long movie) or musical pitch (high note), but the reverse is relatively rare. Could this asymmetry be influenced by constraints on word learning? It is likely easier for children to learn the meaning of a word that labels a spatial attribute compared to one that labels a more fleeting attribute such as pitch. However, if a child has first learned the spatial meaning of a new word, this could help her guess the word's meaning when it is used in more abstract contexts. For example, a child could guess that a word that has labeled high (or low) spatial positions is also likely to label high (or low) pitches, on the basis of pre-existing and symmetric mental associations between pitch and space (Dolscheid et al., 2014). Therefore, children may be able to circumvent the difficulty of learning dedicated words for abstract concepts by reusing easy-to-learn spatial words in abstract contexts. To evaluate this proposal, we taught 3- to 5-year-old English-learning children (N=154) a novel adjective in the domain of space or pitch and then tested their ability to extend the adjective to the untrained dimension (Figure 1). We predicted that children would be more successful at learning the novel word when it referred to a spatial attribute compared to an auditory attribute. However, we predicted no such asymmetry with regards to extending the word to the untrained dimension. If the bottleneck stems from learning the original meaning of the word, then children who have successfully learned the novel adjective should be equally likely to extend it from space-to-sound as from sound-to-space. Additionally, to test whether cross-domain extension depends on children's experience with metaphorical language, we manipulated whether the novel adjective mapped onto a familiar English space-pitch metaphor ("high" or "low"; Height condition) or an unfamiliar metaphor ("thick" or "thin", which label space

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and pitch in Turkish and Farsi; Thickness condition). In training, children demonstrated an advantage for learning adjectives that apply to space relative to pitch, and the ability to learn adjectives for pitch improved with age. However, among children who successfully learned the novel adjectives, we found no asymmetry in cross-domain extension: children were equally proficient in extending from space to pitch and from pitch to space, and extension consistency improved with age. We also found that metaphor familiarity did not affect children's performance, meaning that children were not simply relying on their preexisting knowledge that English uses the same labels for height and pitch. These results suggest that spatial metaphor facilitates word learning by scaffolding the acquisition of abstract word meanings, and that constraints on word learning contribute to asymmetries in metaphorical language.

S36.3: Getting support for 'support': The privileging of 'Support-From-Below' in early spatial language acquisition

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Configurations of support include those that exhibit Support-From-Below (SFB, cup on table), as well as Mechanical Support (stamp on envelope). How do young children learn the spatial language that encodes such an abstract spatial relation? Do children learn about support by learning a very broad, highly abstract category - one that includes stamps on envelopes, coats on hooks, cups on tables, etc.? Much infant cognition research suggests no, with SFB playing a key role in infants' reasoning about, and categorizing, support relations. Does this 'privileging' of SFB have consequences for language learning? The current studies suggest that it does, with very young children learning both canonical expressions for encoding SFB (BE on), as well as more specialized lexical items for Mechanical Support (stick). In Study 1, using the Intermodal Preferential Looking Paradigm, 20-month-olds (N = 24) were simultaneously presented with two events: SFB (cube put on top of box) and 'support via side' (cube put on side of box), while hearing neutral language during Salience ("Look here, what do you see...") and spatial language during Test ("Find the toy that IS ON the box"). An eye-tracker measured looking durations and revealed longer looking at SFB during Test, suggesting the privileging of SFB (Figure 1). In Study 2, children (Ns =14 for 3- and 4-year-olds) were shown a messy playroom and asked to help two children find their missing toy. They then viewed 15 support configurations (5 SFB, 5 hanging, 5 adhesion; e.g., band-aide stuck to apple) and asked "If Nicholas cannot find his band-aide, you'd say 'your band-aide...". Children's responses were coded in terms of BE on use across the three support types. A mixed model logistic regression revealed that Support Type was a significant predictor of BE on, with children using BE on more for SFB (M = .75) than Adhesion (M = .66; B = -.70) and Hanging (M = .65; B = -.80). This further suggests

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the privileging of SFB. In Study 3, children (Ns =15 for 3- and 4-year-olds) were shown the same support configurations as Study 2 (5 SFB, 5 hanging, 5 adhesion) and heard two characters give different descriptions. One character (correctly) described the configuration with BE on ("I say it is on the apple", for band-aide stuck to apple) and the 2nd character either described the configuration (correctly) with a more specific verb ("I say it is stuck to the apple") or with an incorrect verb ("I say it is clipped to the apple"). Mixed model logistic regressions revealed that older children chose BE on more when it was paired with an incorrect verb (e.g., "clip") vs. when it was paired with a correct verb (e.g., "stick") (Figure 2). Thus, children map BE on to core configurations (SFB), and (correct) lexical verbs mapping to non-core, mechanical support. In sum, SFB represents the core for the category of support, and is privileged in supporting early mappings to spatial language. Our findings raise questions about other factors that may substantially contribute, such as parent input.

S37: Cultural differences in mind-mindedness and infant-mother interaction

S37.1: Cross-cultural comparison of maternal mind-mindedness among Australian and Chinese mothers of toddlers

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Introduction: A growing body of evidence suggests that parental mind-mindedness (the tendency to attribute mental states and agency to young children) is important for children's social-emotional development. An important distinction is made between appropriate maternal mind-related comments that appear to accurately reflect the child's mental states and comments judged non-attuned, as they seem at odds with the child's interests and preferences. Almost all research on mind-mindedness has been conducted in Western settings, however, consistent with an "absurdly small" cross-cultural database on parent child attachment relationships in non-western cultures (Mesman, van IJzendoorn, & Sagi-Schwartz, 2016, p. 871). We suggest cross-cultural comparisons with respect to mind-mindedness may be particularly informative in understanding culture-specific conceptualizations of the ideal child and parent-child relationship dynamics. Mind-related language directed to children emphasizes child autonomy and agency, as opposed to external social and contextual factors, which may reflect differences in emphasis on individuality vs. collectivism and group harmony between Western and Confucian cultures. Hypotheses: This paper compares mothers in Australia and mainland China with respect to mind-related comments during live interaction with toddlers. We

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hypothesized that Australian mothers would you use more mind-related comments during free-play than Chinese mothers (Mandarin speaking). We also explored differences in appropriate and non-attuned mind-related comments, but did not make directional predictions. Study Population: Participants were 50 urban Australian mothers, Mean age = 30.34 years, SD = 3.14, and their first-born infants, Mean age = 18.98 months, SD = .87; 56% girls, and 50 urban Chinese mothers and first-born infants, Mean maternal age = 29.18 years, SD = 4.14, Mean child age = 18.50 months, SD = 2.25; 60% girls. Australian mothers spoke English (native mandarin speakers were excluded) and Chinese mothers spoke Mandarin Chinese. Most (62% of Australian mothers and 58% of Chinese mothers) were tertiary educated. Methods: After approval by Ethics Committees in both countries, mothers and infants were visited at home when infants were approximately 19 months old and participated in a 15-minute videotaped free-play interaction using a set of toys provided by the researchers. They were told to "Play as you normally would with [child name]". All mothers' comments during play were transcribed verbatim from videotapes and coded for mind-mindedness, (appropriate and non-attuned comments) using the Coding Manual (Meins & Fernyhough, 2015). Results: An Ancova controlling for maternal education, showed that Australian mothers spoke more to their children, and with a higher frequency and higher proportion of appropriate mind-related comments, all ps < .001, see Table 1. Distributions for non-attuned comments were highly skewed, so we recoded this variable as categorical (no non-attuned comments vs. at least one comment). Chi-square analysis showed a significant difference in likelihood of making non-attuned comments with 58% of Chinese and 6% of Australian mothers making at least one non-attuned comment, $\chi 2$ (1, N= 100) = 31.08, p < .001. Findings, including content analysis of types of comments, are discussed in relation to cultural differences in childrearing goals, beliefs and values and the need for cross-cultural validation of mind-mindedness.

S37.2: How does culture and empathy relate to mothers' mind-mindedness?

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Background: The primary objective of this study was to explore potential determinants of mind-mindedness in mothers from two different cultures. Mind-mindedness is defined in terms of caregivers' tendency to make appropriate versus non-attuned comments on their infants' internal states (Meins et al., 2012). A growing body of empirical evidence shows that mind-mindedness predicts various positive aspects of children's development (see McMahon & Bernier, 2017, for a review), and recent evidence shows that it is possible to intervene to facilitate mind-mindedness (Larkin et al., 2019). However, research has failed to identify caregiver factors associated with higher levels of mind-mindedness. The present study aimed

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to investigate culture and dispositional empathy as potential determinants of mind-mindedness. We focused on families from the United Kingdom (UK) and South Korea (SK). South Korea is a collectivist country which highlights interdependency. Emotional relatedness, or "oneness", is emphasised between parents and children (Park & Kim, 2006). Oneness could be hypothesised to relate either to higher (due to greater attunement to the infant) or lower (due to projection of the caregiver's states onto the infant) levels of mind-mindedness. Empathy was expected to be necessary but not sufficient for mind-mindedness, so no directional hypotheses were made. Methods: Mothers (nUK=63; nSK=66) participated with their infants (UK: Mean=6.14 months, SD=1.55, SK: Mean=7.49 months, SD=1.15). Mind-mindedness was measured from a 10-minute free-play observation. Mothers' dispositional empathy was assessed using a self-report questionnaire (Reniers et al., 2011). Results: There was no significant difference in mothers' appropriate mind-related comments in the UK and Korea. However, British mothers showed more non-attuned mind-related comments than Korean mothers, $F(1, 127)=4.15$, $p<.05$. Regarding empathy, British mothers showed higher levels of cognitive empathy than Korean mothers, $F(1, 127)=9.75$, $p<.01$, but there was no group difference in affective empathy, $F(1, 127)=.29$, $p=.59$. Cognitive empathy was positively related to Korean mothers' appropriate and non-attuned mind-related comments, whereas British mothers' cognitive empathy was not related to mind-mindedness (SK: appropriate mind-related comments, $r=.40$, $p<.01$, non-attuned mind-related comments, $r=.37$, $p<.01$; UK: appropriate mind-related comments, $r=.10$, $p=.433$, non-attuned mind-related comments, $r=-.07$, $p=.572$). Conclusion: The finding that Korean mothers were less likely than their UK counterparts to comment in a non-attuned manner on their infants' internal states suggests that aspects of Korean culture such as oneness may be related to mothers' ability to avoid misinterpreting their infants' thoughts and feelings. The positive correlations in Korean mothers between cognitive empathy and mind-mindedness highlight cultural differences in whether the ability to read another's internal states in the mother-infant relationship generalises to mental perspective-taking in other contexts. The fact that cognitive empathy was positively correlated with both indices of mind-mindedness suggests that self-reported general empathy does not relate to the accuracy with which Korean mothers interpret their infants' minds. In conclusion, the findings of the present study imply that the practice of mind-mindedness may be universal, but the correlates of mind-mindedness appear to be culturally dependent.

S37.3: A cross-cultural comparison of maternal mind-mindedness and speech characteristics between Japan and the UK

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Language can powerfully augment the study of sociocultural structures and individual behaviour (e.g., Hymes, 1972). In Japanese culture, speakers depend on listeners to ascertain their intentions (Doi, 1974; Clancy, 1986). In English, however, speakers are responsible for making their intentions understood (Reddy, 1979). Moreover, a speaker's choice of pronoun and perspective reveals information about his or her level of self-other integration: while the use of singular pronouns highlights a speaker's individual identity and psychological distance from others, the use of plural pronouns highlights a speaker's sense of group belonging and psychological interconnectedness (e.g., Pennebaker, 2002). However, no study has used mothers' subject choice as a means of investigating their psychological closeness to their children or the degree of their mind-mindedness. Nor was there any cross-cultural study which compares maternal mind-mindedness directly between Japan and the West. As a first step to understanding children's cultural environments, we conducted a direct cross-cultural study to compare mind-mindedness and culturally unique speech characteristics among mothers from Japan and the UK. We hypothesised that 1) Japanese mothers would speak less and provide less information about their children; 2) the explicit and direct nature of English would enable British mothers to focus more on their children and provide more mental comments about their children; 3) with the blurred Japanese self-other boundary, Japanese mothers would choose singular subjects less frequently and adopt others' perspectives more frequently when referring to their children. The study sample included 108 mothers' speech samples (nJP = 54; nUK = 54) about their participating preschoolers (Japan: 23 boys and 31 girls; Mage = 4.37 years, SD = .35, range = 3.7- 4.9 years; UK: 24 boys and 30 girls; Mage = 4.31, SD = .45, range = 3.2 - 4.9 years), matched across countries for child age, verbal ability, gender, family structure and maternal education. The mothers gave 5-minute speech samples, which were transcribed and coded for total amount of talk, references to mental (i.e., mind-mindedness) versus non-mental states, and markers of individualistic versus collectivistic sociocultural orientation (i.e., use of singular subject and use of maternal perspective). British mothers spoke significantly more during their 5 minutes than Japanese mothers (i.e., total talk), $t(106) = 5.03$, $p < .001$. Also, British mothers provided a significantly higher proportion of child-related $t(106) = 4.71$, $p < .001$, and mental-related ($t(106) = 4.38$, $p < .001$, comments than did Japanese mothers, indicating that British mothers showed more mind-mindedness than did Japanese mothers. These contrasts remained significant even after controlling for maternal education. Although the two cultural groups did not differ significantly in the use of singular versus plural subjects, British mothers used their own perspective significantly more often than Japanese mothers ($U = 491.50$, $p < .001$, $z = 6.01$). These findings highlight cultural variations in maternal mind-mindedness, and self-other distinction.

S37.4: Cross-cultural differences in mother-infant play behaviour

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The vast majority of data underpinning our understanding of how human infants develop is collected in Western Educated Industrial Rich Democratic (WEIRD) populations. However there is now a growing acknowledgement of the need for data from more diverse populations (Nielsen et al., 2017), and cross-cultural data shows cultural influences on many aspects of parenting style (e.g. mindmindedness (this symposium), and socialisation goals (Keller et al., 2005)). It is less clear, however, how different parental values and goals influence parents' actual interactions with their infants. Play is a central aspect of mother-infant interactions and supports the development of many aspects of cognition (Burriss and Tsao, 2002). Despite its importance for infant development, we know relatively little about variation in early play behaviour across cultures and the factors that predict such variation. Our study aimed to examine (i) the frequency and type of play that infants from the UK and rural Uganda engaged in and (ii) whether any differences could be explained by variation in maternal time budgets or attitudes towards play. Our sample included 92 mother-infant dyads (UK: 53; Uganda: 39). Mothers completed a parenting-goals questionnaire and when the infants were 3m and 6m old, we conducted a full-day follow where we took scan samples of the mother and infant's activity every 30mins for 8 hours which allowed us to calculate infant and mother time-budgets. We then calculated the proportion of scan samples where the infant was engaged in any type of play (i.e., social play, object play or social object play). We found that UK infants played more often than Ugandan infants and in both populations infants played more frequently at 6m than 3m. We then examined the frequency of different types of play at 6m and found that UK infants engaged in more social play than Ugandan infants. When play partner identity was considered, UK infants engaged in more play with their mothers compared to Ugandan infants. Infants in the UK and Uganda differed in the frequency of social object play: At 6m, UK infants engaged in social object play frequently, whereas social play involving objects barely occurred in Uganda. This could not be explained by a lack of objects in the environment or a lack of interest in objects in the Ugandan infants, as there was no difference in the overall amount of object play (social and solo combined) between the two cultural groups. Given that social play and particularly social object play is likely to support the developmental shift from dyadic to triadic interactions and joint attention (Bakeman and Adamson, 1984), it is important to understand the factors that might be driving this variation in early play in our two populations. We will present statistical models examining whether maternal attitudes towards different types of play and the mother's time-budget can explain the patterns we observed. Our study demonstrates the influence cultural group can have on important mother-infant interactions such as play and highlights the need to

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investigate whether these differences in early interactions influence later development.

S38: Better safe than sorry: Infants' use of social information to reason and learn about threat

S38.1: Dangerous ground: Thirteen-month-old infants are sensitive to peril in other people's actions

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Do infants appreciate that other people's actions may fail, and that the possibility of failure endows risky actions with variable amounts of negative utility (hereafter, "peril")? Three experiments addressed this question by presenting 10- and 13-month-old infants (N=124) with an agent who chose whether or not to jump over a trench of varying depth to reach two goals. Experiments 1-2 investigated whether infants infer the value of a goal from the peril of the action undertaken to achieve it. Infants viewed an agent jump a shallow but not a medium trench to attain one goal, and jump a medium but not a deep trench to attain another goal. Then infants were tested with events in which both goals were present with no trenches and the agent approached one or the other in alternation. Thirteen-month-old infants looked longer when the agent chose the target achieved through the lower-peril actions (Mlower=24.6s, Mhigher=21.5s, 95% confidence interval (CI) over difference in log seconds [0.019,0.417], standardized beta coefficient (ß)=0.354, unstandardized coefficient (B)=0.218, standard error (SE)=0.100, p value (p)=0.037, two-tailed). In contrast, ten-month-old infants did not show a statistically significant looking preference between the test events, (Mlower=19.5s, Mhigher=19.1s, [-0.121,0.301], ß=0.168, B=0.09, SE=0.106 p=0.202, one-tailed), and the two age groups did not differ in their looking preferences ([2.798,3.203], ß=-0.288, B=-0.168, SE=0.146, p=0.253, two-tailed). Experiment 3 tested whether 10- and 13-month-old infants expect agents to minimize action peril when goals are equal in value. After infants saw an agent jump over medium-depth trenches for a goal, they saw an agent choose between two identical-looking goal objects beyond a shallow and deep trench. We found that across both age groups, infants looked longer at test when the agent chose to jump the deeper trench than when the agent chose to jump the shallower trench (Mdeeper=25.7s, Mshallower=21.0s, [0.123,0.424], ß=0.410, B=0.273, SE=0.076, p<.001, one-tailed). This preference only appeared in test trials, where infants saw agents jumping over these cliffs, and not in control trials, where infants' attention was drawn to each cliff in turn (difference in preference between test and control, [0.413,0.772], ß=0.891, B=0.592, SE=0.092,

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p<.001, two-tailed). This test versus control event difference was only reliable in 13-month-old infants. In sum, we found that by 13 months, infants expected the agent to minimize the peril of its actions, and they learned which goal the agent preferred by observing how much peril it risked to reach each goal, even though they never observed the agent fail. These findings provide evidence that infants represent peril as a variable in an integrated calculus, trading off positive rewards and negative costs.

S38.2: Social information reduces infants' avoidance of plants

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Plants have been an essential part of human diets over evolutionary time. Yet, for all their benefits, plants pose real danger to humans due to the variety of chemical (e.g., toxins) and physical defenses (e.g., thorns) they manufacture. Accordingly, recent developmental work has shown that infants exhibit a reluctance to touch plants--a behavioral avoidance strategy that is an effective way of mitigating plant dangers (Wertz, 2019). Interestingly, during the early stages of exploration, infants treat all plants as potentially dangerous, whether or not they are benign-looking or possess sharp-looking thorns. The high costs of individual trial-and-error experimentation for candidate plant food sources suggest that human food learning is likely largely achieved via cognitive design for social learning. Accordingly, there is evidence that social information plays an important role in learning about plants (Wertz, 2019). Infants look more often to adults when confronted with plants and use social information to learn about plant edibility. However, no study to date has directly examined the effect of social information on infants' plant avoidance. In the current study we examined whether infants modify their behavior when social information about plant properties is presented. To test this, 8- to 18-month-old infants (N=50) were presented with 24 stimulus objects presented one at a time in a counterbalanced order across two experimental sessions separated by a short break. The stimulus objects were plants, novel artifacts, and familiar artifacts (see Fig. 1). The stimuli presented in one of the sessions had infant-safe thorns (plants) or pointed parts (artifacts), while the stimuli presented in the other session did not. Critically, the stimuli presented in the first half of each experimental session were accompanied by social information. This social information involved an experimenter touching each stimulus object and then reacting with either delight (positive information) or pain (negative information); the type of social information (positive or negative) presented varied between subjects. Infants' latency to touch each stimulus object, as well as the frequency and duration of their subsequent touches, were coded. The results suggest that, in comparison to previous conditions in which no social information was demonstrated, the social information presented in this study reduced infants' reluctance to touch plants, but

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did not influence their reaching behavior toward the other object types ($F(3,357) = 2.79$, $p < .05$, see Fig. 2). Nevertheless, infants remained relatively more reluctant to touch plants compared to the other object types even when the additional social cues were present ($F(2,984) = 23.59$, $p < .001$ see Fig. 2). Further, infants remained more reluctant to touch the stimuli with thorns ($F(1,984) = 7.88$, $p < .01$, see Fig. 2), irrespective of social information. Surprisingly, infants did not respond differently to objects in the negative and positive social information conditions. Taken together, these results provide the first evidence that infants' plant avoidance can be reduced by social information from adults. This work demonstrates that considering the adaptive problems humans faced with respect to plants can provide new insights into the development of food cognition in infancy.

S38.3: Friend or foe? Impression formation in the human infant brain

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Forming an impression of another person based on her behavior is considered a vital building block of human social cognition as it can guide adaptive action by approaching friendly and avoiding hostile or threatening individuals. Much research with adults implicates the dorsal medial prefrontal cortex (dmPFC) in impression formation and person perception (Amodio & Frith, 2006). There also exists behavioral evidence to suggest that preverbal infants evaluate (non-human) agents' social actions and tend to approach helpful and avoid harmful agents (Hamlin, Wynn & Bloom, 2007). Yet little is known about the brain processes which underpin the early developing ability to form impressions about another human agent. The current study examined impression formation in the context of face-to-face encounters using a novel task combining functional near-infrared spectroscopy (fNIRS) and eyetracking in a sample of 11-month-old infants (N = 77). During the impression formation (learning) phase, infants viewed four different individuals (faces) expressing either happiness (social affiliation cue) or anger (social threat cue) directed at them (direct gaze) or directed away from them (averted gaze) while their brain responses in dorsal medial prefrontal cortex (dmPFC) and superior temporal cortex (STC) regions were measured. This was followed by a test phase during which infants' person preference was assessed using eyetracking (infants saw the four individuals' faces again showing direct gaze and a neutral expression). The fNIRS results revealed that only in the dmPFC, but not in the STC, there was a significant interaction between emotional expression (happy versus angry face) and gaze (direct versus averted gaze), indexing that this brain region integrates information about expression and gaze when viewing dynamic face changes. More importantly, our results show that infants' dmPFC responses during learning predicted their person preference during the test phase, Beta = .250, p =.036 (see Figure 1). Specifically, greater dmPFC responses were associated with greater preference for

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the person who previously expressed happiness and gazed directly at the infant. This suggests that mPFC is involved in impression formation in human infants, attesting to the early ontogenetic emergence of brain processes supporting person perception and social evaluation.

S38.4: Not all negative emotions are equal: Infants selectively attend to threat

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Infants are robust social learners (e.g., Carpenter et al., 2005) who may attend to and learn more from negative than positive information (Vaish et al., 2008). Do infants see all negative information as equally relevant, or are they tuned in specifically to signals of threat? Here, we investigate 16- to 20-month-olds' expectations and actions after seeing negative evaluations that are or are not threat-relevant. In Study 1, we used violation-of-expectation to examine expectations about negative emotions. Specifically, during familiarization, infants saw one model look into an opaque container and express a negative emotion (pain, fear, or anger) at the object inside. In test, a second model alternated between positively evaluating the item in that container and positively evaluating another item. If infants generalize the first model's response to the second model, they should be surprised (and look longer) when the second actor expresses positivity towards the item that was previously evaluated negatively. Indeed, in the Pain condition, infants looked longer when the second model liked the object that had caused the first actor pain ($p=.011$, one-tailed). A similar (though non-significant) trend was seen when the first model had expressed Fear ($p=.068$, one-tailed). However, infants did not generalize all negative emotions. In particular, when the first model expressed Anger towards the object (which does not convey that the object is threatening), infants were not surprised when the second model evaluated that object positively, and in fact looked marginally longer when the second actor interacted positively with the new item ($p=.050$, one-tailed). Thus, infants were more likely to generalize negative emotions towards objects when those emotions convey threat-relevant information (Figure 1). In a second study, we examined infants' own responses to negative evaluations. To do so, we showed each infant up to 8 trials in which a model reached into an opaque container and responded positively or negatively to the object inside. After each emotional expression, infants were given 20s to interact with the container and the object inside. We measured whether infants reached into the container and how long it took them to reach into the container. Infants were randomly assigned to the Anger or the Pain condition. In both conditions, the model expressed Liking in positive trials. Preliminary results indicate that although infants are generally more likely to reach into containers associated with positive (64% of trials) than negative (45% of trials) reactions, infants did not treat all negative

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reactions equally. They were more likely to reach into containers associated with Anger (65%) than with Pain (26%; Figure 2). And, whereas 89% of infants in the Anger condition reached into at least one container associated with anger, only 25% of infants in the Pain condition ever reached into a container that was associated with pain. Thus, infants respond differentially to discrete negative emotions: they are more likely to generalize threatening emotions (over negative but not threatening emotions; Study 1) and may actively avoid threatening objects (over negatively evaluate by non-threatening objects; Study 2).

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