

Where language meets attention: How contingent interactions promote learning

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ABSTRACT

Contingent interactions between caregivers and infants, in which caregivers respond promptly and meaningfully to infants' behaviors, lay a foundation for language learning. Three pathways have been proposed for how contingent interactions promote the development of language skills: temporal, semantic, and pragmatic. Here, we argue that these pathways act through a reciprocal relation between infant attention and contingent interactions. We present evidence that attention facilitates contingent interactions to help infants understand communicative intent and, in turn, contingent interactions promote attention to allow infants to better learn from the language directed to them. This new framework suggests that contingent interactions operate through domain-general skills, thereby establishing a foundation for learning more broadly.

Children around the world learn language, yet they vary in the rate and extent to which their skills develop. A surge of recent research indicates that contingent interactions between infants and caregivers offer a key ingredient for understanding these varied rates of development (Cartmill et al., 2013; Hirsh-Pasek et al., 2015; Romeo, Leonard et al., 2018). Much of the work in this area is dominated by a domain specific focus on how properties of the quantity and quality of language interactions relate to the development of language skills (Tamis-LeMonda et al., 2014; Reed et al., 2016). Here, we broaden the focus on contingency to the domain general construct of attention, a core pathway that enables contingent interactions to take place which in turn support attention development and fuel language growth.

We present the argument for our reciprocal framework in three parts. The first part reviews research on contingent interactions and language development, highlighting longitudinal studies, intervention studies, and current theoretical models. The second part presents our reciprocal framework, examining the evidence for how attention enables contingent interaction, how contingent interactions refine infant attention, and the implications of reciprocal associations for language development. The third part examines the significance of this framework for theory, science, and practice.

Contingency and language development

Contingency describes the prompt and meaningful exchange between caregiver and infant during an interaction that sets the stage

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for fluent and connected communication. For example, if an infant holds up a sock and caregiver remarks “That’s your sock. Where does your sock go?”, the response is contingent because it is prompt, occurring shortly after the infant’s action, and meaningful, relating to the infant’s behavior (Bornstein et al., 2008; Reed et al., 2016; Tamis-LeMonda et al., 2014). The caregiver’s response also functions to initiate a conversation with the infant.

How contingency is conceptualized varies across development (Reed et al., 2016). In the postnatal period, contingency focuses on synchrony, or the match between infant and caregiver affect and behavior (e.g. Feldman, 2015). Around the middle of the first year, as infants begin to more actively explore their environment, the focus on contingency assesses how the responses of caregivers correspond in real time to the behaviors of infants, such as when a caregiver follows an infant object by naming the object within a 3-sec time window (e.g. Bornstein & Tamis-LeMonda, 1989; Tamis-LeMonda et al., 2001). In the second half of the first year, infants’ social skills become more refined and they begin to engage in shared attention and proto-conversational exchanges with caregivers (e.g. Scaife & Bruner, 1975; Snow, 1977). Around age one year, infants initiate bouts of joint attention (e.g. Bates et al., 1975; Carpenter et al., 1998) and as they approach age two years, they begin to engage in fluid conversational exchanges with caregivers (e.g. Gilkerson et al., 2017; Hirsh-Pasek et al., 2015) and infuse their bouts of shared attention with symbols and communication (Adamson et al., 2004). Despite the focus on different aspects of contingency at different points in development, research converges on the association between contingent engagements and language outcomes. Here, we use the term contingency to refer broadly to these different approaches.

Contingency relates to several aspects of language development

The power of contingency in language learning is indisputable. Contingent interactions relate to a range of language learning milestones across the first two years of life (Tamis-LeMonda et al., 2001). In the first year of life, infants perform better on phoneme production and discrimination (Goldstein & Schwade, 2008; Kuhl et al., 2003) and syntactic rule learning (Ferguson & Lew-Williams, 2016) when hearing or engaging in a contingent, compared to non-contingent, exchange. In the second year, infants’ word learning is improved when engaging in a contingent versus a noncontingent interaction (Roseberry et al., 2014; Reed et al., 2017) and caregiver’s contingent responses to the infants’ bids related to vocabulary growth (Baumwell et al., 1997; Bornstein et al., 1999). Longitudinally, contingent interactions, as measured by conversational turns, in toddlerhood account for 19% to 32% of variance in language skills up to ten years later (Gilkerson et al., 2018). Engagement in frequent, high-quality of contingent exchanges show stronger associations to later language skills than does the amount of talk that infants hear (Hirsh-Pasek et al., 2015; Masek et al., 2021). In fact, the role of contingency in learning even goes beyond human interaction to on-screen virtual agents, suggesting that even when interacting with a cartoon-like character on a screen, infants learn words better from contingent exchanges (Tsuji et al., 2020).

The importance of contingent interactions extends to the classroom as well. Contingent interactions between 2- to 3-year-olds from low-socioeconomic status (SES) households and their teachers predicted growth in language skills over the course of the school year. In fact, contingency was a better predictor of language than was the amount of teacher talk children heard (Perry et al., 2018), mirroring research on caregiver-infant interactions (Hirsh-Pasek et al., 2015; Masek et al., 2021).

Research on contingency and language development is even changing the conversation around differences in language development based on SES. Contingent interactions predict language outcomes in children from a range of SES backgrounds (e.g., Gilkerson et al., 2017; Hirsh-Pasek et al., 2015; Perry et al., 2018) and contingency itself has been found to be less variable across SES than the amount of caregiver talk (Cartmill et al., 2013; Masek et al., 2021) though not in all studies (e.g. Gilkerson et al., 2017).

Advances in neuroscience suggest a reason why contingency might matter more than sheer amount of talk. The number of conversational turns, but not the amount of caregiver talk, relates to connectivity in Broca’s area and activation during a language processing task (Romeo, Leonard et al., 2018; Romeo, Segaran et al., 2018). Such studies reveal interesting possible neural underpinnings that reflect contingent interactions in language-related areas of the brain, supporting the behavioral associations between contingency and language.

Interventions suggest a causal connection

If contingency is key to language learning, then interventions aimed at increasing contingency should boost language growth. This is precisely what some researchers have found. The Duet Project, an intervention designed to increase the quantity and quality of contingent interactions between caregivers and infants from very low-income families (Luo et al., 2019) improved engagement between caregiver and infant, and also improved standardized language scores (Alper et al., in revision). Similarly, the Video Interaction Project, an intervention in pediatrician offices targeting responsive parenting interactions, found positive effects on caregivers (Cates et al., 2016; Mendelsohn et al., 2011) and infants (Mendelsohn et al., 2007; Weisleder et al., 2016). And an intervention targeting contingent talk found increases in the amount of caregiver talk, the proportion of contingent talk, and infant language use (McGillion et al., 2017).

Contingency has even become an outcome of interest in interventions developed to improve other areas of caregiver-infant interaction. An intervention targeting emotional bonding between preterm infants and their mothers improved contingency between mothers and their 4-month-old infants and led to enhanced cognitive, language and attention skills at 18 months (Beebe et al., 2018). These interventions suggest a causal (rather than merely correlational) association between contingency and child outcomes, mandating a closer examination of how contingency might act on the language learning process.

Proposed theoretical mechanisms

Prior research has focused on domain-specific pathways to account for associations between contingency and language development (Tamis-LeMonda et al., 2014; Reed et al., 2017). Tamis-LeMonda and colleagues (2014) postulate three features of contingent interactions that enhance language learning: temporal, semantic, and pragmatic mechanisms (see Fig. 1). Temporally, the probability of the two events binding together in memory is enhanced when they co-occur within a brief time window (Rovee-Collier, 1995), a mechanism that should generalize to the binding of “words” to the objects and actions of infant interest. Semantically, contingent interactions reduce referential ambiguity by naming or describing objects and events that map meaningfully to the objects and actions of infant focus. Pragmatically, engagement in contingent interactions with caregivers allows infants to experience the joint goals of communication and to develop an understanding of communicative intent. Although each is distinct, temporal, semantic, and pragmatic features likely work together synergistically to account for the relation between contingent interactions and language development.

These features of contingent interactions have helped explain the effect on language learning, though they generally reflect mechanisms specific to the domain of language. Here, we propose an expanded framework for understanding how contingency relates to language development specifically and learning more broadly—namely the idea that attention, a domain general process, might prove to be the glue that binds contingent input to learning and that enables infants to engage in contingent social interactions.

A new framework: The role of attention in contingency and language

Our reciprocal framework highlights attention as the core mechanism that underlies contingency-language associations (see Fig. 2). This model considers attention to be the glue that both enables infants to engage in contingent social interactions and then enables the contingent input to lead to learning. Specifically, we posit that as infant attentional skills develop, infants increasingly participate in high-quality contingent interactions. In turn, participation in contingent interaction supports infants’ development of attentional skills, likely because caregivers’ input heightens and focuses infants’ attention. In proposing this new framework, we present the evidence for each pathway: attention to contingency and contingency to attention. We further integrate pre-existing theoretical models into our framework, to demonstrate how consideration of infant attention advances a deeper understanding of language development.

This model focuses on the first two years of life when key attention skills develop, including sustained attention, the maintenance of focus in the presence of distractors, attention shifting or orienting, the disengagement of attention from one stimuli to shift to another, and joint attention, shared attention with others (Colombo, 2001; Ruff & Rothbart, 1996). At birth, attention is largely exogenous, driven by stimuli in the environment rather than the infant’s own control. Between four and six months, infants develop endogenous control of their visual attention, leading to shorter bouts of sustained attention and faster orienting (e.g. Johnson et al., 1991; Hood et al., 1996). Also during this time, infants begin to actively explore their environments, giving caregivers more opportunity to respond to their behavior (e.g. Chang et al., 2016). Around six months of age, infants begin to follow another’s gaze, allowing for shared attention with caregivers (e.g. Morales et al., 1998; Scaife & Bruner, 1975). Around twelve months, infants begin to direct another’s attention through behavior such as pointing, allowing for more balanced interactions with caregivers. Sustained attention and attention shifting, continue to improve into the second year of life and beyond (Bahrick et al., 2018), as infants increasingly engage in sustained interactions with caregivers and begin to use language themselves to communicate (see Fig. 3 for an illustration of the co-development of attention and contingency).

In this field, the research has generally (with a few exceptions; e.g. Salley et al., 2016) centered around visual, sustained attention, or the maintenance of focus for at least three seconds. This is likely because most research focuses on infants in the first years of life, when sustained attention is steadily increasing (Ruff & Lawson, 1990), and visual attention is more readily observable compared to auditory or tactile attention. Indeed, during play interactions with caregivers, most bouts of infant visual attention to objects last under 3 s, with 3 s denoting what researchers consider to be relatively sustained attention at young ages (e.g. Suarez-Rivera et al., 2019). This model primarily refers to visual, sustained attention, as this is the focus of most research to date, though future research should interrogate different ways to examine attention across development and its relation to contingent interactions and language learning.

Infant attention supports participation in contingent interactions

In the first year of life, infants gradually develop control of their focused attention and at the same time shift from face-to-face

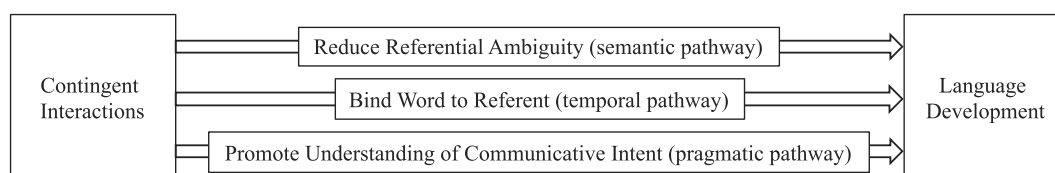


Fig. 1. Theorized Pathways Between Contingent Interactions and Language Development. *Note.* This model represents the work by Tamis-LeMonda and colleagues (2014) who theorized three pathways through which contingent interactions relate to language development: 1) reduction of referential ambiguity (semantic pathway), 2) binding words to referents (temporal pathway) and 3) promoting the understanding of communicative intent (pragmatic pathway). These pathways operate synergistically to predict language outcomes.

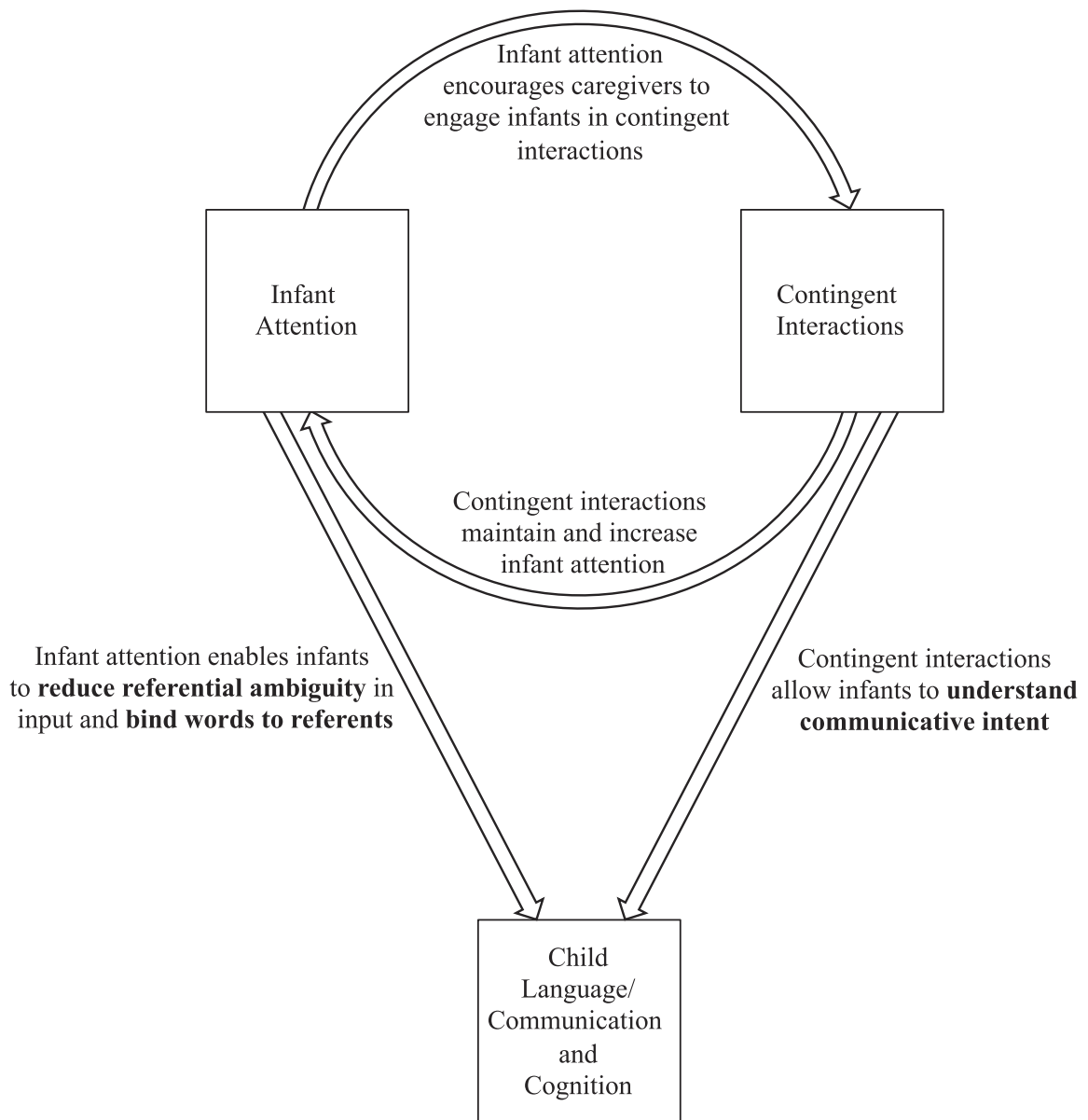


Fig. 2. Reciprocal Model of Contingent Interactions, Attention, and Language Development. *Note.* This model encompasses and builds on the three pathways proposed by Tamis-LeMonda and colleagues (2014) by showing how infant attention and contingent interaction reciprocally build on each other. When infants pay attention to objects or events, caregivers and infants are more likely to engage in contingent interactions, such that infants are better positioned to develop an understanding of communicative intent (pragmatic pathway). Contingent interactions, in turn, help to maintain infants' attention, thereby helping infants to reduce referential ambiguity in caregivers' language input (semantic pathway) and increasing the likelihood that infants will bind words to referents of focus (temporal pathway). Thus, reciprocal relations between infant attention and contingent interactions support the development of language and communication skills, and cognition more broadly.

interactions to bouts of shared engagement with objects (triadic attention) and proto-conversational exchanges (Chang et al., 2016; Deák & Triesch, 2006). Research suggests that individual differences in attention early in the first year may affect how infants engage with caregivers during interactions. Some early studies of attention and language found that infants whose caregivers reported them to be attentive also had better language skills. The researchers speculated that caregivers may have found it to be easier to interact with infants perceived to be more attentive (Dixon & Shore, 1997; Dixon & Smith, 2000). Indeed, researchers have begun to examine this possibility by examining the role of infant attention development in establishing contingent interactions.

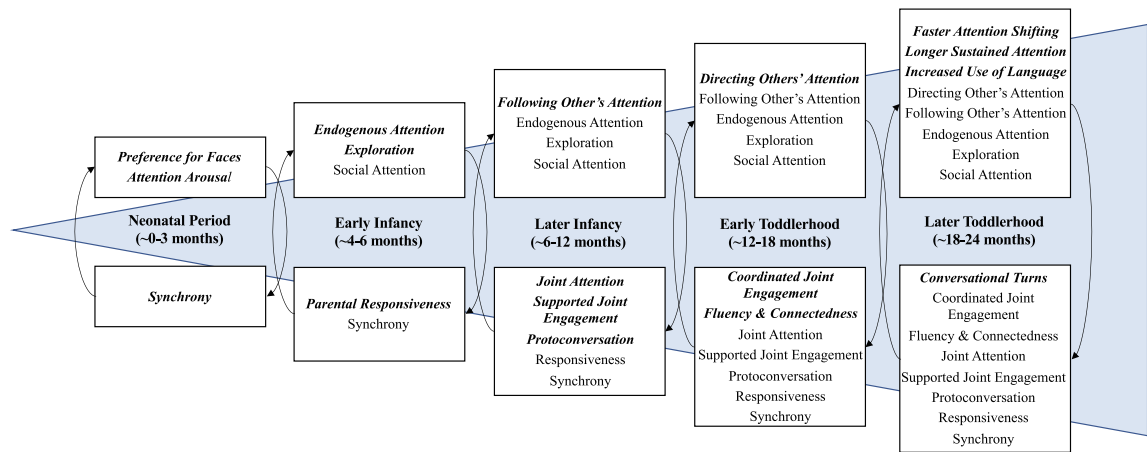


Fig. 3. Reciprocal relations between infant attentional skills and contingent interactions across the first two years of life. *Note.* Over the course of development, new skills build upon older competencies and interactions build in complexity. This figure provides an example of when infants might begin to demonstrate certain skills and the potentially co-occurring changes in the interaction. It is important to note that there are significant individual differences in both infant skills and infant-caregiver interactions, so these relations will differ individual to individual.

Attention supports contingent interactions: Longitudinal evidence

Do early individual differences among infants in attention contribute to later contingent interactions? Two recent studies suggest that they do. In a study of high-risk infants from a range of SES backgrounds, infant attention orienting at one month of age predicted 8% of the variance in the number of joint attention bids (i.e., spontaneous looks to the examiner) that 12-month-old infants made to adults after controlling for infant social engagement at 4 months of age and demographic characteristics (Salley et al., 2016). Joint attentional bids allow infants to establish shared topics with caregivers, thus providing a rich context for contingency and back-and-forth exchanges (Bakeman & Adamson, 1984). Another study showed that infants with better sustained attention at 4.5 months engaged in more frequent and higher-quality contingent exchanges with their mothers at 15 months (McMillan et al., under review). Furthermore, attention at 4.5 months related to the infant's vocabulary skills at 15 months, but only through contingency.

Attention supports contingent interactions: Implications for language development

Infant attention in social contexts is important for language development. In one study using a middle-to high-SES sample, 11-month-old infants viewed a social stimulus (a woman talking) with a nonsocial distractor (generic, moving patterns). Infants who sustained attention to the social stimulus had larger vocabularies at 14 months and were more likely to use multi-word productions at 18 months (Salley et al., 2013). Studies on gaze following provide further evidence for the role of attention to social stimuli in language learning. Infants who are better at following another's gaze in infancy have better language skills as toddlers (Brooks & Meltzoff, 2015; Tenenbaum et al., 2015). Attention to faces and gaze likely facilitates infant attention to contingent interactions, which provide a wealth of opportunity to learn about language.

Attention to and participation in contingent interactions helps infants to develop an understanding of communicative intent and learn to respond contingently to the communicative behaviors of their caregivers (Kuchirko et al., 2018). Hearing and producing sounds does not constitute a conversation; there must be a shared understanding that the speaker intends to convey a message and the listener intends to comprehend that message (Bruner, 1983). Such an understanding allows infants to transition from the face-to-face interactions that characterize early infancy (Meltzoff & Moore, 1977; Trevarthen, 1979; Trevarthen, 2011) to triadic interactions in which caregiver and infant share attention to objects and activities (Bakeman & Adamson, 1984; Sigman et al., 1986; Tomasello & Todd, 1983). Indeed, theoretical models posit contingent interaction to be an underlying factor in the development of gaze-following, as the predictability inherent to contingent interactions allows infants to infer the caregiver's focus based on contextual cues such as head position (Deák & Triesch, 2006). Indeed, naturalistic interactions between caregivers and infants provide a vital context for infants to learn social skills (Deák et al., 2014; Triesch et al., 2006). For language, contingent responding lies at the core of reciprocal conversation: The caregiver both conveys a message and acknowledges a message from the infant.

To illustrate how contingent interaction promotes the understanding of communicative intent, consider two caregivers. One caregiver talks about objects that their infant manipulates and responds to the infant's vocalizations as though engaging in a conversation. As the caregiver responds to the infant, and joins in to share goals, the caregiver supports the infant's understanding and expression of communicative intent. The second caregiver talks to the infant about topics unrelated to the infant's behaviors and often talks over or ignores the infant's vocalizations. Such behaviors fail to establish shared goals and provide less support for the infant's understanding of communicative intent. As infants grow in their understanding of communicative intent, they begin to use socio-communicative cues, such as a partner's gaze to distinguish between what is and is not important for language learning (Akhtar & Tomasello, 1996; Golinkoff, 1986; Woodward & Hoyne, 1999).

Several studies illustrate the importance of the communicative context offered by contingent interactions for infant language learning. One set of experiments examined how different sources of input relate to 9-month-old, English-speaking infants' abilities to distinguish among Mandarin phonemes. They found that infants maintained their ability to distinguish Mandarin phonemes after interacting with a Mandarin-speaking adult, but not after hearing Mandarin speech from a video or audio recording (Kuhl et al., 2003). The researchers speculated that the absence of social contingency between caregiver and infant in the video condition compromised infants' learning of Mandarin phonemes. In a study on infant rule learning, 7-month-old infants heard patterns of tones used either in a back-and-forth communicative context or in a noncommunicative context. When tested on the pattern, infants evidenced learning only if they had heard the tonal pattern in a back-and-forth exchange (Ferguson & Lew-Williams, 2016). In a word-learning study with 24-month-old infants, researchers taught infants novel verbs either via live interaction, contingent video chat, or a noncontingent video. Toddlers learned the words equally well from the video chat and live interaction but not from the noncontingent, yoked video, suggesting that contingency was the ingredient most central to word learning (Roseberry et al., 2014).

In sum, contingent interactions establish a communicative context that is uniquely important for infant language learning, and infant attention facilitates participation in such interactions. As Kuhl and colleagues (2003) stated, "What does a live person provide that a DVD cannot? ... A live human being generates interpersonal social cues that attract infant attention and motivate learning" (p. 9100). Such observations spotlight the role of attention in infants' participation in contingent social interactions. As infants develop attentional skills over the first year of life, they are better able to control and direct their attention during interactions with caregivers, and grow in their understanding of the communicative nature of language. In turn, participation in contingent interactions allows infants to cull meaning from the language around them.

Contingent interactions increase infants' attention in social situations

Our reciprocal model suggests that just as infant attention facilitates participation in contingent interaction, contingency facilitates the development of infant attention. Paralleling developments in infant attentional control over the first year, contingent interactions change in their characteristics—from the high density of face-to-face interactions that elicits infant attention to people (Fausey et al., 2016), to triadic interactions around objects that require infants to shift attention between people and objects to glean meaning from ongoing activities and talk. Indeed, engagement in contingent interactions scaffolds infant attention both in real time and across development. Real-time studies examine contingency and attention in the moment to illuminate possible mechanisms, and longitudinal studies reveal connections between contingency and later attention.

Contingent interactions increase infant attention in real time

The fluid, back-and-forth interactions that characterize contingency may support infant attention by encouraging infants to maintain focus on shared objects and events. For example, a caregiver who responds "Where do you put the brown bear?" as an infant picks up a toy, prompts the infant's continued focus on the bear in the context of a contingent, back-and-forth exchange. Thus, research on the real-time processes that lead from contingency to infant attention highlight this pathway in our conceptual model.

Studies examining caregiver-infant interactions moment-by-moment help to elucidate possible mechanisms behind contingency-to-attention associations. In a study of middle-to-high-SES families, researchers categorized caregivers as either "sensitive" (contingently responsive) or "redirective" (not contingently responsive) toward their 5-month-olds. Infants with sensitive caregivers attended more to the objects of caregiver engagement, were less likely to shift gaze in response to non-sequiturs (e.g., a gasp), and were faster at shifting attention when their caregiver redirected them (Mason et al., 2018)—behaviors that suggest attentional control. Thus, even when endogenous attention is limited, caregiver contingent responses facilitate attention organization, particularly to social stimuli. Similarly in a sample of working to middle class families, one-year-olds looked at objects for longer when in a state of sustained joint attention than when in a state of brief joint attention (Yu & Smith, 2016), and during bouts of joint attention, infants looked longer when caregivers spoke as infants explored objects (Suarez-Rivera et al., 2019), again indicating real-time supports of contingent interactions on infant attentional control. For young infants, contingent interaction may guide the timing and speed of infant attentional shifts, but as infants get older, contingency may extend the duration of attention bouts.

Experimental research further supports a contingency-to-attention pathway by manipulating contingency and observing effects on infant attention. In a set of experiments with middle-SES participants, researchers tested whether experimental manipulations of contingency affect infants' moment to moment attention. Researchers examined infant attention during two within-participant play conditions: one in which the adult responded contingently by following in on the infant's focus and one in which the adult responded noncontingently by changing the infant's focus. At 9-months of age, infants made approximately a quarter fewer attentional shifts when interacting with a contingent experimenter resulting in fewer, but longer bouts of engagement (Miller et al., 2009). At 13 to 16 months of age, infants, also made fewer attention shifts when interacting with a contingent caregiver, and additionally displayed longer bouts of attention, vocalized more, used more gestures, and showed overall more engagement (Miller & Gros-Louis, 2013). Such studies offer strong support for a direct, causal effect of contingency on maintaining infant attention in real time, spurring further questions about whether contingent interactions likewise improve infant attention over time.

Contingent interactions support infant attention across development

Longitudinal studies provide important insight into the relation between contingency and attention over time. An early longitudinal study of contingency and attention with middle- to high-SES participants revealed that parents' contingent responses to infant

non-distress (e.g., vocalizations) at 5-months accounted for approximately 15% of variance in infants' attention to toys at 13-months, but only 2% of variance in language comprehension at 13-months (Bornstein & Tamis-LeMonda, 1997). Early in development, contingency may be more important for attention than for language, because young infants are developing endogenous control of attention, but receptive language does not begin to accelerate until the end of the first year.

Intervention studies that target contingency provide additional evidence that contingency may improve infant attentional capacity across age. The aforementioned Video Interaction Project, in which low-SES caregivers with neonates were randomly assigned to receive an intervention to promote parent responsiveness or a control intervention to promote parenting self-efficacy, found that infants whose families were enrolled in the responsiveness intervention had better attentional skills at 24-months, as reported by their parents, than infants in a control intervention (Weisleder et al., 2016). Thus, instructing caregivers on how to respond to their infants in a way that facilitates back-and-forth exchanges appeared to improve infants' attentional skills. There is also some evidence from interventions with preschool children that changes in parenting affect child attention. A study with low-income children compared a parent-focused intervention, a child-focused intervention, and business-as-usual Head Start programming. Compared to the other two groups, children whose families enrolled in the parent-focused intervention had better sustained attention, as measured by neural data, and they engaged in more conversational turns with their parents (Neville et al., 2013). These studies show that changes in parenting can impact infant and child attention and further suggest that contingency may play a role.

Contingent interactions build infant attention: Implications for language development

Attention is fundamental for learning language because infants are likely to connect words to the targets of their attention. Indeed, studies that manipulate infant attention show that word learning is compromised when object labels are misaligned with infant attention. When 10-month-old infants from middle-SES homes heard a novel word in the presence of a boring object (e.g., a white cabinet latch) and an interesting object (e.g., a blue sparkle wand), they attributed the word to the interesting object regardless of which object the speaker labelled. Thus, infants tended to attribute labels to the object they were attending to, albeit sometimes incorrectly (Pruden et al., 2006). Indeed, attention was key for infants to learn novel words. Because infant attention was misdirected to the distractor, experimenters had to tap the top of the apparatus, call infant' name, or make noises to get infants' attention and facilitate learning.

A similar phenomenon is seen in older infants (Hollich et al., 2000). Even 3-year-olds were less able to identify the referent of a novel word that was paired with a picture of a familiar, interesting distractor (e.g., a cat) than one paired with a familiar but boring distractor (e.g., a cardboard box; Pomper & Saffran, 2019). The failure to learn words in the presence of visually interesting distractors highlights the importance of attention and fragility of the learning system.

The Human Simulation Paradigm (Gillette et al., 1999; Trueswell et al., 2016) further demonstrates how contingency combines with infant attention to create opportune learning moments. In this paradigm, naïve adult observers view a videotape of an infant and caregiver interacting around a set of toys. The observers attempted to guess the word (indicated by a beep) that a caregiver was saying to the infant (with audio turned off) based solely on the context around the word. The context included the saliency of the object or the caregiver's gesture and gaze. Adult observers most accurately guessed the word during contingent exchanges (Trueswell et al., 2016). Indeed, when adults guessed accurately, the target referent was more likely to align with the infant's focus (82%) compared to when adults guessed inaccurately (23%). For example, if the infant picked up a teddy bear and the caregiver said "bear", adult raters were better able to identify the target word than if the caregiver watched the infant pour tea from a pretend teapot. When contingency was disrupted by changing the timing of the target word by just a few seconds, the observer was significantly less likely to guess the target word. Furthermore, studies based on families from diverse SES-backgrounds show that an observer's accuracy at guessing a target word from an interaction between caregivers and their 14-months-old infants accounted for 22% of variance in children's language ability at 54-months old controlling for the amount of caregiver talk (Cartmill et al., 2013). Thus, contingent labeling moments may enable infants to disambiguate meaning, feeding into growth in language skills over time.

Findings from the Human Simulation Paradigm provide compelling evidence for the role of contingency in providing referential clarity, but they do not speak to *how* referential clarity affects attention or word learning. To better understand referential clarity as a causal mechanism between contingency and word learning, researchers have examined the coupling of eye gaze with words and behaviors to evaluate moment to moment changes in caregiver-infant interactions. For example, head-mounted cameras allow researchers to pinpoint which objects are most salient from a toddler's viewpoint during interactions with caregivers (e.g., Pereira et al., 2014; Yu et al., 2019). Infants were more likely to learn the name of a novel object when the named object was salient (centrally located in the infant's view and larger than other objects), and when this saliency began a few seconds before and continued for a few seconds after the naming event (Pereira et al., 2014). In other words, infants learned words best when caregivers provided contingent labels that capitalized on infants' current attentional focus.

In conclusion, attention narrows the search space for identifying word meaning and contingent interaction both increases and capitalize on this attention. Contingent interactions enhance infant attention in the moment and the tight temporal connections between word and attention clarify the word's intended referent, creating a powerful learning moment (Dunham et al., 1993; Tomasello & Farrar, 1986; Trueswell et al., 2016). As the exchange continues, the infant is likely to repeatedly hear words in the same meaningful contexts, establishing additional opportunities to map labels to objects (Smith & Yu, 2008).

A reciprocal framework for attention and contingent interactions: Implications for theory, science, and practice

The nature of attention development and caregiver-infant interactions, combined with the findings on attention and contingency,

support the proposed framework for reciprocal, bidirectional associations between attention and contingency as well as the implications for language development. Infant attention, particularly to social stimuli, facilitates engagement in contingent interactions with caregivers facilitating infants' understanding of the communicative nature of language. In turn, contingent interactions elicit more sophisticated attentional control from the infant, including longer bouts of sustained attention towards the end of the first year, when infant vocabulary comprehension is accelerating. The independent contributions of attention and interaction to language development are well established. For example, in the book-sharing literature, infant interest (including attention) and adult talk (including conversational engagement), predict later language (Deckner et al., 2006; Muhinyi & Rowe, 2019). Our model proposes that infant attention and contingent interactions are intertwined and interdependent, such that each contribute to the development of language at least in part through their relations with each other.

Our reciprocal framework accounts for prior theory on language learning in the social context (Tamis-LeMonda et al., 2014) by demonstrating how previously proposed pathways work through infant attention. The development of attention allows infants to increasingly participate in contingent interactions that promote an understanding of caregivers' communicative intent. Moreover, to the extent that contingent interactions facilitate the development of infant attention, infants gain access to the social communicative cues for word learning which helps resolve referential ambiguity in the language input.

A reciprocal framework for associations between attention and contingency suggests that the process of learning language from social interaction may rely on domain-general mechanisms that not only support language learning specifically, but underpin learning more broadly. That is, contingency may lay a foundation for *all learning*, including cognition broadly defined. For example, through its connection to infant attention, contingency may have important implications for executive function. Indeed, language is the mediator between mothers' supportive guidance during a challenging task and the development of executive function (Matte-Gagné & Bernier, 2011). Once again, attention is implicated in this finding; if infants fail to attend to what caregivers offer, this relationship will be weakened.

By considering bidirectional associations between contingency and attention, a fuller picture emerges on how early attentional skills come to be modified by the way caregivers do or do not encourage the infant's attention during contingent interactions. A reciprocal model between attention and contingency harkens back to Piaget's writings on children's active role in their own learning (Piaget, 1952); in our model, individual differences in attention shape how infants engage with caregivers. Relatedly, Vygotsky (1978) focused on the role of the adult caregiver in supporting children's development beyond what children could accomplish alone. In our model, contingent interactions are a key way that caregivers scaffold infant focus—by supporting infants' attention to and engagement with the world. Of course, these systems do not work in isolation, but interact with each other across development (Oakes & Rakison, 2019; Smith & Thelen, 2003). We propose that the infant attentional system interacts with emerging social competencies and exploration of the environment. These behaviors further interact with the responses from the caregiver and the immediate context to create rich, contingent exchanges. The moment-to-moment interaction of these systems then lay a foundation for learning language, and development over months and years.

To better understand the implications for the proposed model, future research should investigate how attention and contingency interact within larger environmental systems such as SES. Most studies examining attention and contingency in infancy rely on participants from high-SES households and those that extend to diverse samples rarely analyze the role of SES. Some studies of older children suggest that child attention, like language and contingency, does differ across SES-strata (e.g. Stevens et al., 2009; Wray et al., 2017), yet differences in the quality of parenting predict individual differences in child attention over and above SES-related factors (NICHD Early Child Care Research Network, 2005). Future studies on contingency and attention should consider how larger environmental factors, such as SES, may affect such relations.

Most research to date focuses on typically developing infants. However, what attention and contingency look like may vary for children with different abilities. In considering differences in attention, infants who are visually impaired may use other sensory modalities, such as touch, to attend to objects and establish joint attention with caregivers (Bigelow, 2003). Although use of different modalities may change how visually impaired infants engage in contingent interactions, it does not seem to significantly delay language learning (Landau & Gleitman, 1985). These findings suggest that although attention in typically developing children is often operationalized as visual, attention through other modalities may be equally important to consider. Differences in patterns of visual attention, such as those seen in infants at risk for autism, may also relate to differences in joint attention and contingent interactions (Bhat et al., 2010). Interventions targeting contingent interaction between infant and caregiver, particularly in the first year of life, may have a positive effect for infants at risk for autism (Green et al., 2017; Neimy et al., 2017; Webb et al., 2014).

Differences in infants' abilities may also impact engagement in contingent interactions directly. Infants with motor impairments may have limited abilities to access, manipulate, and share objects with others, and so their active role in establishing contingency may be altered (Iverson, 2010). For example, delays in crawling are often accompanied by delays in the development of joint attention skills (e.g. Campos et al., 2009). However the onset of crawling does not necessarily accompany an increase in joint attention skills for infants with motor impairment (Dillmann et al., 2019) suggesting alternative routes to the development of joint attention skills. Relatedly, caregivers may interact differently with a child who is less independent in their movements, using more directive and less responsive speech (e.g. Pennington & McConachie, 2001). Infant joint attention skills and caregiver responsiveness interact to build contingency, which may help explain why some children with motor impairments also have language delays (e.g. Hustad et al., 2014).

A reciprocal framework between attention and contingency also informs interventions aimed at enhancing contingent interactions between typically developing infants and their caregivers. By expanding an understanding of the role of attention in the efficacy of interventions, researchers come closer to explaining why some families benefit more than others and how to best support all families. A focus on attention also suggests that interventions should start early, in the first year of life, before infants are producing language and when attention undergoes rapid development. Finally, a framework that considers reciprocal relations among attention, contingency,

and learning can help advance an understanding of why language and interventions targeting language have such strong implications for school readiness, as the factors that build language may also be building the broader learning system.

Conclusion

We posit attention to be a core mechanism that underlies associations between contingent interactions and language development, thus expanding focus beyond temporal, semantic, and pragmatic features of contingent interactions. Our reciprocal model proposes that contingency and attention reciprocally affect one another in ways that pave the way for learning: Attention supports infants' participation in contingent interactions; contingent interactions scaffold infant attention; and reciprocal paths between attention and contingency allow infants to map language input to the objects and events of their environments. Indeed, a rich, cross-disciplinary body of research supports our proposed model and converges on our broader claim that attention and contingency establish a critical foundation for learning and cognition more generally.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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