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THEORETICAL NOTE

From Social Contingency to Verbal Reference: A Constructivist Hypothesis

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In the first year of life, infants' word learning is slow, laborious, and requires repeated exposure to word-referent co-occurrences. In contrast, by 14–18 months, infants learn words from just a few labeling events, use joint attention and eye gaze to decipher word meaning, and begin to use speech to communicate about absent things. We propose that this remarkable advancement in word learning results from attaining a *referential understanding of words*—that words are linked to mental representations and used intentionally to communicate about real-world entities. We suggest that verbal reference is supported by codeveloping conceptual, social, representational, and statistical learning capacities. We also propose that infants' recognition of this tri-directional link between words, referents, and mental representations is enabled by their experience participating in and observing *socially contingent interactions*. Understanding verbal reference signals a qualitative shift in infants' word learning. This shift enables infants to bootstrap word meanings from syntax and semantics, learn novel words and facts from nonostensive communication, and make inferences about speakers' epistemic competence based on their language production. In this paper, we review empirical findings across multiple facets of infant cognition and propose a novel developmental theory of verbal reference. Finally, we suggest new directions of empirical research that may provide stronger and more direct evidence for our theory and contribute to our understanding of the development of verbal reference and language-mediated learning in infancy and beyond.

Keywords: verbal reference, social contingency, constructivist theory of development

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Human language permits us to call to mind objects, events, and ideas that we cannot witness directly (Deacon, 1997). We learn about people we have never met, about time that has not passed ("tomorrow"), and about concepts as abstract as weak subatomic force. We propose that this communicative power of words is enabled by *verbal reference*—a link between words, real-world phenomena, and their mental representations that enables words to refer to those phenomena even when they are perceptually unavailable. How do infants establish this tridirectional link and begin to engage in language-mediated learning by extracting information encoded in language to establish, retrieve, and modify mental representations of absent or abstract referents?

With the rapid accumulation of empirical evidence on infants' vocabulary development in the recent decades (Bloom, 2002; Carey, 2010; Frank et al., 2009; Hidaka & Smith, 2010; Markman, 1989; Perszyk & Waxman, 2018; Swingley, 2010; Waxman & Lidz, 2007; Yurovsky, 2018), when and how young children understand the referential nature of words has become an apple of discord in language acquisition (Golinkoff et al., 2000; Sloutsky, 2009; Waxman & Gelman, 2009). The proponents of perception-driven early word learning theories tend to explain the emergence of verbal reference through domain-general cognitive mechanisms, such as associative learning and cross-situational statistics (e.g., Howard, et al., 2005; Samuelson & Smith, 1999; Smith & Yu, 2013; see Smith et al., 2014, for a review). In contrast, some have argued that verbal reference may be inherent in human communication, a conceptual primitive hard-wired in infants' minds, present in preverbal communication in infancy, and pertaining to words from the outset of verbal communication (e.g., Burge, 2010; Csibra, 2003, 2010; Macnamara, 1982). Still others have proposed that the interplay between conceptual knowledge, social cognition, and language enables the development of verbal reference in infancy, in the spirit of constructivist theories of cognitive development (Karmiloff-Smith, 1992; Piaget, 1954; Tomasello, 2010; Waxman, 2003; Xu, 2019).

To address this divergence of views, we integrate insight from multiple accounts of word learning, draw on findings across several lines of empirical research on cognitive and language development, and propose a novel constructivist theory of the development of verbal reference in the first 2 years of life. We aim to better

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understand the processes governing this development by considering its precursor capacities (see Appendix) and the mechanisms facilitating its emergence.

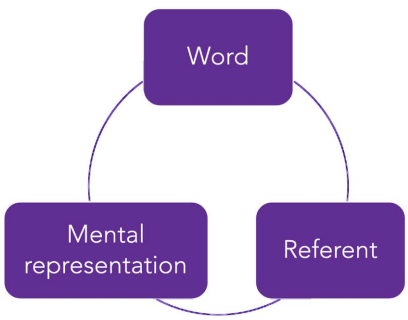
Following Bloom (1993), we define verbal *reference* as a property of words (or other signals) that are linked to mental representations and are used intentionally by people to communicate about real-world or abstract entities[1]. This tridirectional link (Figure 1) allows us to establish, retrieve, and modify mental representations based on language alone. An important property of this link is *referential specificity*, which entails that words do more than just indexing parts of a scene, like objects, events, or locations ("there is something in this location"). Instead, they allow us to communicate about specific aspects, states, or changes of state of those entities ("the car is damaged," "the car is red," "there is a Prius in the garage"). This property distinguishes verbal reference from its nonverbal precursors, like pointing or gaze direction. In this article, we will make the following three claims and discuss the supporting empirical evidence to date.

We propose that (1) the precursor capacities of verbal reference include the ability to represent absent entities and the understanding that those entities can be communicated about and that words are the means of such communication. At the same time, infants employ powerful statistical learning mechanisms that segment speech into words, track their co-occurrences with objects or events, conduct cross-situational comparisons, and propose and revise word-referent links as more distributional information becomes available. These capacities must operate in concert to get word learning off the ground.

We also propose that (2) infants' experience with *socially contingent communicative exchange* enables them to employ these precursor capacities and attain a referential understanding of words. As infants accumulate observations of people interacting in a contingent manner via language and as they accumulate first-hand experiences participating in such interactions (e.g., by vocalizing and being responded to with actions accompanied by language), they infer that language is the means of such communication and recognize the referential status of words. Thus, attaining a referential understanding of words is a gradual process scaffolded by a combination of precursor capacities and experience with socially contingent interactions.

Finally, we propose that (3) attaining a referential understanding of words leads to a qualitative shift in word learning. Understanding the referential nature of words enables infants to engage in language-mediated learning, such as learning new word meanings and novel facts from language alone (directed to them or overheard), integrating multiple cues to meaning from syntax, semantics, and pragmatics, and making inferences about speakers' epistemic competence from their language use.

Figure 1
Word-Referent Links Enabled by the Referential Status of Words



Note. See the online article for the color version of this figure.

Development of the Referential Understanding of Words in Infancy

We begin by summarizing the findings in the literature on the development of verbal reference from the last two decades and tracing its trajectory over the first 2 years of life. Infants' comprehension of verbal reference has been researched using multiple methods, such as pitting referential cues (e.g., eye gaze) in a labeling situation against visual salience of an object (Pruden et al., 2006) or against infants' intrinsic preference for an object (Baldwin, 1993b). However, when the referent object is present at the time its label is introduced, there is always the possibility that infants' success in learning the label is driven by perceptual association.

We, therefore, focus here on studies that leveraged infants' ability to comprehend speech about *absent objects*[2]. In such studies, infants either first observe a labeling event (usually a count noun that refers to an object), after which the referent is hidden, and an experimenter subsequently enquires about the absent object ("How about the wug? Where is the wug?"), or they first hear utterances containing object labels ("I have a bike") and are subsequently presented with objects corresponding to those labels and distracter objects, displayed in silence. Infants' looking direction (suggesting their search for the object in a particular location) and pointing are typically measured to evaluate their comprehension of the target words. If infants can map a label to its referent, even if it is perceptually unavailable, it constitutes strong evidence that they understand that words refer.

Developmental Timeline of Absent Verbal Reference

By 12 months, infants show the first signs of understanding "anchored" absent *verbal reference*—reference to recently removed objects primed by perceptually available entities associated with it ("anchors"), such as their former locations (Gallerani et al., 2009; Ganea, 2005; Osina et al., 2013, 2014). In Osina et al. (2013), for example, infants are first presented with a toy dog, which is subsequently placed inside an ottoman, so that infants can no longer see the toy. After a delay, during which the experimenter sang "Twinkle, Twinkle, Little Star" and pointed to decals on the ceiling,

[1] Abbott (2010) points out a distinction between pragmatic reference and semantic reference. In the case of pragmatic reference, words cannot refer on their own, they are tools used for speakers to communicate about something (see Clark & Bangerter, 2004; Clark & Wilkes-Gibbs, 1986; see also Michaelson & Reimer, 2019, for. a discussion of the "intentionalist" model). Semantic reference, which, as Abbot remarks, has arisen within formal logic, relates expressions to things out in the world (e.g., Wittgenstein, 2017). In this latter sense, any expression reliably linked to a phenomenon or a class of phenomena can be considered referential, so long as it signifies those phenomena. Our definition emphasizes the pragmatic aspect of reference, while embracing the semantic aspect as well, that is, words are linked both to representations and to things in the world.

[2] For brevity, we refer to both objects that have been recently seen but hidden and objects that exist but have not been displayed before infants' word comprehension is probed as "absent." Importantly, some objects can be absent and not retrievable (e.g., ones that ceased to exist or are imaginary) or do not have stable physical manifestations ("democracy"). The latter kind of permanently absent word referents is beyond the scope of our discussion (but see Bergelson & Swingley, 2013, for a discussion on infants' acquisition of abstract words).

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the experimenter then asked infants about the hidden toy, first in a hint-like manner ("What about the dog? Have you seen the dog?") and then directly ("Where is the dog? Could you find the dog?"). After being prompted 3–5 times, infants looked, or pointed to, or approached the ottoman, suggesting that they understood reference to the hidden object.

At 14 months, infants interpret verbal requests for hidden objects using social information, such as individuals' history of interacting with an object (e.g., which of the two balls the experimenter played with; Saylor & Ganea, 2007). At this age, infants track *properties* of recently removed objects, such as their color or former location, whose labels are mentioned in utterances (Saylor, 2004) and produce communicative behaviors toward these anchors (e.g., pointing to the panel that occludes the absent referent, or searching for an absent person; Ganea & Saylor, 2013; Saylor & Baldwin, 2004). Around 14 months infants also begin to comprehend reference to objects hidden from view without "anchoring," albeit provided with visual exposure to those objects before they are removed from view (Hendrickson & Sundara, 2017).

Infants begin to *retrieve mental representations* of objects based on language input alone, without pre-exposure to those objects within the experiment by 16 months. For example, Luchkina et al. (2020) showed that 16- but not 13-month-olds look more to familiar objects previously mentioned in speech unaccompanied by any images when those images become available. Sixteen-month-olds also use language to *update their representations* of the locations of recently shown objects (e.g., "Now the *dog* goes on the table") and look longer if the revealed outcomes mismatch the language input (e.g., a *cat* is on the table; Ganea et al., 2016).

By 18–22 months, infants not only retrieve detailed mental representations of familiar objects based on language alone, but also can *form representations*[3] of novel word-referent mappings even if those referents are perceptually unavailable (Baldwin, 1993a; Ferguson et al., 2014). Baldwin (1993a), for example, showed that 19-month-olds (but not 15-month-olds) successfully learn labels for novel objects that are first demonstrated but subsequently removed from infants' view and labeled while being sealed in an opaque container (e.g., the experimenter looks into the container and says, "Look, a fep!"). At this age, infants also update mental representations of states of the absent objects that are being referred to in speech ("Lucy is *wet now!*"; see Galazka & Ganea, 2014; Ganea et al., 2007).

Notably, younger infants may have a nascent ability to form a representation of a perceptually unavailable object based on language input. Xu et al. (2005), for example, showed that 12-month-olds search longer in an opaque box after retrieving one object, if they previously saw an experimenter peek into the box and utter two distinct labels than if the experimenter uttered the same label twice. This finding suggests that these infants appreciate the link between the number of words and the number of referents (a rudimentary form of mutual exclusivity; Markman, 1989; see also Pomiechowska et al., 2021). However, it is not until several months later that infants show the signs of moving beyond this link and establish a specific representation of a previously unseen object based on language input alone.

Taken together, this evidence suggests that the ability to extract information encoded in language to establish, retrieve, and update mental representations based on language develops between 12 and 18 months. This ability allows infants to comprehend speech about absent things without "anchors" and ultimately engage in language-mediated learning. What are the learning mechanisms that drive this development?

Existing Developmental Accounts of Verbal Reference

From the *perception-driven bottom-up view*, the explanation lies in the accumulation of linguistic data via domain-general associative learning mechanisms. The second year of life is marked by substantial advances in syntactic learning and a rapidly growing cache of associative information about word-referent co-occurrences (see Smith et al., 2014, for a review). With this growing body of linguistic data, young learners become better positioned to take advantage of their semantic and syntactic knowledge to make inferences about the meanings of words that are uttered in the absence of any referents (e.g., Sloutsky, 2009). These capacities, however, are insufficient to form or modify mental representations on the basis of language alone: Without having previously experienced a referent of a novel word, one cannot form a new perceptual association or use that word to access the representation of its referent.

Alternatively, some have argued that *reference is a primitive inherent in our conceptual and linguistic system* (e.g., Burge, 2010; Csibra, 2003, 2010; Macnamara, 1982). Six-month-old infants, for example, exhibit a nascent understanding of the referential nature of gaze by following an actor's gaze toward a present object if cues signaling communicative intent—eye contact or infant-directed speech—were present (Hernik & Broesch, 2019; Senju & Csibra, 2008). By 12 months, infants reliably recognize the referential nature of gaze to a hidden object and are surprised if the location indicated by an actor's gaze is revealed to be empty (Csibra & Volein, 2008). At 12 months, infants also reliably comprehend and produce pointing gestures to refer to not only present but also absent entities. They begin to point at an object's empty location to request that object from an adult or to draw the adult's attention to it (Behne et al., 2012; Bohn et al., 2018; Gräfenhain et al., 2009; Liszkowski et al., 2009).

This comprehension of nonverbal reference may serve as a steppingstone to understanding verbal reference to absent entities. However, nonverbal reference is limited in two significant ways. First, nonverbal reference, such as pointing or gaze direction, lacks *referential specificity*—a fundamental feature of verbal reference that enables us to communicate about various aspects of objects or events.[4] For example, pointing can direct attention (e.g., there is *something* there; or even "there is a car" *if a car had been seen previously*), but only words can refer to specific aspects and properties of an object and communicative about it with precision (e.g., "there is a car, not a cup"; "the red car" if there are more than

[3] It is unclear, however, how lasting these representations are outside of the context of the experiment (see Horst & Samuelson, 2008). To elucidate this matter, an investigation involving a delay (or a longitudinal investigation) is necessary.

[4] Great apes, similar to human 12-month-olds, request absent entities (e.g., treats) by pointing to their former locations (e.g., Bohn et al., 2015). However, they do not seem to move beyond indexical reference and develop referentially specific links between words (or other symbols) and their present and absent referents. Even great apes trained to use sign language to request objects do not respond to messages about states or locations of those objects and appear to be using signs by pairing them with perceptual categories of the corresponding objects (Savage-Rumbaugh et al., 1993), suggesting that referential specificity does not characterize apes' verbal communication.

one car; "the car is broken"). Referential specificity entails that infants not only realize that words can index nonpresent entities, but also discover that different kinds of words (e.g., nouns, adjectives, verbs) take on different kinds of meaning, even if these words reference the same object. Further, while pointing or gaze can reference objects, it is significantly harder to use these referential tools for events or changes of state. For example, pointing to one's eye is unlikely to communicate that *one is seeing*; pointing to the direction of the wind is unlikely to communicate that *it became windy*. Second and relatedly, only verbal reference enables one to create, maintain, and update *detailed mental representations based on language alone*, thereby enabling effective language-mediated learning and communication. Verbal reference, but not nonverbal referential actions, allows one to learn about objects, events, or ideas that one has not experienced directly or that do not have stable perceptual forms and thus cannot be pointed to or looked at (e.g., atoms, viruses, yesterday, tomorrow, or the 23rd century).

New Proposal: A Constructivist Account of Verbal Reference Development

In our view, infants' vocabulary in the first year of life and early, nonverbal, reference are marked by the lack of (or fragile and unstructured) connection between words and reference.[5] That is, 6–12-month-old infants possess some word knowledge—likely acquired via associative mechanisms—and possess an understanding that reference is possible, but they have not yet made the connection between the two. Indeed, although 9–12-month-olds show some understanding of nonverbal reference, their word knowledge appears to be chiefly driven by perceptual salience and associative mechanisms (e.g., Hollich et al., 2000; Pruden et al., 2006). For example, Pruden et al. (2006) found that 10-month-olds learn novel words by relying on the perceptual salience of an object instead of social cues provided by a speaker[6].

By 12–14 months, infants begin to treat concurrently present words and deictic gestures alike, realizing that both can index hidden objects (Gliga & Csibra, 2009; see also Graham & Kilbreath, 2007). They also use gesture to disambiguate between possible referents of a novel word (Pomiechowska & Csibra, 2020; c.f. Lucca & Wilbourn, 2018). Furthermore, infants begin to establish links between different types of words and different types of meaning during this developmental window, for example, count nouns map onto object categories, adjectives map onto properties or attributes, and verbs map onto actions or events (see Perszyk & Waxman, 2018, for a review). This signals the beginning of referential specificity. Thus, by the beginning of the second year, infants start to realize that words refer, and this realization qualitatively changes their word learning strategies, enabling referentially specific use of words to communicate about both present and absent entities.

Our key question remains: What mechanisms underlie this realization and enable the development of verbal reference? As Hollich et al. (2000, p. 5) put it: "The development of reference is a mystery." We propose that first, the codevelopment of conceptual, social, representational, and statistical learning precursor capacities is necessary to enable the emergence of verbal reference, and reference to perceptually unavailable objects or events in particular, and second, an understanding of socially contingent interactions drives the establishment of the tridirectional link that is the core of verbal reference (Figure 1). We outline the respective contributions of these precursor capacities and the effects of their concurrent development in the next section (for a more concise discussion, see Luchkina & Waxman, in press) before turning our attention to discussing the key role of social contingency.

Development of Precursor Capacities

Representing Absent Entities

The ability to store representations of objects or events and to access those representations through their names entails that infants form representations of real-world phenomena, link them with words, and possess sufficient memory capacity to store such links. In some cases, verbal reference can be built on representations of concrete objects or events (e.g., persons, their manner of moving or speaking). However, to enable reference to previously unencountered instances that belong to the same object or event categories, these representations need to abstract away from concrete instances. Moreover, such abstraction allows for a more efficient use of the learner's memory capacity: By focusing on category-defining features, infants can use fewer resources to store information about objects or events they encounter and extend relevant properties to those entities by recognizing their category membership. Evidence from the developmental literature suggests that infants begin to form abstract representations from an early age.

Infants begin to form visual categories based on perceptual features by about 3–4 months of age. For example, 3–4-month-olds readily categorize dot patterns and create prototypes by abstracting away from concrete exemplars (Bomba & Siqueland, 1983; Quinn, 1985). At this age, infants also categorize and distinguish pictures of different animal kinds (e.g., Eimas & Quinn, 1994; Quinn et al., 1993). By 9 months, infants form both perceptual and conceptual categories based on visual features (e.g., they can generalize category information from static images to dynamic point-light displays; see Arterberry & Bornstein, 2002). In addition to categorizing visual stimuli, 3–4-month-olds create auditory categories, such as the time of voice onset in consonant-vowel syllables (Eimas et al., 1971). By 6 months, they also categorize speech sounds (Kuhl, 1979, 1980, 1983) and intonation patterns (Morse, 1972). Between 6 and 12 months, infants fine-tune their speech sound categories and hone in on the relevant categories for their native language (Werker, 2018; Werker & Tees, 1984).

[5] An electrophysiological investigation found that even 9-month-olds exhibit mismatch negativity if they hear a word (e.g., a "duck") in the absence of an object and then see an object with a different name (e.g., a cookie; Parise & Csibra, 2012), suggesting a possibility that hearing words activates visual representations of objects. This finding may reflect 9-month-olds' referential understanding of words, or alternatively demonstrate a stable link between the word "duck" and a mental picture of a duck. However, because this evidence is limited, future research is needed to further test these possibilities.

[6] Bergelson and Swingley (2012) showed that 6–9-month-olds can recognize a handful of concrete object referents of highly familiar nouns (e.g., "banana"; see also Jusczyk & Aslin, 1995; Mandel et al., 1995). Yet, infants of the same age fail to recognize the referents of common verbs (e.g., kiss, drink; Bergelson & Swingley, 2015). This is likely because verbs take on arguments (events often also contain multiple objects; see Gentner, 2006), which means that perceptual salience is a poor cue to meaning in the case of verbs. In contrast, by 12–14 months, when infants' word knowledge is increasingly driven by conceptual representations (Pomiechowska & Gliga, 2019; Waxman & Leddon, 2011; Yin & Csibra, 2015), their verb comprehension also becomes more robust.

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This parallel development of visual and auditory categorization enables infants to create and recognize word-object links and use them to retrieve object representations. At 6 months, infants preferentially look to familiar object images upon hearing their names (e.g., looking to an image of a banana when hearing "banana" vs. an image of a sock; Bergelson & Swingley, 2012; see also Tincoff & Jusczyk, 1999). By 9 months, they begin to treat words as "invitations" to create visual categories: Upon observing several instances of a novel category (e.g., dinosaurs) consistently paired with the same word (e.g., "blicket"), infants establish a corresponding category and subsequently recognize its novel instances[7] (e.g., Balaban & Waxman, 1997). At this age, words also guide infants' flexible category formation: The number of labels influences the number of discrete categories infants create along a continuum of object stimuli (e.g., Althaus & Westermann, 2016; Havy & Waxman, 2016). Further, research on infants' object individuation indicates that by 9 months, infants also rely on words to make judgments about internal properties of object kinds (Dewar & Xu, 2007, 2009) and to keep track of individual objects that have been recently displaced (Xu, 2002). At least by 12 months, infants not only expect words to be linked with categories but also use nonverbal category knowledge to extend the meanings of newly learned words (Pomiechowska & Gliga, 2019; see also Graham et al., 2004). This bidirectional link between words and categories positions infants well to begin accessing mental representations of objects or events when hearing their names.

Finally, infants need accessible and sufficiently durable memory to enable effective access to representations and thus support the development of verbal reference. Although the earliest evidence of infants' accessing their declarative (vs. procedural) memory has been reported in 3.5–4-month-olds (see Mandler, 1988, for a reivew), this memory is short-lived (3–4 min; see Baillargeon et al., 1989; Baillargeon & Graber, 1988; Luo et al., 2003) and depends on perceptual availability of features or events that cooccurred with the represented object or event. By 6 months, however, infants can retain memory of an event for at least 24 hr, represent the existence and location of recently hidden objects (Baillargeon, 1986), and imitate demonstrated actions upon encountering the object used in the demonstration (Hayne et al., 2000). By 9–10 months, infants can remember such sequences of events over the span of months (Bauer, 2002; Bauer et al., 2000; Carver et al., 2000; Mandler & McDonough, 1995).

Thus, investigations of infants' categorization and memory development suggest that at least by 9 months, infants are capable of forming sufficiently abstract representations of objects or events, store them over extended periods of time, and access them by hearing words linked to those representations. Albeit crucial for the development of verbal reference, however, these capacities do not guarantee reference. A link between a representation and a corresponding word does not automatically confer the understanding that the word encodes that representation for communication purposes. How and when do infants gain such an understanding?

Using Speech to Communicate About Absent Entities

Infants' ability to understand that speech can communicate about perceptually unavailable entities emerges around 6 months and is reliably present by the first birthday (Cheung et al., 2012; Martin et al., 2012; Vouloumanos, 2018; Vouloumanos et al., 2012, 2014). Vouloumanos et al. (2012), for example, showed that 6-month-olds expect speech to communicate unobservable intentions. Infants first observed an actor (A1) who looked at two objects and indicated her preference for one of the objects by grasping it. Subsequently, A1 no longer had access to the objects and turned to another actor (A2), who had access to the objects but had not seen A1's preference demonstration, uttering a nonsensical word. Infants looked significantly longer when A2 handed A1 the object she did not prefer, suggesting that they understood that A1's utterance must have transferred information about her preference to A2. By 12 months, infants can link their inferences about the intended outcome of an attempted but failed action (by A1; e.g., attempting to reach for an object) with the communicative function of speech. They expect A2 to achieve A1's intended outcome upon hearing speech. Crucially, such an understanding requires that infants (1) appreciate others' beliefs and intentions and (2) recognize that language can be used to communicate about such beliefs and intentions.

Consistent with Vouloumanos et al. (2012) results, research on infants' understanding of intentions suggests that by 6 months, they attribute goal-directedness to others' actions (e.g., Woodward, 1998), appreciate the causal role of intentions in such actions (Southgate & Vernetti, 2014), and recognize the role of access to information in interpreting those actions (e.g., Luo & Johnson, 2009). At 7 months, infants keep track of others' beliefs and show surprisal, as they would expect others to show, when an outcome of an occlusion event is inconsistent with others' beliefs (Kovacs et al., 2010). By 10–15 months, they recognize others' false beliefs and how those beliefs guide actions (Luo, 2011; Onishi & Baillargeon, 2005; see Heyes, 2014, for a review).

Recall that around their first birthdays, in addition to recognizing that others have beliefs and intentions, infants begin to recognize that these beliefs or intentions can be about absent objects, which can be referred to, at least in an indexical way. Combined with the advances in infants' ability to form abstract representations and access them via associated words, the understanding that speech can communicate about perceptually unavailable entities prepares them to make the leap toward verbal reference. Indeed, the first signs of understanding reference to absent objects appear around 12–14 months (see section I). By 14 months, infants reliably use verbal cues to retrieve memories of absent objects (Ganea, 2005; Moore & Meltzoff, 2004; Osina et al., 2013, 2014) and past events (Bauer et al., 2000).

Proposing and Revising Links Between Words and Their Meanings

Finally, effective command of verbal reference entails that infants not only recognize that reference to absent or abstract entities via words is possible in principle, but are also able to propose, or hypothesize, and revise the meanings of words that refer to those entities. To succeed on this task, infants need to resolve at least two computational problems. First, they need to extract structure from the language input: Because most of the time, infants hear

[7] Some evidence suggests that this effect might be present as early as 3–4 months of age (e.g., Ferry et al., 2010). This evidence, however, should be taken with caution, as this facilitative effects appears to be sensitive to the acoustic properties of the stimuli (Lau et al., in press) and not necessarily represent word-referent links. For example 3- and 4-month-olds show a categorization effect driven by lemur vocalizations and English utterances, but not Cantonese utterances or birdsongs (see Woodruff Carr et al., 2021).

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continuous streams of speech, they need to determine where word boundaries are and what governs word-word co-occurrences. Second, infants need to resolve instances of referential ambiguity when learning novel word meanings. Does a word refer to an object, its parts, its properties, or its super-ordinate category? In order to learn correct word meanings, infants need to consider different mapping hypotheses and determine the most likely word-referent mappings.

The first problem is addressed by infants' capacity to discover structure in language input and segment it based on statistical regularities. This capacity enables 8-month-olds (Aslin et al., 1998; Jusczyk & Hohne, 1997; Saffran et al., 1996; see Saffran, 2020, for a review on word segmentation) and even 6-month-olds (Shukla et al., 2011), to extract words from a continuous stream of speech and visual input (Kirkham et al., 2002). At this age, infants can generalize their acoustic representations of words to novel speakers and can also recognize familiar words, even when they were mispronounced (Bergelson & Swingley, 2018; interestingly, 11–14-month-olds perform poorly with mispronounced words, suggesting a shift in infants' understanding of linguistically relevant sources of variation). At least by 7 months, infants are able to recruit their statistical learning capacity to distill abstract rules from auditory (Ferguson & Lew-Williams, 2016) and visual input (e.g., Ferguson, Franconeri, et al., 2018; Rabagliati et al., 2012, 2019). By 9–10 months, infants integrate distributional cues both within and between words and with a combination of prosodic and phonotactic cues to determine the location of word boundaries (Mattys et al., 1999; see Jusczyk, 1999, for a review). By 12 months, infants use distributional cues not only to determine word boundaries but also to infer the rules of grammar (Gomez & Gerken, 1999; Morgan & Demuth, 1996). In this way, infants can identify unfamiliar words in a stream of speech and register their pattern of occurrence within utterances.

The second problem may be addressed by cross-situational comparison. By 14 months, infants become competent statistical learners and use a combination for co-occurrence statistics and cross-situational comparison to strip away noise in labeling data and learn correct word-referent associations (Smith et al., 2014; Smith & Yu, 2008). In considering their hypotheses about the meanings of novel words, infants may rely on a variety of strategies (Yurovsky & Frank, 2015). Some accounts claim that infants simultaneously acquire information about multiple candidate referents for the same word (e.g., McMurray et al., 2012; Yu & Smith, 2007; Yurovsky et al., 2014). Others have argued that word learners maintain a single hypothesis about the referent of any given word (e.g., Medina et al., 2011; Trueswell et al., 2013; these accounts however mainly draw on evidence from adults and preschoolers).

In addition, infants need to recognize that when different words regularly co-occur with the same object, they may pick out different aspects of that object. For example, when someone mentions a neighbor's car, they can be talking about its category membership ("car"), its color ("red"), or its speed ("fast"). By leveraging their ability to register commonalities and differences among the different situations and utterances in which they encounter a given word, infants may infer which aspect of an object or an event is the intended referent of that word. Indeed, both infants and adults rely, at least in part, on cross-situational statistics to establish mappings between syntactic categories (e.g., nouns, verbs) and kinds of meaning (e.g., objects, actions) (Monaghan & Mattock, 2009; Rebuschat et al., 2021). This capacity for cross-situational comparison, combined with the capacity to extract syntactic rules from word co-occurrence patterns, enables 14-month-olds to map nouns to kinds and adjectives to kind properties (e.g., Booth & Waxman, 2009). Infants' appropriate extensions of novel adjectives to object properties, and not kinds, illustrate that they recognize that a given entity can be described by different words depending on communicative intention and context.

Taken together, the reviewed evidence illustrates that by the time the first signs of verbal reference are observed, infants (1) possess representational capacities to maintain memories of absent entities and retrieve them upon hearing their names, (2) appreciate others' mental states and recognize the communicative function of speech, and (3) are equipped with powerful statistical learning mechanisms—distributional analysis and cross-situational comparison—that enable them to detect word boundaries, propose a set of possible word-referent mappings, and revise their hypotheses about those mappings as they accumulate more linguistic data. A question that remains open is what brings these precursor capacities together to enable verbal reference.

The Role of Social Contingency in Recognizing That Words Refer

As our review suggests, most precursor capacities of verbal reference are in place between 6 and 12 months of age. Yet infants' early word learning is slow and laborious (Carey, 1978; Fenson et al., 1994; Hollich et al., 2000; Nelson, 1973; Woodward, 2000) and there has been little evidence of referential understanding of *words* before age 1 (e.g., Pruden et al., 2006). In contrast, at 12–18 months, infants demonstrate substantial advances in their rate of word learning (Goldfield & Reznick, 1990; Nazzi & Bertoncini, 2003; Werker et al., 1998; but see Ganger & Brent, 2004, for an alternative view), begin integrating multiple cues to meaning (Beier & Carey, 2014; Pruden et al., 2006), and comprehend reference to absent entities. What changes in infants' word learning in this developmental window and what drives this qualitative shift (see Bergelson & Swingley, 2013, for a discussion)? We propose that infants gain insight into the words' referential nature and realize the tridirectional link between words, real-world referents, and mental representations (Figure 1) through their experience observing the power of words to trigger behaviors and other changes in their surroundings.

This key phenomenon has been described as *socially contingent responsivity*—a property of human interactions, in which an action or an utterance of one interlocutor is *contingent*[8] on actions or utterances of the other (Csibra, 2010). We will refer to this construct as "social contingency," for brevity. As infants experience and accumulate observations of language-mediated socially contingent interactions, they learn that others' speech and their own vocalizations and behaviors can elicit targeted responses from other people. Social contingency plays a critical role in establishing the tridirectional link: (a) By observing specific words (or vocalizations, if their own) used in socially contingent interactions resulting in fulfilling specific needs (e.g., getting food or a toy), infants realize that *words*

[8] While contingency does not guarantee causality, it is likely that contingent behaviors are perceived as causal. From 3 months, infants appreciate causal relations between events (White, 1988) and may understand causal effects of human actions (Leslie, 1982).

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are connected to real-world entities in a principled, lawful way, (b) By observing others produce specific intentional behaviors in response to specific words uttered in socially contingent interactions, infants realize that *words are also linked to mental states and mental representations* in a principled, lawful way, and (c) Finally, by observing others' intentional behaviors that are not ostensibly motivated by anything in their environment other than speech (e.g., wanting a cup of tea and asking for it) resulting in changes in that environment (e.g., an interlocutor brings a tea), infants may infer that *mental representations are linked to representations of real-world entities*, and words may be used to elicit specific mental representations in others that lead to corresponding changes in the world. Thus, *social contingency* may serve as the "glue" that enables an understanding of verbal reference that includes all three key components: Words, mental representations, and the real world. Moreover, infants' sensitivity to social contingency undergoes significant development throughout the first year (see below). This development, along with the development of the precursor capacities of verbal reference, may explain why the first signs of infants' comprehension of verbal reference to absent entities are observed by 12–14 months of age. Notably, this developmental window is marked by a nonlinear[9] qualitative shift in infants' word comprehension (Bergelson, 2020). Infant's word comprehension becomes substantially more robust, as measured by the proportion of looking to the target object in looking-while-listening procedures (Fernald et al., 2008). Bergelson shows that this shift is not explained by changes in infants' word input and instead must be driven by changes in infants' ability to take advantage of their word input. Our proposal is consistent with this argument and offers a mechanism that enables infants to take better advantage of word input.

If our hypotheses are correct and the shift toward appreciating the referential nature of words is indeed driven by social contingency, then several assertions must be supported by empirical evidence in developmental research. First, infants must attend to social contingency and show a preference to observe and participate in socially contingent interactions. Second, we should be able to show that increased exposure to socially contingent interactions predicts the quality of infants' language development, and word learning in particular. And third, infants' processing and perception of language should be enhanced by social contingency.

Infants' Sensitivity to Social Contingency

Investigations of parent–child interactions suggest that infants are indeed sensitive to social contingency and that parents' responsiveness to infants' vocalizations shapes infants' expectations about the power of those vocalizations to trigger others' behaviors. Among the first socially contingent interactions experienced by an infant is breast feeding, which is sometimes described as a proto-conversation between an infant and a mother (see Csibra, 2010). As an infant ceases to suck, a mother encourages sucking by jiggling him or her. The infant then resumes sucking after jiggling stops (Kaye, 1977). Soon after, at 3–5 months, when infants begin to engage in contingent face-to-face interactions with others, they show a preference for more contingent partners, associate the level of contingency with their personal identities, and retain this association over time (Bigelow, 1996; Rochat et al., 1998). By 5 months, infants appear to infer that their own actions evoke responses from others. For example, using a still-face procedure,[10] Goldstein et al. (2009) showed that 5-month-olds significantly increased noncry vocalizations in response to the experimenter's ceased contingent responsiveness. These vocalizations may signal attempts to initiate contingent interactions with the experimenter and indicate that infants are not only capable of engaging in contingent interactions but also actively seek them.

Further, by setting expectations about the level of social contingency and selectively responding more to some behaviors than others, caregivers help infants clarify the link between their own behaviors and expected responses. For example, in Bigelow and Rochat (2006), infants were less responsive to strangers whose level of contingency was either significantly higher or lower than that of their mothers. Evidence from still-face experiments also shows a strong predictive effect of caregivers' responsiveness on infants' own level of contingency. Mcquaid et al. (2009) found that maternal contingent smiling predicted infants' individual differences in smiling during the still-face phase of the procedure, which indicated that infants had expectations about social interactions and their own ability to initiate an interaction. Bornstein et al. (2015) investigated the development of infant–parent contingent interactions in naturalistic settings and found a strong tendency among mothers of 5.5-month-olds to speak to their infants following nondistress (not related to hunger or discomfort) vocalizations. Moreover, as parents shift communicative actions directed at their infants from mood regulation to behavior influence over time (e.g., from 7 months to 15 months; see Kochanska & Aksan, 2004), infants' positive responsiveness to those actions increases. In particular, infants' social overtures and influence attempts increased and distress reactions decreased in response to parents' communicative bids.

In sum, studies of infant–adult interactions strongly suggest that social contingency plays a significant role in infants' communicative development, guiding both their social expectations and communicative behaviors directed at others. What about the effects of social contingency on spoken language development? Do infants' sensitivity to social contingency and their strong association between social contingency, agency, and communicative signals influence their language acquisition, and word learning in particular?

Looking to establish a link between social contingency and language outcomes, Gros-Louis et al. (2014) observed 8–14-month-olds' interactions with their mothers in naturalistic settings over the course of 6 months. Mothers' responses and imitation of infants' vocalization correlated with the increase in infants' mother-directed vocalizations in the following month and predicted more mature consonant–vowel vocalizations. Further, infants of more responsive mothers had larger productive vocabularies at 15 months. These results suggest that social contingency may indeed facilitate language development, and that this facilitative effect permeates multiple facets of language acquisition.

A number of correlational and longitudinal studies also found a predictive effect of parents' contingent responsiveness on verbal and social competence later in development. For example, Bornstein and Tamis-LeMonda (1989) observed mother–infant dyads when infants

[9] Some have proposed that this shift, described geometrically as an inflection point on the graph of infants' receptive vocabulary as a function of their age, is best modelled by a logistic function (e.g., Ganger & Brent, 2004).

[10] An infant first interacts with an adult who responds contingently to infant's actions and vocalizations. The adult then turns away and turns back, showing a "still face," or a lack of responsiveness to the infant. The adult later resumes a contingent interaction with the infant (see Cohn & Tronick, 1983).

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were 2–5-months and assessed their cognitive development at 13 months and 4 years. Maternal responsiveness predicted language comprehension and pretend play at 13 months and higher scores on Wechsler Preschool and Primary Scale of Intelligence at age 4. Similarly, Olson et al. (1984) reported a significant relation between maternal responsiveness[11] when infants are 6 and 13 months and their receptive vocabulary at 24 months (measured by Bayley Mental Developmental Index [Bayley MDI] and Peabody Picture Vocabulary Test [PPVT]). Moreover, when maternal responsiveness was measured specifically in terms of mothers' verbal activity in response to infants' vocal or exploratory behaviors[12], the analyses revealed that such responsiveness at 9 months predicted infants' language comprehension at 13 months (Baumwell et al., 1997). Similarly, Rollins (2003) observed parent–infant dyads engaged in naturalistic interactions and found that words uttered within socially contingent interactions at 9 months, where the mother *talked about* an object of joint focus of attention or *narrated* an ongoing activity, predicted language comprehension at 12 months.

These studies lend support to our hypothesis that increased exposure to and participation in socially contingent interactions benefits infants' word learning and broader language development at later ages. Notably, the reviewed longitudinal studies report language learning benefits of exposure to social contingency at 12–14 months—the developmental window associated with the emerging ability to comprehend verbal reference to absent objects and marked by a nonlinear increase in infants' word comprehension (see Bergelson, 2020). Thus, the observed effects may indeed reflect the hypothesized facilitative influence of social contingency on infants' understanding of the referential nature of words.

It is possible, however, that infants who experience more socially contingent exchanges simply hear more language from their parents and benefit from the increased exposure to more types and tokens of words compared to infants who experience fewer such exchanges. To our knowledge, there has been no direct empirical investigation of the relation between social contingency and the development of verbal reference. However, converging evidence from several lines of work suggests that the effect of social contingency on the development of verbal reference cannot be explained by the mere increase in exposure to word input.

First, findings from the investigations linking children's exposure to vocabulary and their language learning outcomes provide evidence that rich vocabulary input alone is not sufficient to facilitate qualitative shifts in one's understanding of the referential nature of words. Although some findings suggest that children who hear a lot of child-directed speech (CDS) and children whose CDS input is relatively scarce are exposed to comparable total word input, after ambient speech has been taken into consideration (e.g., Sperry et al., 2019), only child-directed speech has been consistently linked to vocabulary growth (e.g., Hoff, 2003; Shneidman et al., 2013; Shneidman & Goldin-Meadow, 2012). Importantly, child-directed speech is more likely to be socially contingent as caregivers respond to infants' and children's vocalizations and word productions (e.g., Gratier et al., 2015; Tomasello & Farrar, 1986; Veneziano & Parisse, 2010), suggesting that the effect of social contingency on language development goes above and beyond mere exposure to words. Indeed, Donnelly and Kidd (2021) examined infants' natural language environment (using LENA recordings) between 9 and 24 months, measuring their language input and participation in socially contingent verbal exchange, operationalized as conversational turns. They found that conversational turns predicted change in infants' vocabulary even after word input variables (i.e., types and tokens) were controlled for.

Second, Tamis-LeMonda et al. (1996) showed that maternal verbal responsiveness to infants' verbal bids (vocalizations, word production), but not their verbal responsiveness to play behavior, predicted 13- and 20-month-olds' language comprehension and production (see also Tamis-LeMonda et al., 2001). This finding suggests that the rate of mothers' verbal responses specifically to verbal behaviors and not mothers' overall verbal responsiveness predicted infants' success with language. Further, a study with older slow-to-talk children revealed that maternal expansions, imitations, interpretations, and responsive questions positively correlated with 24-month-olds' language comprehension and production (evaluated on Preschool Language Scale, Zimmerman et al., 2002), while labeling responses negatively correlated with these measures (Levickis et al., 2014). This finding provides additional support to the idea that increased exposure to word input alone is unlikely to explain the effects of social contingency on the development of verbal reference in infancy.

Third, young children appear to ascribe communicative properties to signals that are embedded in socially contingent interactions, even if those signals are not typically associated with human behaviors. Six-month-old infants privilege speech sounds over sine-waves (Vouloumanos & Werker, 2004) and preferentially treat speech but non sine-waves as invitations to form categories (Fulkerson & Waxman, 2007), which suggests that at this age they have a strong bias to treat speech as a communicative signal. Ferguson and Waxman (2016), however, showed that despite not normally treating sine-wave tones as language, after a period of exposure to those tones used in a rich communicative exchange between two actors, 6-month-olds extended word-like properties to them. Infants formed object categories based on a series of tone-image presentations—an effect normally observed for words but not sine-wave tones at this age (see Fulkerson & Waxman, 2007). Similarly, hearing 26-month-olds, who have accumulated substantial experience using speech, and not sign language, to communicate, accepted signs as object labels after observing sign language embedded in a socially contingent exchange between two interlocutors (Namy & Waxman, 1998). These results provide a powerful demonstration of the effects of social contingency on the perceived referential status of new stimuli, which can be achieved even within a short experimental exposure to those stimuli. In contrast, infants and children with autism spectrum disorders, who have difficulties detecting and responding to social

[11] Maternal responsiveness was measured as (a) contact and proximity behaviors (look at infant for at least 2 s, approach infant, pick up infant, put down infant, affectionate touch, bounce, jiggle, or rock, put to shoulder, leave infant's view), (b) facial expression (smile, grin at infant, frown/grimace at infant), (c) verbal or vocal stimulation(distal vocalization to infant, proximal vocalization, "sweet, musical quality"; proximal vocalization, normal quality; negative vocalization), (d) play stimulation (give toy or object, give toy or object and work it for infant, return dropped toy, tickle or poke infant), and (e) physical needs caregiving.

[12] Responsiveness was defined as a positive and meaningful change in mother's verbal behavior subsequent to and dependent on a child exhibiting a vocal or exploratory act. If a child looked at the brush and mother said "brush," mother was credited with responsiveness. In order for a maternal verbal activity to be credited as responsive, mother had to change her ongoing behavior within 5 s of a change in a child visual or vocal activity.

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contingency, tend to have difficulties attributing communicative properties even to natural languages (see Northrup, 2017, for a review).

Finally, corroborating evidence comes from investigations comparing infants' and young children's speech processing and word learning in contingent and noncontingent settings. Kuhl et al. (2003), for example, evaluated 9-month-olds' sensitivity to a foreign language phonetic contrast after 5 hr of exposure, split into 12 laboratory sessions. One group of English-acquiring infants interacted with a native speaker of Mandarin Chinese. The speaker played with the infants and read books to them. The other two groups were exposed to a video- or an audio-recording of the same speaker. In the video, the speaker looked to the camera to emulate eye contact. Only infants in the live interaction condition performed above chance on the phonetic discrimination test after 12 weeks, at the level comparable to that of Mandarin-acquiring infants. Consistent with our hypothesis, these results suggest that phonetic learning is facilitated by social contingency, which may be due to infants' enhanced processing of linguistic information: Socially contingent interactions may have boosted infants' understanding of Mandarin Chinese as a form of communicative signal. Further, although the same word-referent co-occurrence cues are present in both live and video-recorded speech, infants often fail to learn new word-referent links from watching video-recordings—a phenomenon known as the "video deficit" (Anderson & Pempek, 2005). Infants and young children exhibit such a deficit even when watching television programs that emphasize repetition and emulate infant-directed speech in labeling events (DeLoache et al., 2010; O'Doherty et al., 2011; Richert et al., 2011; Robb et al., 2009). In contrast, when offered an opportunity to learn novel words via socially contingent video chat, 24–30-month-old children succeed and show word-learning outcomes comparable to that in a live in-person interaction (Roseberry et al., 2014). A recent finding also demonstrates that 12-month-olds infants' word learning from a digital screen is enhanced by the presence of a contingent virtual agent who uses referential cues (Tsuji et al., 2020). Critically, a mere co-presence of a socially contingent interaction does not enhance infants' word learning outcomes. DeLoache et al. (2010) found that 12–18-month-olds did not learn words presented on video by an *experimenter*, if *parents* contingently interacted with their infants during the video exposure. They only learned the new words *presented by the parents* during socially contingent interactions, suggesting that social contingency enhances infants' word learning if those words are taught *within* a socially contingent interaction, rather than merely co-occurring with it.

Together, cross-sectional and longitudinal investigations suggest that increased exposure to social contingency early in infancy predicts larger vocabularies in the long term and enhances phonetic and word learning in the short term. These studies provide highly suggestive evidence for our hypothesis and illustrate that accumulated exposure to social contingency and infants' growing sensitivity to socially contingent displays indeed facilitate infants' realization that words are used for communication and they refer to mental representations that correspond to the real world.

Importantly, infants' attention to social contingency increases with age and becomes dissociated from morphological properties of interlocutors, which may be the reason why we begin to observe its effects on the development of verbal reference by 12–14 months and not earlier. For example (as reviewed in Thiele et al., 2021), at 6 months, infants shift visual attention to a reciprocal social interaction of two people facing each other (Augusti, 2010). By 12 months, infants look longer at socially contingent over nonsocially contingent events (Bakker et al., 2011) and engage in gaze following (or orientation) with entities that act in a socially contingent way, even if they do not have faces (Johnson et al., 1998). Shimizu and Johnson (2004) also found that 12-month-olds will attribute goal-directedness to morphologically unfamiliar but socially contingent agents who engage in reciprocal communication. Finally, at 13 months, infants' preference for socially contingent displays manifests even in associative learning scenarios: Infants are better at learning a predictive relation between a visual cue and a socially contingent display than a visual cue and a non-contingent display (Thiele et al., 2021).

These findings suggest that at this age infants may not only prefer socially contingent displays but also recognize socially contingent entities as agents and privilege the value of information coming from those agents (see Rochat, 2007, for a review). Thus, between 6 and 13 months infants' developing sensitivity to socially contingent interactions begins to influence their interpretation of the information presented in the context of such interactions (see Rochat, 2001, for a review). Infants' growing social competence factors into this development by informing their inferences about social and nonsocial type of contingency and selectively privileging information presented in the context of *socially contingent* interactions.

In sum, extant research suggests that participating in and observing socially contingent interactions, and especially *language-mediated* interactions, affects infants' communicative development by providing insight into the *referential status of words*. Infants are more likely to learn novel words and phonetic contrasts in socially contingent contexts. They are also willing to extend word-like communicative properties to non-linguistic signals used in socially contingent interactions. Infants who participate in and observe socially contingent interactions more often tend to have larger vocabularies. Although socially contingent interactions are present early, infants' gradually increasing attention to such interactions, combined with the development of other precursor capacities, likely explains why the first signs of understanding that words refer (measured as absent reference comprehension) emerge at around 12–14 months of age.

Developmental Advances of Attaining a Referential Understanding of Words

Attaining an understanding of the referential nature of words allows infants to establish strong bidirectional links between words and mental representations, as well as the links between mental representations and their real-world counterparts, and to realize how words can affect the world via mental representations. This implies an appreciation that words are used intentionally and are meant to cause change in others' actions or mental states. It also entails the capacity to propose hypotheses for word meanings and revise these hypotheses as more linguistic (e.g., syntactic contexts) and word-referent co-occurrence data are accumulated. In concert, these capacities constitute verbal reference and enable infants to integrate multiple cues to word meanings (by 12–14 months; see Luchkina & Waxman, in press) and acquire vocabulary with high efficiency (see Hollich et al., 2000, for a review).

Gaining the appreciation of the tridirectional link between words, mental representations, and real-world referents enables infants to recognize that words likely encode and transmit relevant information and are worth their attention, without needing a socially contingent context any longer. Knowing that words are linked to the world in a principled, lawful way, they realize that even speech not addressed to them has that property. This realization enables them to engage in increasingly decontextualized forms of language-mediated learning and expand their social knowledge and factual knowledge, rapidly acquire new vocabulary and syntax. We elaborate on several key advantages of attaining a referential understanding of words below.

One such advantage is the ability to learn new information in nonostensive contexts, such as overhearing a conversation. Floor and Akhtar (2006) compared 18-month-olds' ability to learn novel object labels in two contexts—while being directly addressed and while observing an interaction as a third party. In the Addressed condition, an experimenter interacted with the infant, made eye contact, and ostensibly labeled a novel object (additional three novel objects were ostensibly demonstrated but not labeled). In the overhearing condition, the experimenter interacted with an adult confederate while the infant was present and had an opportunity to observe their interaction. The same objects were demonstrated and one labeled, as in the Addressed condition, in which the interaction was between the experimenter and the infant. The results revealed that 18-month-olds learned the novel object-labels equivalently well in both conditions and their test performance was not driven by an intrinsic preference for a specific object. These findings illustrate that 18-month-olds have the ability to learn word meanings in nonostensive scenarios, without being directly addressed.

At this age, infants also begin to make sophisticated inferences about word meanings in nonostensive contexts based on social cues. For example, Tomasello et al. (1996) found that 18-month-olds learn novel words equivalently well in a situation in which an experimenter introduces a novel word and retrieves its referent from a container immediately after ("Now let's find the gazzler"; ostensive context), and in a situation, in which she first retrieved an incorrect object, frowned at it, and replaced it with the correct one (non-ostensive context). Despite having seen a distractor object demonstrated right after the novel word was introduced, infants used social cues to infer the intended meaning of the word. By 24–30 months, children are able to learn novel word meanings in non-ostensive contexts from a third-party interaction, even when they are distracted by an engaging activity (Akhtar, 2005). Finally, at least by age 3, children can learn object names and facts about those objects from overhearing a seemingly irrelevant cell-phone conversation, or "halfalogue" (Emberson et al., 2010; Foushee et al., 2021). Critically, this form of learning cannot be explained from a strictly associationist perspective. Not only is the linguistic information presented in a nonostensive manner, but the naming events often happen in the absence of word referents, which necessarily entails that children map words onto mental representations and recognize that these word-representation links extend to real-world objects or events. These advances in learning from overhearing substantially expand the reach of children's learning beyond the here-and-now and allow them to benefit from the information exchanged in their social environments but not directed at them. Such information can include diverse vocabularies (e.g., used in adult-directed speech), social routines (e.g., greeting, expressions of sympathy), and facts about the world ("The neighbor's dog is dangerous").

Another significant advantage of attaining a referential understanding of words is the ability to create and update mental representations of objects based on language alone. For example, by 18–19 months, infants can establish a representation of nonvisible novel object, learn its name, and subsequently use this name to identify the correct referent when it becomes perceptually available, based on referential cues and mutual exclusivity inferences (Baldwin, 1993b; Tomasello et al., 1996). By 22 months, children update mental representations of previously seen objects based on language alone. In Ganea et al. (2007), for example, 22-month-olds were familiarized with a toy frog "Lucy" that was subsequently hidden, and infants heard a story in which Lucy became wet. When presented with a wet toy frog and an identical-looking dry toy frog and asked to identify "Lucy," 22-month-olds selected the wet toy, demonstrating having successfully extracted novel information and updated existing representations based on language alone. By 30 months, children can learn names of novel objects and facts about them from verbal descriptions and subsequently identify the correct objects without having previously seen them (Saylor et al., 2016). Similar to learning words from overhearing, learning facts from language alone necessarily requires that a child's understanding of word-referent link surpasses the level of perceptual associations. Without being able to link language input with representations of word referents, a learner should have no basis for identifying a referent of a word or an utterance they had heard in the absence of any objects or events that can be associated with it. Thus, these studies illustrate the far-reaching impact of verbal reference on children's capacity to extract novel information from language, create and modify mental representations on its basis, and use this knowledge to identify their real-world counterparts. This capacity is central to formal and much of informal instruction (as both convey information via language) and has profound implications for knowledge acquisition and school readiness.

In addition to gaining access to information encoded in language and learning in non-ostensive contexts, the understanding that words refer may boost children's ability to take advantage of linguistic cues to infer the meaning of novel words from language alone. Before realizing that words are linked to mental representations, infants may notice a pattern in which an unfamiliar word co-occurs with known words within utterances. However, without anything to map that word onto, they may not be able to leverage this information. The referential understanding of words may benefit vocabulary acquisition by allowing infants to create a representation of a novel referent based on semantic and syntactic bootstrapping. For example, at 19 but not at 15 months, infants can establish a mental representation of an object, paired with a novel label, without seeing that object and just relying on semantic properties of the carrier phrase (Ferguson, Graf, et al., 2018). Specifically, 19-month-olds inferred the animacy of an object corresponding to a novel name, presented in the absence of any conceivable referents, based on the predicate that modifies it, "the dax is crying" versus "the dax is right here." When shown a pair of images and asked to identify the "dax," infants who encountered "dax" in an utterance that implied its animacy, were significantly more likely to select the animate referent than infants who heard a neutral utterance. By age 2, children can use syntactic information, such as verb transitivity, to create a representation of a novel action (Arunachalam et al., 2013; Yuan & Fisher, 2009).

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Arunachalam and Waxman (2010) demonstrated that children who observed two speakers converse and mention a novel verb in a transitive sentence ("The lady mooped my brother") subsequently were significantly more likely to choose a causative video scene than toddlers who heard that verb in an intransitive sentence ("The lady and my brother mooped"). At this age, children also generalize animacy-selecting restrictions of novel verbs, learned in the absence of any visual information, to other nouns within the animate and the inanimate categories (e.g., first hearing "I stiped the pig" and subsequently selecting an animate object when asked to identify an object that can be "stiped"; Yuan et al., 2011). Finally, by 27 months, children can make these inferences even when they hear the novel words in socially -impoverished contexts: Mentioned in adult-directed speech, with no discourse, and with linguistic information unaccompanied with any visual information (Arunachalam, 2013). Combined, these studies suggest that from the onset of the referential understanding of words, infants leverage syntactic and semantic bootstrapping to infer the meanings of novel words in increasingly decontextualized situations. Being able to infer the properties of a novel referent from the word's surrounding linguistic context helps infants narrow the range of possible candidate meanings of the novel word and increase the likelihood of identifying the correct referent when it becomes perceptually available.

Yet another advantage of attaining a referential understanding of words is that it changes infants' sensitivity to distributional information, such as word-referent co-occurrence statistics. By realizing that words refer, infants gain additional appreciation of the relevance of this information: Knowing that words refer to mental representations and their real-world counterparts and encode information intentionally communicated by others, infants may pay more attention to word input and referential cues in their learning. Combined with targeted consideration of the most likely word-referent hypotheses, this enables infants to transition from slow and laborious word learning that results from repeated exposure to co-occurrence statistics, to learning novel word meanings from witnessing only a few word-referent co-occurrences. For example, Woodward et al. (1994) show that by 18 months, infants successfully learn novel word meanings after just nine mentions of the target word and retain them after 24 hr. Notably, 18-month-olds in this study responded correctly on test trials 76% of the time, while 13-month-olds' performance averaged around 62%. In a recent report, LaTourrette and Waxman (2019) show that by age 2, children learn novel word meanings after observing only two members of a category labeled as well as when all six members of that category are labeled. By age 4, children learn novel word meanings from a single labeled example as well as from three examples and successfully generalize those meanings to other members of the same subordinate, basic-level, or superordinate category (Xu & Tenenbaum, 2007b). One may argue that this developmental progression is driven by children's increasing memory capacity. However, investigations of infants' memory development indicate that by 9–10 months, infants successfully remember sequences of events over the span of months (Bauer, 2002; Carver et al., 2000; Mandler & McDonough, 1995). Thus, it is unlikely that this rapidly increasing ability to learn novel word meanings from only a few examples can be entirely explained by the growing memory capacity. Instead, we suggest that these effects may be a consequence of children's encoding of labeling information being enhanced by attaining a referential understanding of words.

Other developmental benefits of attaining a referential understanding of words include advances in social reasoning, such as the ability to make inferences about others' knowledge based on their language production. Recall that we define verbal reference as a tri-directional link between words, real-world referents, and their mental representations used for intentional communication between people. This implies that a naming event reflects both their intention to communicate information about a referent, their knowledge of the word-referent mapping, and their ability to recognize a given object or event as an instance of a known referent category paired with a word. Thus, upon attaining a referential understanding of words and aided by recognizing the conventional nature of words (by at least 14 months; Buresh & Woodward, 2007; Colomer & Sebastian-Galles, 2020; Henderson & Woodward, 2012; Scott & Henderson, 2013), infants begin to make inferences about such states based on the quality of information they communicate via language. For example, by 18 months, infants track whether others use correct words to describe familiar objects and only learn novel word meanings from speakers who do not make mistakes in naming (e.g., Brooker & Poulin-Dubois, 2013; Luchkina et al., 2018). Luchkina et al. (2018) showed infants a video of two actors, one of which demonstrated familiar to the infant objects and labeled them accurately and the other demonstrated a different set of familiar objects and labeled them inaccurately (e.g., "Look, a shoe," while showing a book). The infants subsequently saw a video, in which either the accurate or the inaccurate speaker (between-subject) introduced two novel objects and labeled them. Infants' word knowledge was probed in an intermodal preferential looking procedure. While infants in both groups performed well on control trials and consistently looked to the correct familiar objects, only infants who learned the novel labels from the accurate speaker looked significantly more to the target novel object. These findings suggest that 18-month-olds track others' accuracy in object naming, use this information to make inferences about others' knowledge states and selectively learn new words from speakers they deem epistemically competent. This developing capacity allows infants to leverage their word knowledge to monitor the quality of the language input they receive and selectively learn and retain information from reliable sources. In preschoolers, studies also found that learners can take into account the epistemic state of the speaker and decide accordingly how best to integrate the language input in learning new words (Harris & Corriveau, 2011; Koenig & Harris, 2005; Sobel & Kushnir, 2013; Xu & Tenenbaum, 2007a; see Harris, 2012, for a review).

The empirical evidence reviewed above illustrates the profound and far-reaching effects of understanding the referential nature of words. We propose that this understanding fundamentally changes the way infants attend to, process, and retain linguistic information and powers multiple learning capacities that are essential for cognitive development. These proposed effects invite new empirical investigations, some of which we outline in the final section.

Conclusions and Future Directions

In this paper, our goal was to explain the development of verbal reference through aggregating insights from multiple facets of research on language and cognitive development. We reviewed empirical evidence on infants' emerging understanding of the referential nature of words; argued that conceptual, social, representational,

and statistical learning capacities must operate in concert to enable such an understanding; and hypothesized that infants arrive at the realization that words refer via engaging in and observing socially contingent interactions. We also argued that by serving as "cement" that brings together multiple cues to meaning, verbal reference facilitates a qualitative shift in infants' word learning, enabling them to acquire novel words with remarkable efficiency. Finally, we proposed that this shift ultimately enables infants to engage in language-mediated learning and acquire knowledge about the world and about their communicative partners via language.

In sum, we reviewed multiple literatures on early cognitive development and proposed a constructivist account of the origins and mechanisms of the development of verbal reference, having discussed cross-sectional and longitudinal evidence corroborating our arguments. Our account represents the constructivist approach to language and cognitive development because it offers a set of primitives (or building blocks) that in combination drives conceptual advances in infants' understanding of word-referent relations, which in turn, lead to shifts and new constraints in infants' interpretation of linguistic and social input. These properties are characteristic of constructivist views of human development and contrast sharply with pure nativist (which emphasizes innate cognitive architectures) and pure empiricist (which emphasizes the role of associative mechanisms operating on primitives) approaches (Cohen et al., 2002; Xu, 2019; Xu & Kushnir, 2013; see also Hirsh-Pasek et al., 2004; Hollich et al., 2000).

In addition to the existing evidence, more direct empirical tests will be necessary to provide strong evidence for our proposed account. We, therefore, invite such investigations and suggest several directions of research that will contribute to our understanding of the development of verbal reference and its role in transforming lexical acquisition and enabling language-mediated learning.

One direction of empirical investigations is to test whether social contingency indeed facilitates the referential understanding of words. For example, longitudinal studies can test whether infants of more socially contingent parents begin to show signs of comprehending speech about absent entities earlier and whether changes in infants' own socially contingent vocalizations predict the onset of this comprehension. Cross-sectional laboratory studies can investigate caregiver–infant interactions and examine whether and how caregivers' contingent responsiveness helps infants recognize that words, referents, and others' behaviors are linked in a principled, lawful way. Similarly, observations of such interactions can be instrumental in determining whether infants who observe and participate in socially contingent interactions more often are more likely to recognize the communicative nature of speech and link it to mental states. Further, laboratory and longitudinal investigations measuring the properties of parents' language production will distinguish between the effects of social contingency and the effects of the quality and quantity of verbal input. The combination of cross-sectional and longitudinal studies will provide a more complete picture the mechanisms driving the development of verbal reference. It will also help address the outstanding questions about infants' ability to learn novel words without seeing their referents and their ability to retain those mappings.

Another direction of empirical research is to test whether having attained a referential understanding of words indeed predicts qualitative shifts in infants' word learning and whether it marks the onset of language-mediated learning. For example, are infants who display the comprehension of speech about absent entities more likely to learn novel words from just a few labeling events than their peers who do not yet display such a comprehension? Similarly, are infants who demonstrate an ability to learn novel word meanings in the absence of their referents earlier also more likely to learn novel facts from language alone at earlier ages, and be able to update their mental representations of objects and events via language alone? To conduct these investigations, it is critical to establish an experimental procedure that can effectively measure whether infants have attained a referential understanding of words. One such procedure, which leverages infants' ability to learn the meanings of words in the absence of their referents using infants semantic networks, has been proposed by Luchkina and Waxman (2021). A longitudinal follow-up that investigates whether differences in this ability at 15 months predict differences in language-mediated learning at 22 months, is underway.

These and other empirical investigations will help us gain a better understanding of the mechanisms underlying word learning and the development of verbal reference in the first 2 years of life. Combined, these insights will advance our understanding of the development of the fundamental human capacity to establish, retrieve, and modify knowledge based on information encoded in and transmitted via language.

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(*Appendix follows*)

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Appendix

Developmental Timelines of Verbal Reference and its Precursor Capacities

Capacity	3–6 mo	6–9 mo	9–12 mo	12–14 mo	14–18 mo	18–24 mo
Representing absent entities	• Form visual categories • Form prototypes • Form vowel and consonant categories • Recognize intonation patterns • Form short-term memories • Represent the existence and location of hidden objects	• Form superordinate categories • Distinguish between content and function words • Retain memory of an event for at least 24 hr	Remember sequences of events over the span of months			
Using speech to communicate about absent entities		• Keep track of others' desires and beliefs • Expect speech to communicate about objects and desires	• Recognize that beliefs can guide actions • Only admit words and gestures as ways to communicate about beliefs	• Infer information transfer based on verbal exchange • Use verbal cues to retrieve memories of absent objects		
Segmentation			Extract words from a continuous stream of speech and remember them for extended periods of times	Integrate distributional cues with prosodic and phonotactic cues to identify word boundaries	Use distributional cues to infer the rules of grammar	
Cross-situational comparison			Show evidence of being guided by word-learning constraints	Leverage co-occurrence statistics and cross-situational comparison to learn correct word-referent associations	Adaptively choose different strategies n considering alternative word-referent mappings	
Words pick out different aspects of objects				• Map different grammatical forms to different aspects of objects • Words denote kinds (vs. instances)		
Attention and sensitivity to social contingency	• Engage in contingent face-to-face interactions with others • Expect one's own actions evoke responses from others	• Produce parent-directed vocalizations • Extend word-like properties to non-speech signals used in communicative exchange • Shift visual attention to a reciprocal social interaction of two people facing each other	• Show enhanced learning of phonetic contrasts embedded in socially contingent interactions • Look longer at socially contingent over non-socially contingent events	• Show enhanced word learning from a digital screen in the presence of a contingent virtual agent who uses referential cues • Attribute goal-directedness to morphologically unfamiliar but socially contingent agents who	Show enhanced learning of novel words first introduced in a socially contingent context	

(*Appendix continues*)

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Appendix (*continued*)

Capacity	3–6 mo	6–9 mo	9–12 mo	12–14 mo	14–18 mo	18–24 mo
				engage in reciprocal communication • Show enhanced associative learning in a socially contingent display than a visual cue and a non-contingent display		
Referential understanding of words				• Understand that pointing can refer to recently hidden objects • Use pointing for such reference; understand verbal reference to objects recently removed from sight • Interpret verbal requests for hidden objects using social information	• Recognize properties of recently removed objects whose labels are mentioned • Comprehend reference to absent entities that is not "anchored," or primed	• Update mental representations of absent objects based on speech alone • Establish representations of novel objects based on speech alone

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