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The Pervasive Role of Pragmatics in Early Language

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Abstract

Language is a fundamentally social endeavor. Pragmatics is the study of how speakers and listeners use social reasoning to go beyond the literal meanings of words to interpret language in context. In this article, we take a pragmatic perspective on language development and argue for developmental continuity between early nonverbal communication, language learning, and linguistic pragmatics. We link phenomena from these different literatures by relating them to a computational framework (the rational speech act framework), which conceptualizes communication as fundamentally inferential and grounded in social cognition. The model specifies how different information sources (linguistic utterances, social cues, common ground) are combined when making pragmatic inferences. We present evidence in favor of this inferential view and review how pragmatic reasoning supports children's learning, comprehension, and use of language.

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INTRODUCTION

From a toddler pointing at a toy and saying "dat!" all the way to an adult writing a lukewarm letter of recommendation, human beings use language to communicate an infinite range of meanings both flexibly and efficiently. Although all linguistic forms have conventional meaning within a language community, these meanings nevertheless can give rise to interpretations that are unique to the current circumstances. The term pragmatics describes this flexible use of language in context, deriving from the Greek noun πρᾶγμα (*pragma*), which refers to an act or deed. Literally, pragmatics refers to aspects of linguistic meaning that derive from the act of speaking in a particular situated context.

Human communication in context is fundamentally inferential. Because of the flexibility of pragmatic interpretation, speakers' intended meanings are always underdetermined by the linguistic forms they utter.[1] For example, the same utterance ("This is my favorite") can be used to refer to very different things depending on the speaker and the context. Thus, to recover a speaker's intended meaning, a listener must combine observable information from the utterance with information about the circumstance, the speaker and their relation to the listener, and any other relevant details of the context. Because this inferential process is social in nature—its goal is to infer another agent's internal state—from a psychological perspective, pragmatic inferences are essentially an application of social cognition (Clark 2009, Shafto et al. 2012, Sperber & Wilson 1995, Tomasello 2008).

Anyone who has interacted with young children knows that, although their knowledge of linguistic forms and conventions is imperfect, they can communicate quite effectively. How do

[1] We use the terms "language," "speaker," "utterance," and "word" to refer to any kind of conventional symbolic system, independent of the modality of expression.

communicative abilities emerge and develop during infancy and early childhood? A rich research tradition links the emergence of communication and the processes of language acquisition. Researchers in this tradition argue that children learn language by reasoning about the intentions of the people who produce it. From its descriptive beginnings in work by Nelson (1973) and Bates (1976), this line of research has become an influential strand in our understanding of the processes underlying language learning (e.g., Bloom 2002, Clark 2009, Tomasello 2003).

In recent years, an equally rich empirical literature has used frameworks from linguistic pragmatics (e.g., Grice 1975) as a starting point for investigating children's ability to make pragmatic inferences (e.g., Huang & Snedeker 2009, Papafragou & Musolino 2003, Stiller et al. 2015). The focus in this second strand of work is on how children resolve linguistic ambiguities by reasoning about the speaker's intentions. Thus, both traditions emphasize the importance of social cognition for communication.

The key findings in these two literatures seem to contradict one another, however. Research on the origins of language describes 1-year-olds as deeply engaged with others' intentions in communicative interactions. In contrast, research on the development of linguistic pragmatics has focused on phenomena such as scalar implicature and has emphasized children's struggles with pragmatic inferences at ages of 3 to 6 years. In this article, we attempt to synthesize these sometimes-disparate literatures, relating the development of pragmatic communication from its roots in early social cognition to the sophisticated linguistic inferences available to adults.

Along the way, we have several interlocking goals. First, we hope to connect research on many different aspects of pragmatic inference by making use of an emerging theoretical framework for pragmatic inference, the rational speech act (RSA) framework (Goodman & Frank 2016). Second, using this framework, we can ask questions about the loci of developmental change. We focus specifically on whether we see evidence for developmental changes in the core components of pragmatics, especially the extent to which inference abilities develop.

Our final goal is polemical. We argue that throughout early language development, social communication is the central organizing principle of language use. Since, as we will argue, language learning occurs in the context of use, communication is central to learning as well. And since the core of this kind of communication is inference about unseen goals, language learning occurs within an inferential, pragmatic context. Thus, pragmatics plays a pervasive role in early language learning, such that the theoretical framework for pragmatic inference that we use here can also be thought of as an organizing framework for language learning more broadly. Put another way, language learning is just language use with a higher degree of uncertainty about the language itself.

Our outline is as follows. We begin our review by introducing the RSA framework in the context of previous theories of pragmatics. We next turn to the origins of communication in infancy (ages 6–18 months), arguing that the evidence supports a view by which infants' early linguistic knowledge is rooted in an understanding of its communicative role. We then review how this communicative view underpins processes of early language learning (ages 1–3 years), unifying a range of phenomena in the literature on vocabulary acquisition. We end by turning to the literature on communication and communicative inference in early childhood (ages 3–6 years), reviewing evidence on developmental changes in pragmatic abilities. The developmental view that emerges from our review is one in which fundamental assumptions about the nature of communication are largely conserved through infancy and childhood, even as children's other abilities—ranging from their linguistic competence to their more general cognitive abilities—are undergoing substantial changes. This combination leads to a radical expansion of children's competence despite continuity in their assumptions about the nature of communication.

WHAT IS PRAGMATIC INFERENCE?

A central challenge to organizing the literature on communication in early language learning is that the term pragmatics and its various related constructs and subcomponents mean such different things in different literatures. In some sense, interpreting the term pragmatics is itself a pragmatic issue. For example, some literature takes the terms pragmatic information and pragmatic cues to mark all contextual and paralinguistic information (e.g., pointing, gesture, gaze, grounded context cues). Other literatures, in contrast, use these terms as a shortening of the term pragmatic inference in the sense of Grice (1975). In what follows below, we attempt to clarify this terminological issue by being more precise about the distinction between information sources on the one hand and assumptions that are used in pragmatic inferences and the computations themselves on the other.

To do so, we begin by introducing the general approach of linguistic pragmatics. We next introduce the RSA framework, which was designed to capture phenomena in this domain. RSA is a computational framework for modeling pragmatic inference that has been used to explain a wide variety of linguistic and psycholinguistic phenomena (Frank & Goodman 2012, Goodman & Frank 2016). Although we make only limited use of the computational formalism in this review, the model provides an explicit theory of language use in context that operationalizes what can otherwise be a vague and intangible set of concepts.

Linguistic Pragmatics

From a historical perspective, theories of meaning only gradually began to distinguish semantics (context-invariant or truth-conditional meaning) and pragmatics (contextually varying aspects of meaning) over the course of the middle of the twentieth century (Bühler 1934, Wittgenstein 1953; see Levelt 2012 for a comprehensive early history). The work of Grice (1957, 1975) played a critical role by describing a view of meaning in context as deriving from a speaker's rational use of specific utterances to convey a particular intention. Under the Gricean formulation, speakers are assumed to be rational actors who are cooperatively following a series of maxims governing communication. By making this assumption, listeners can then recover aspects of meaning that are deniable but likely, according to the speaker's assumed goals. These elements are deemed to be pragmatically implicated, and the process of inference is known as implicature. The inference itself can be described as counterfactual: The listener reasons that if the speaker would have wanted to express a different message, other utterances would have been better suited to do so.

In the decades following Grice's work, others have taken on and refined the context-sensitive view on language and communication. For example, Sperber & Wilson (1995) criticized Grice's account, with its layering and nesting of intentions, as psychologically implausible and instead introduced the concepts of ostension and relevance. Ostension marks an action as communicative and leads the listener to interpret it as providing relevant information. To infer the intended meaning, the listener thus asks themselves in what way the utterance is relevant to them. Sperber & Wilson's (1995) account also explicitly extended to nonlinguistic forms of communication. Levinson (2000) also considered the cognitive burdens of pragmatic inference, asking whether some implicated meanings could be active by default. Clark (1996) situated communication in the broader context of joint action and argued that meaning is largely grounded in the structure of the overarching social interaction. And Tomasello (2008) linked the evolution of language to the phylogenetic and ontogenetic emergence of cooperative communication.

Although these theories have been immensely influential, they are verbal descriptions of the psychological processes involved in communication, and the actual computations that lead to inference are not further specified. This lack of specification both limits their testability and makes

it difficult to use them to make quantitative predictions. Thus, connecting them with the growing psycholinguistic literature on grounded language comprehension (e.g., Katsos & Cummins 2010, Noveck & Sperber 2004) has often proved problematic. The RSA framework that we adopt here and its predecessors in the literature on game-theoretic pragmatics (reviewed in Jäger 2012) were designed to address this issue. RSA and its variants have now been used successfully to describe and predict a wide variety of phenomena in adult language comprehension, including implicature (Goodman & Stuhlmüller 2013), hyperbole (Kao et al. 2014), vagueness (Lassiter & Goodman 2017), generic language (Tessler & Goodman 2019), and politeness (Yoon et al. 2018).

The Rational Speech Act Framework

RSA is an agent-based approach to formalizing pragmatic reasoning. Listeners are modeled as reasoning recursively about the goals of speakers, and vice versa. Although the framework is explicitly designed to capture the back-and-forth of Gricean reasoning, it is consistent with much newer theorizing as well (for example, it explicitly incorporates a relevance distribution over possible messages). Although RSA has been used to study speaker behavior as well, we illustrate the basic RSA architecture from the perspective of a listener who is interpreting an utterance. The task of the listener L is to estimate the probability of a particular intended message m given the observed utterance u by the speaker, which we notate $P_L(m|u)$. (By convention, the utterance comprises linguistic as well as nonlinguistic components.) The listener is assumed to compute the posterior probability P_L via Bayesian inference through the integration of two components, the likelihood of the utterance given the message and the prior probability of the message:

$$P_L(m|u) \propto P_S(u|m)P(m).$$

The characteristic feature of RSA is the way that the likelihood term P_S (representing the speaker) is computed. The listener (notated L) is assumed to have an internal model of the speaker (notated S), who is modeled as choosing their utterance by maximizing their own utility. The speaker's utility is higher the more information they transmit through their utterance (for alternative utilities, see Goodman & Frank 2016). Utility maximization through cooperative communication reflects the central idea that humans communicate in a relevant (Sperber & Wilson 1995), cooperative (Clark 1996, Grice 1975, Tomasello 2008) way. This utility function can be computed in terms of whether a listener correctly inferred the intended message—producing a circularity as L reasons about S, who in turn reasons about L. In practice this recursion is typically broken by a speaker reasoning about what is called a literal listener, who considers only the (truth-functional) semantics of the message (see the sidebar titled The Rational Speech Act Model for details).

In addition to the recursive computation for speaker likelihood described above, listeners also take into account the prior $P(m)$, which represents evidence for (or against) a particular message, independent of the utterance. This prior term can be considered a distribution over relevant messages in context. Through the combination of these two terms—speaker likelihood and prior—the listener's belief represents the outcome of a social-cognitive inference about the likely intended meaning of an utterance in context.

Taken at face value, the RSA model can seem implausibly complex or cognitively demanding. Although this topic is treated more extensively in other places (e.g., Goodman & Frank 2016), we make several remarks here. First, the RSA framework is a description of the computational problem being solved by agents rather than being a model of a psychological process (as in the computational level of analysis described in Marr 1982). Although we use the representational structure of the model as a psychological description, we do not expect particular aspects of the

THE RATIONAL SPEECH ACT MODEL

The Gricean idea that communication is a cooperative endeavor is incorporated in the way RSA models compute the likelihood term $P_S(u|m)$. The speaker is assumed to choose the utterance that maximizes their own expected utility:

$$P_S(u|m) \propto \exp[\alpha U_S(u; m)].$$

The scalar value α can be interpreted as an indicator of how rational the speaker is in choosing utterances (i.e., how strongly they prefer the higher utility option). The utility of an utterance in turn depends on how much epistemic certainty it provides to the listener:

$$U_S(u; m) = \log P_{Lit}(m|u).$$

Through this recursive reference back to a listener, the model captures the interdependence of speaker and listener in communicative interactions. To avoid an infinite regress, however, at this point the listener is taken to be a literal listener (represented by P_{Lit}) who interprets utterances in accordance with their literal semantics:

$$P_{Lit}(m|u) \propto [\![u]\!](m)\, P(m).$$

Here, $[\![u]\!]$ simply denotes whether or not the utterance is true of a given message, and $P(m)$ is the prior probability of this message. This model definition offers several ways to realize developmental change and/or individual differences. For example, individuals may differ in their assumptions about how rational speakers are (represented by α). Changing linguistic competence can also be incorporated by making the link between utterances and messages probabilistic (instead of truth functional), thereby capturing that individuals may be more or less certain about what a word means (see also Bohn et al. 2019c).

RSA computation to map directly onto those computations performed by language users. Second, despite this relatively limited commitment to empirical correspondence, in practice RSA models tend to provide a very good description of adults' average pragmatic inferences in schematic situations and under no time constraints. Thinking about the ways that performance might degrade under suboptimal conditions is an important goal for future work. Relating aspects of the computational architecture of RSA models to more traditional measures of social cognition will be an important goal as well. Finally, relevant for our use of RSA in the current review, we are primarily interested in the broad decomposition of the problem of contextual language interpretation rather than the numerical predictions of the model or the specific parameter values recovered in a particular situation. Thus, for our purposes, almost any Gricean or neo-Gricean account would be sufficient; we choose RSA here because its ontological commitments are the most explicit.

Pragmatics and Grounded Communication

We next walk through a schematic case of grounded communication between two agents. These agents could both be adults, or one could be an adult and the other a child learning their native language. **Figure 1** gives an overview of the different observed environmental variables, psychological constructs, and inferential computations posited in this framework. Importantly, although specific representational components are depicted separately, pragmatic inference in this model is a unified process in which evidence from these different sources is integrated. We find that this set of distinctions—between the information sources that enter into pragmatic inferences, the representational components of the inference, and the inferential process itself—can help clarify some of the terminological confusion surrounding whether so-called pragmatic cues are truly pragmatic.

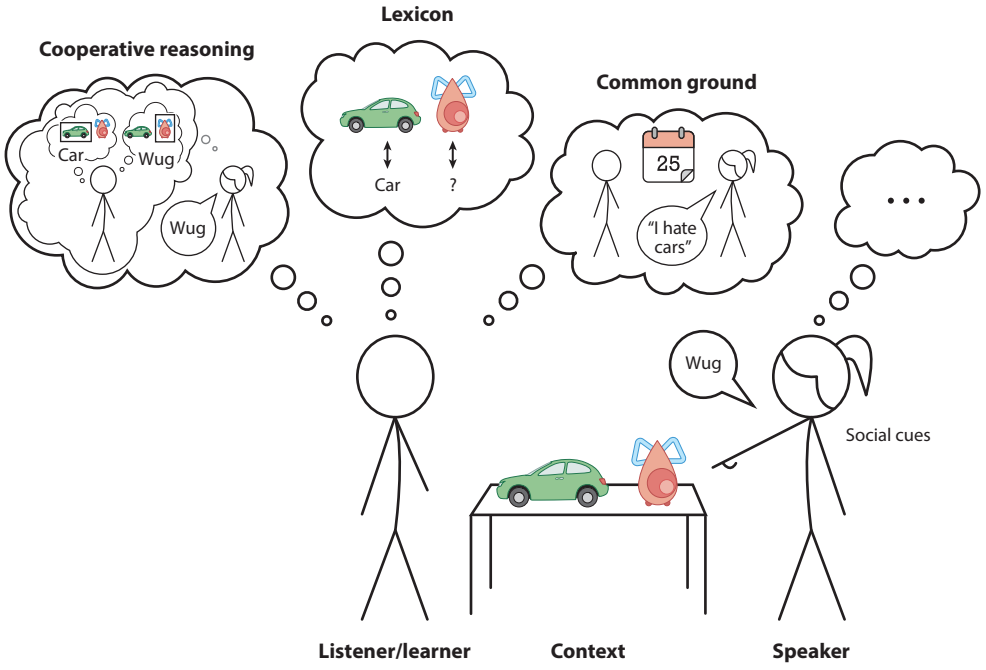

Figure 1

Schematic overview of the theoretical framework. Observable variables are the utterance ("wug"), the context, and additional social cues provided by the speaker. Unobserved (psychological) variables are the lexicon, common ground, and the cooperative reasoning process. Even though components are depicted separately, we think of pragmatic inference as a unified process, during which different sources of information are integrated. The speaker is assumed to go through a complementary reasoning process (signified by the ellipsis) that we do not discuss here.

Observable variables. The observable variables pictured in **Figure 1**—those that are part of the observed physical world—can be divided into three broad groups. First, the speaker's (linguistic) utterance is observed. Although the utterance itself is likely perceived by the listener with some uncertainty (e.g., as in noisy channel models of language perception; see Gibson et al. 2013, Yurovsky et al. 2017), for simplicity here we consider it to be observed directly. Second, the physical context of the utterance is also observed, and it shapes the likely interpretation. By virtue of being perceptually available, objects in the immediate environment are more likely referents compared with absent ones. Salience due to physical characteristics and positioning relative to the conversational participants have similar effects. More broadly, contexts generate expectations about contents of utterances. For example, the word "ball" in "Where is the ball?" will be taken to refer to very different things when asked outside a ballroom and when asked on a soccer field. In our modeling framework, these factors affect the prior probability of a message.

Third and finally, speakers produce directly observable social cues that serve communicative functions. Examples are orienting toward, looking at, pointing to, or touching an object. These indexical cues are often indicative of the speaker's attention and allow the listener to align their own attention to the same target as the speaker, thereby creating episodes of joint attention—mutual focus—on objects in the here and now. In principle, representational acts, such as iconic gestures, can serve a similar function. These social cues relate to the intended message by directly denoting a referent. Within the RSA framework, social cues are considered to be part of the utterance and

supplement the literal meaning given by the linguistic properties of the utterance. For example, if an utterance contains the word ball combined with a point to a ball, the message is likely to be about that particular ball. Aside from providing referential information, social cues can also be used to mark actions as communicative. These ostensive cues show the listener that the current action is a communicative act that is intended to provide relevant information. We return to the issue of ostension below in the section titled The Origins of Communication in Infancy.

Unobserved (psychological) variables. The first major psychological construct posited in RSA is the lexicon, which stores conventional forms of reference. These include words or signs that are part of a language. The semantics given to individual parts of the lexicon is truth-functional: When applied to a particular state of affairs (a world), semantic mappings return a truth value (which is often assumed to be a probability, rather than a deterministic value, to capture that language learners have some uncertainty about what, e.g., a message refers to). Although we do not discuss this topic here, agents are also assumed to have combinatoric syntactic and semantic abilities such that they can create complex expressions from parts in the lexicon. The operation of pragmatic inferences in compositional utterances is an active research topic (e.g., Bergen et al. 2016, Potts et al. 2016).

The second psychological construct in our framework is common ground. Common ground refers to bits of information that are assumed to be shared between interlocutors and constitutes the background against which utterances are interpreted (Bohn & Köymen 2018; Clark 1996, 2015). Listeners expect speakers to produce relevant utterances in light of common ground. For example, imagine we are doing a puzzle together and there is one last piece missing. If I point to a place under your chair, you take this to tell you that the last piece fell under your chair, because it is part of our common ground that we are looking for the last piece. The same gesture would have a different interpretation when embedded in a different social interaction.

Common ground comes in different forms and has multiple layers (Clark 1996). Objects and events that are jointly perceivable can be assumed to be part of the perceptual common ground. Events that have been jointly experienced enter personal common ground, which is specific to a dyad or a group. Finally, communal or cultural common ground refers to shared knowledge on the community level (e.g., schooling, profession, culture). In RSA models, common ground takes the form of a shared prior distribution over messages, making some messages more likely compared with others.

Inferences. The last component of RSA models is the process of reasoning that listeners go through in computing the speaker's intended message (and that speakers go through in selecting their utterances). This process is described formally in the section titled The Rational Speech Act Framework. One key part of this reasoning process is the comparison of alternative messages and the evaluation of whether those messages could have been expressed in less ambiguous ways compared with the utterance the speaker used. This comparison happens within the system of recursive RSA reasoning and is pictured at the far left of **Figure 1** (cooperative reasoning). In the depicted example, the listener imagines the speaker reasoning about how the (literal) listener would interpret different utterances ("car" and "wug"). The inference that "wug" refers to the novel object follows because the listener expects the speaker to use the word "car" when they want to refer to the car.

THE ORIGINS OF COMMUNICATION IN INFANCY

We next turn to the developmental literature, asking whether core components of the communicative framework described above are observed during infancy. In this section, we review research

on infants' language and communication in the period from 6 to 18 months of age. We begin by discussing the nature of the early lexicon. Next, we discuss the relationship between language and other communicative signals, primarily focusing on pointing and gestures. We end by discussing the role of ostension in communication.

The Beginnings of Language

Infants produce their first words around their first birthday; vocabulary grows rapidly thereafter (Fenson et al. 1994). Early discussion of the nature of the early vocabulary tended to focus on the productive use of language (e.g., Bates 1976, Kamhi 1986). This large literature has been upended, however, by a growing body of evidence on infants' receptive abilities. This work suggests that, even by 6 to 9 months of age, the beginnings of receptive language are emerging (Bergelson & Swingley 2012, Tincoff & Jusczyk 1999). This evidence invites us to ask whether early language is communicative in the sense of our framework: involving inferences about the goals of social partners.

Associative accounts of early language posit that this early receptive vocabulary is not communicative in the same way as older children's language use is. That is, infants treat words not as intentionally produced communicative acts that reflect an underlying goal but as regularly co-occurring properties of the objects they refer to. Sloutsky and colleagues (2001, 2017) embrace this associative view, highlighting the importance of spatiotemporal co-occurrence for word learning. Word learners track the statistical regularities with which words and objects co-occur and thereby build direct associations between the acoustic and visual input (Smith & Yu 2008). In this view, social inference is at best secondary and is a downstream consequence of—rather than a prerequisite for—language learning.[2]

In contrast, on the inferential continuity account that we have been sketching, even infants assume that words serve a communicative function: The speaker uses them to express a certain intention or to convey some kind of information to the speaker. Though associative accounts are prima facie plausible, several pieces of evidence now speak in favor of the view that infants treat language as intentional communication from an early age—that is, in the language of **Figure 1**, that both communicative gestures and lexical representations enter into pragmatic computations about intended meaning.

First, infants seem to expect communicative acts to transmit information even when they don't know the meanings of the words that are used to do so. In a striking series of demonstrations, Vouloumanos and colleagues (Vouloumanos et al. 2012; see also Martin et al. 2012, Vouloumanos et al. 2014) had infants 12 months old and younger watch an actor trying to complete an action but failing. When an observer used unknown speech to communicate with the actor (presumably to instruct them), infants expected the actor to successfully complete the action. When the observer produced an unintentional vocalization (e.g., coughing) instead, infants had no such expectation. These results are not predicted by a view in which the early lexicon is composed of direct associative linkages.

[2] A related view posits that infants around their first birthday are unable to interpret social cues as referential, making word-meaning mappings instead based on object salience. The predictive power of social cues is then learned through experience, allowing infants to "discover the intentionality" of their communicative partner (Hollich et al. 2000). Contrary to this view, however, Yurovsky & Frank (2017) found that even young infants in a simple object-mapping paradigm followed social cues to reference at very high rates; the difference was that younger children appeared less able than older children to overcome referent salience during test trials (even though they might have made the correct mapping).

Second, children generalize words beyond the referents they are paired with during learning. Even in the first year after birth, infants appear to encode semantic relationships in their lexicon (Bergelson & Aslin 2017). And shortly after their first birthday, infants expect the same word to refer to a member of a category (e.g., horses), even when the referent at test is different from the referents for which children learned the words (Booth & Waxman 2009, Waxman & Markow 1995). That is, children make inferences about what the speaker might refer to even when they have never encountered the particular word-object pairing during training trials. Relatedly, even younger infants use the presence of labels to individuate objects, showing surprise when a speaker uses two distinct labels to describe objects in a scene but later only one object is visible (Dewar & Xu 2007, Xu 2002). Although there are plausible associative accounts of some semantic categorization phenomena in early word learning (e.g., Regier 2003), this group of findings is parsimoniously explained by communicative accounts. For example, the use of different words signaling the presence of different objects emerges naturally from communicative word learning but not from associative accounts (Frank et al. 2009).

Third, the use of novel signals in communicative contexts appears to lead infants to learn and generalize more from them. For example, in a study by Ferguson & Lew-Williams (2016), watching a conversation in which one adult communicated by beeping (tones were contingent on the actors' mouth movements) resulted in generalization of simple repetition rules. Infants learned that beeps always followed an ABA pattern and showed surprise when the pattern suddenly changed to a different structure (e.g., AAB); the same result was not found when the beeps were played noncontingently over the same video. And hearing a similar communicative familiarization appeared to boost category-based attention when the tones later accompanied a set of novel objects (Ferguson & Waxman 2016).

Fourth, shortly after language production begins, toddlers both use and understand language for reference to absent objects, indicating that they are not simply viewing words as possible perceptual associates for objects that are present in the current context. Bates (1976) described this behavior in her case reports, and Fenson et al. (1994) reported that most parents believe their 16-month-olds understand absent referents. Experimental evidence for comprehension of absent referents is present at 12 months (e.g., Ganea 2005; Ganea & Saylor 2013; Osina et al. 2014, 2017), the same age at which infants themselves refer to absent entities using pointing gestures (Bohn et al. 2015, 2018; Liszkowski et al. 2009).

Finally, perhaps the strongest support for an inferential view on early language comes from studies showing that slightly older infants' word learning is contingent on social cues provided by the speaker (e.g., Baldwin 1993, Bottema-Beutel 2016, Dunham et al. 1993, Hirotani et al. 2009). For example, 18-month-olds readily learn the label for a novel toy they are engaged with when it is uttered by an experimenter who is also attending to the toy. In contrast, when the label is produced by an experimenter who is out of view, infants do not learn the label even though their own attention and the spatiotemporal contingency between label and object are the same (Baldwin et al. 1996).

Can prelinguistic communication based on social cues such as pointing, gaze, or gesture be considered inferential as well? One might argue that because these cues can directly highlight objects, no additional inference is required. Comparative work with great apes provides a method to test this idea. If social cues such as gaze, pointing, or iconic gestures were sufficient to communicate a message without any communicative inference, great apes should readily understand them. After all, great apes follow the directionality of an experimenter's gaze or point and make use of iconic relations when learning the association between a gesture and a referent (Bohn et al. 2016, Kano & Call 2014, Tomasello 2008). However, when an informant (human or conspecific) uses gaze, pointing, or iconic gestures in a communicative context (i.e., to indicate a food location),

great apes often fail to make use of this information (e.g., Bohn et al. 2019a, Hare et al. 2002, Tempelmann et al. 2013). In contrast, human children readily locate the reward in such contexts (Behne et al. 2005, Bohn et al. 2019a). Thus, while these cues can be used to highlight a referent, it appears to take an additional ingredient—perhaps a social inference, as in the case of language—to understand the intention that makes the referent relevant in context.

In sum, a variety of evidence supports the inferential view of early language and early communicative gesture. Further, because the inferential view assumes that nonlinguistic and linguistic signals can be used interchangeably, it predicts continuity between infants' early communication through the use of social cues and later language abilities. Thus, a prediction of this account is that those children who are better at using social information should also be better at learning and using language. We next turn to evidence supporting this prediction.

Relationships Between Language and Social Communication

One of the most reliable findings in the area of early language is the strong correlation between social-communicative abilities and early language. In a meta-analysis, Colonnesi et al. (2010) found both concurrent and longitudinal relations between infant pointing and language abilities: Children who produced more points or comprehended pointing better had higher productive and/or receptive language scores (see also Lüke et al. 2017). Similar evidence, on an even larger scale, comes from parent reports using the MacArthur–Bates Communicative Development Inventory. In cross-linguistic adaptations of the Communicative Development Inventory in the Wordbank database (Frank et al. 2017), early gestural communication was strongly correlated with early vocabulary across eight languages (Frank et al. in press).

This large-scale evidence for relations between linguistic and nonlinguistic communicative development is further corroborated by a set of smaller-scale, but more detailed, longitudinal studies. For example, Carpenter et al. (1998) studied infants between 9 and 15 months of age and found that infants who showed earlier sensitivity to social cues (gestures or gaze) started to produce referential language earlier (see also Tomasello & Farrar 1986). Brooks & Meltzoff (2005, 2008) showed that the propensity to follow others' gaze at 10 and 11 months of age predicted vocabulary growth throughout the second year of life. And on an even longer timescale, Rowe & Goldin-Meadow (2009) reported that differences in gesture use at 14 months of age related to differences in language abilities at 4.5 years of age.

In sum, this evidence supports strong ties between early nonlinguistic communication and early language. But why are social cues related to learning language? We argued that social cues, like words, mark actions as communicative and also provide direct evidence for the intended message; thus, these two abilities may arise from the same capacity. But there are likely other causal pathways that connect nonlinguistic and linguistic communication. First, there is undoubtedly some shared variance between these two constructs that reflects general developmental advancement—thus, children who point early may speak early in part because they tend to be early for all milestones. Initial evidence against this view comes from the observation that pointing and early language are far more interrelated with each other than they are with walking (Moore et al. 2019; cf. Walle & Campos 2014). Second, nonlinguistic communication may create opportunities for learning, providing bids for labeling that caregivers respond to (e.g., Donnellan et al. 2020). Intervention research is a promising method for disentangling these complex causal relationships.

Marking Communication Through Ostension

We have argued that human communication is inferential from an early age; thus, pragmatic inference is a special case of social inference. One sense in which communication is special is that

the speaker—whose mental state has to be inferred—has a vested interest in the success of the inference process (Shafto et al. 2012). As a consequence, speakers should try to mark their actions as communicative to signal to the listener that a communicative inference is appropriate. So-called ostensive signals serve this function.

A substantial number of studies have shown that overtly ostensive behaviors, such as eye contact or infant-directed speech, lead infants and children to interpret actions as communicative. For example, 6-month-old infants are more likely to follow an actor's gaze to a target when it is preceded by gaze or speech cues (Senju & Csibra 2008). Similar results have been found in 5–7-month-old infants in a non-Western sample (Hernik & Broesch 2018). Tauzin & Gergely (2019) showed that turn-taking exchanges with abstract beeping signals can be an ostensive cue for 11-month-olds. Fourteen-month-olds interpret a pointing gesture as communicative only when it is produced in an overtly ostensive way (Behne et al. 2005). At 18 months, children understand indirect communicative acts only when accompanied by overt ostensive cues (Schulze & Tomasello 2015). Word learning also seems to be modulated by accompanying ostensive cues (Baldwin 1993, Egyed et al. 2013), and ostensively produced pointing gestures may even override linguistic information (Grassmann & Tomasello 2010).

Aside from these prime examples, however, ostension is notoriously hard to define on a purely behavioral level, and children often interpret acts as communicative even when they are not paired with ostensive cues. For example, 6-month-olds follow gaze in nonostensive contexts (Gredebäck et al. 2018, Szufnarowska et al. 2014), and with some contextual framing, 2-year-olds interpret instrumental actions such as pressing a light switch as communicative (Moore et al. 2015). To reconcile these findings, we may say that ostensive cues are a sufficient but not necessary condition for communicative inference. This conclusion is congruent with the broader inferential framework that we propose, in which the communicative value of a particular action itself can serve as prima facie evidence for it being communicative (a logic we can roughly paraphrase as, "Why else would they have done that—other than to tell me something?").

THE ROLE OF PRAGMATICS IN EARLY WORD LEARNING

The previous section titled The Origins of Communication in Infancy reviewed how children's early communication and language are based on social cues and assumptions. Next, we turn to how these early-emerging skills for inferential communication support language learning in the period from 1 to 3 years of age. Although there is a rich body of observational work describing this time period (see Clark & Amaral 2010 for review), we focus here primarily on experimental work that aims at elucidating psychological processes that underlie language learning. To begin with, we want to contrast two different timescales on which word learning happens: in-the-moment identification of a referent and long-term learning of mappings between concepts and words (items in the lexicon). At first sight, it seems appealing to view these timescales as largely independent. Psychologically, one might say that they are separate: Social inferences about speaker intentions guide comprehension, while statistical or associative learning processes underlie the growth of the lexicon. But we believe this distinction masks an underlying unity. We see these two components as complementary parts of a joint inference problem.

In this joint inference, in-the-moment inference is guided by lexical knowledge, and the learning of lexical items depends on the degree of certainty with which the message (or at least the referent) can be identified in the moment. In other words, if you know what someone is talking about, it's easier to infer what specific words mean; if you know what words mean, it's easier to figure out what someone is talking about. Frank et al. (2009) formalized this view and showed that the resulting probabilistic model predicted a broad range of phenomena characteristic of early word

learning such as a mutual exclusivity inference, one-trial learning, and cross-situational learning (for a neural network model with similar timescale dynamics, see also McMurray et al. 2012). Critically, this linkage between in-the-moment interpretation and longer-term word learning means that many phenomena that are seen as word learning phenomena actually occur in the context of pragmatic interpretation. A paramount example of this linkage between timescales comes from joint attention.

Word Learning Through Joint Attention and Common Ground

Joint attention describes situations in which two individuals are knowingly attending to the same object at the same time (Tomasello 1995). In many cases, jointly attending to something coincides with both individuals looking at the object, combined with occasional eye contact between them. This dense clustering of ostensive and referential social cues presents the child with an information-loaded learning opportunity, especially at the onset of lexical development around the age of 1 year. From our theoretical perspective, joint attention facilitates inference about the speaker's intention (and thereby word learning) in two complementary ways: On the one hand, a sustained attentional focus on a set of objects (or aspects of objects) increases the probability that the speaker will communicate about them later, changing the learner's prior. And on the other hand, attentional cues such as eye gaze provide referential information in the moment that can be interpreted as a referential part of the utterance.

Consistent with this general idea, a very robust link between joint attention and word learning has been found in numerous correlational studies (for a recent meta-analysis, see Bottema-Beutel 2016) and experimental studies (e.g., Baldwin 1993, Dunham et al. 1993, Hirotani et al. 2009), including in non-Western samples (e.g., Childers et al. 2007). With increasing age, infants improve in their ability to coordinate attention with a partner (Mundy et al. 2007). Overt cues such as gaze or eye contact are less important for children above the age of 2 years (Adamson et al. 2004, Scofield & Behrend 2011), which is also evidenced by studies showing that children learn words through overhearing (Akhtar et al. 2001, Gampe et al. 2012). This suggests that children come to use other (less direct) sources of information to infer the speaker's intention.

One such information source is the common ground that is shared between interlocutors. Common ground guides inferences about interpretation because it makes some messages more likely compared with others (changing the prior probability of the message in our framework). This constraint is conditional on the identity of the speaker, however, in that what is part of common ground with one person might not be shared with another.

How do we know what is part of common ground and what is not? The most straightforward way in which information can be grounded is through direct social interaction. And in fact, even very young children have been found to adjust their communication to common ground established that way (Liszkowski et al. 2008, Saylor et al. 2011). For example, 12-month-olds were more likely to refer to an absent object by pointing to its previous location if the recipient had interacted with them while the object was still present and less so if the recipient had not (Bohn et al. 2018). Common ground established in direct social interaction also supports young children's word learning (e.g., Akhtar et al. 1996, Diesendruck et al. 2004, Saylor et al. 2009).

From a conversational perspective, common ground also includes the immediate discourse context of an utterance, and the structure of the unfolding interaction thus offers cues to the speaker's intended meaning. From 2 years of age onward, children interpret new words as referring to objects (or properties of objects) that are relevant in a given discourse context (Akhtar 2002, Horowitz & Frank 2015, Sullivan et al. 2019). For example, when a speaker asks for "the dax" (an unknown word) after saying they are hungry, 2-year-olds choose something edible as the referent (Sullivan & Barner 2016).

Considering these observations together, we may say that the early emergence of sensitivity to common ground suggests developmental consistency in the assumption that communicative acts are produced and interpreted in light of common ground. What appears to change developmentally are the skills that allow children to determine how information comes to be part of common ground (Bohn & Köymen 2018). The process of adding information into common ground involves reasoning about group-specific knowledge and conventions (Srinivasan et al. 2019), others' perspectives (Nadig & Sedivy 2002, Nilsen & Graham 2009), others' beliefs about the world (Király et al. 2018, Southgate et al. 2010), and eventually even others' beliefs about one's own beliefs (Grueneisen et al. 2015).

Word Learning Through Pragmatic Inference

A speaker's choice of words is also informative with regard to their intention: A particular word choice contrasts with what the speaker did not say but could have said. In our inferential framework, this general logic can give rise to a wide variety of word learning phenomena (often with distinct names in the literature). For example, in a classic study, Carey & Bartlett (1978) explicitly contrasted a novel color word with a known one ("the chromium one, not the green one") and showed that 3-year-olds took it to refer to an object with an unknown color. Subsequent studies removed the explicit contrast and showed that from 17 months of age onward, and perhaps even earlier (Markman et al. 2003), infants seem to expect labels to be mutually exclusive and infer that novel words refer to novel objects (e.g., Halberda 2003, Markman & Wachtel 1988).

A large number of theoretical explanations have been put forward for this mutual exclusivity effect (see Lewis et al. 2019 for an overview and meta-analysis). Because of its parsimony with our general framework, we favor a pragmatic explanation as at least one possible source of the effect (Clark 1988, Clark & Grossman 1998). In this account, mutual exclusivity follows from the interplay between lexical knowledge and expectations about speaker informativity. The least ambiguous way to refer to the known object would be to use the label stored in the lexicon. As a consequence, the fact that the speaker did not use the known label tells the listener that the speaker is not referring to the known object, which makes the novel object the more likely referent for the novel word (see Frank et al. 2009 for a formal analysis). In this view, mutual exclusivity should be linked to the listener's lexical knowledge, a prediction that is supported by data on the correlation between vocabulary size and mutual exclusivity inferences (Lewis et al. 2019). The pragmatic account is further supported by work showing that 3-year-olds do not make a mutual exclusivity inference when the speaker is introduced as speaking a different language (Diesendruck & Markson 2001). We also note that the pragmatic view is consistent with data showing that children (Horst & Samuelson 2008) and models (Smith et al. 2013) both may sometimes make correct mutual exclusivity inferences without retaining the implied word meaning.

Further, in a direct test of the communicative word learning hypothesis, Frank & Goodman (2014) created a word learning situation in which 3- and 4-year-olds were taught labels for features of objects. A target object (e.g., a dinosaur) had two features (e.g., a headdress and a bandana). The only disambiguating information came from the presence on a distractor object of one of the features (e.g., the headdress) but not the other. This asymmetry made the more unique feature (the bandana) a more informative label for the target object in the context. Consistent with the inferential model, both age groups were successful at inferring that the speaker was referring to the more unique, informative feature.

The work we have reviewed in this section largely tested how children use one form of pragmatic information in a word learning context. In addition to explaining these individual findings, our theoretical framework provides a way to think about how different forms of information can

be integrated. In a recent study, we investigated how children and adults integrate common ground information with expectations about speaker informativity in a word learning context (Bohn et al. 2019b,c). We used an RSA model to generate a priori predictions about how information integration should proceed. We then collected new data for conditions in which common ground information and expectations about speaker informativity were manipulated at the same time. The model predictions for these conditions were closely aligned with the data, and a model comparison suggested that word learning was best explained by a model that flexibly traded off between the two information sources (common ground and speaker informativity) compared with models focusing only on one aspect or the other. This finding highlights the utility of the integrative, inferential framework presented here for explaining children's behavior across a wide range of word learning tasks.

PRAGMATICS IN CHILDREN'S COMMUNICATION AND COMPREHENSION

In the previous section titled Word Learning Through Pragmatic Inference, we reviewed how children's language learning is supported by pragmatic inference. In the last part of our review, we turn to children's language use and comprehension, focusing on 3- to 6-year-old children who have sufficient vocabulary and grammatical ability to interpret more complex utterances reliably. Of course, pragmatic inferences based on social cues and context continue to help older children learn language. We see developmental change as a gradual shifting of emphasis, in which, more often, older children's more sophisticated linguistic abilities allow them to infer word meanings from the linguistic context (Gleitman 1990), making them less dependent on pure pragmatic inference. During this period, however, pragmatics allows children to begin engaging subtle, context-specific use and interpretation of language, making their communication more efficient (and occasionally even polite).

Conversation Sensitive to Social Context

As we discussed above, the decision about what information to include in an utterance is partly determined by the common ground shared between interlocutors (Clark 1996). Communication can be made more efficient (in the sense of reducing the cost of producing unnecessary utterances) by tuning what to say to what the partner already knows because of common ground. Although such prior expectations are likely used in language learning substantially earlier, more sophisticated uses of social context in conversation begin to be visible slightly later in productive language use.

By the age of 2 years, children can adjust the informativeness of their utterances to the knowledge state of their partner. For example, they name a hidden object and its location more often, and produce more referential gestures, when their partner has not witnessed the hiding (O'Neill 1996). Children of the same age also supplement their pointing gestures with linguistic information when pointing alone would be ambiguous (O'Neill & Topolovec 2001). Slightly older children are also more likely to use pronouns (which are usually shorter) instead of nouns to refer to an object if that object was mentioned in the ongoing discourse (Matthews et al. 2006). In a peer context, 3- and 4-year-olds selectively mention facts when justifying a decision depending on whether their partner knows those facts already (Köymen et al. 2016). And from 5 years of age onward, children give general information about an object when the listener is unfamiliar with it but choose to mention more specific facts when the partner already knows about the object (Baer & Friedman 2018; see also Gelman et al. 2013). In our theoretical framework, these effects are all captured by changes in the prior over messages and referents. Because the utility of an utterance takes into account this prior, referents that have a high a priori probability will have a high

posterior probability of being interpreted correctly even when a less informative utterance is used. Thus, in these situations, communication can be successful even with shorter or vaguer utterances.

In addition to decisions about how much information to include in the utterance, pragmatic considerations also influence speakers' choice of which words to use. Over the course of a conversation, specific expressions can be fine-tuned to refer to specific objects or aspects of objects. For example, to distinguish between two types of shoes, interlocutors may come to refer to one of them as the man's shoe and the other as the dress shoe (Brennan & Clark 1996). The results of this tuning are called referential pacts. These local conventions make communication more efficient because they allow otherwise ambiguous utterances to be used unambiguously to refer to a particular target within a discourse. Such pacts can be produced in RSA-style models that simultaneously learn words and infer contextual interpretations (e.g., Hawkins et al. 2017).

Children generate these partner-specific expectations about referential expressions at least from 3 years of age onward (Matthews et al. 2010). Supporting this claim, children were slower to respond to a request when their partner violated a referential pact, but not when a different experimenter, with whom no pact was formed, used the same expression. Graham et al. (2014) also provided evidence that referential pacts made children's communication faster: In an eye-tracking paradigm, 4- to 5-year-old children were faster to fixate on an object when a familiar speaker used a previously used expression compared with when a new speaker used the very same expression. Children between 4 and 6 years old also form referential pacts in a peer context to differentiate between similar referents (e.g., they use the terms "horse" and "pony" to differentiate between two horses). Interestingly, they retain the partner-specific expressions even when they are technically no longer required because one of the competing referents has been removed (Köymen et al. 2014).

Pragmatic Implicature

Turning at last to utterances themselves, we consider the implicature phenomena that are core to most analyses of linguistic pragmatics. For example, when hearing "I ate some of the cookies," the listener may assume that the speaker did not eat all the cookies—if they had eaten all, they should have used the word all instead of the word some. From a purely semantic perspective, however, using the word "some" as part of a message where "all" is intended is not strictly false. The implicature follows from the assumption that speakers consider alternative utterances ordered along an entailment scale (all entailing some in this case). Hence, these inferences are referred to by the term scalar implicature.

In light of the work we have reviewed so far, which we took to show that children engage in context-sensitive inferential communication from 1 year of age onward, the findings from this strand of research present a puzzle. Many studies have found that children 5 years old and even older struggle to compute implicatures, especially under time constraints (Huang & Snedeker 2009, Noveck 2001). How can these failures be reconciled with the evidence reviewed above that children of even younger ages are so good at pragmatic inferences more broadly?

The apparent contradiction between early competence and later failure can be resolved by looking at the facilitating conditions under which younger children succeed (for a summary, see Papafragou & Skordos 2016). For example, Skordos & Papafragou (2016) showed that increasing the availability of the stronger alternative (the word all in the example above) improved 5-year-olds' performance, and Horowitz et al. (2018) showed that children who succeeded in making scalar implicatures were those who best knew all the quantificational alternatives. This pattern of data is consistent with our inferential framework, in which the utility of an utterance (given a message) depends on the specific alternatives being considered (for analysis, see, e.g., Peloquin & Frank 2016). This interpretation suggests that children struggle not necessarily with inference per se, but with generating the alternatives that are the basis for it (Barner et al. 2011).

Further evidence consistent with the hypothesis that children's pragmatic abilities are intact, despite their struggle with specific linguistic materials, comes from ad hoc (contextual rather than linguistic) implicatures. Stiller et al. (2015) used a simplified design in which the alternatives for an implicature were perceptually available features of a scene and found success at 3 years of age, substantially earlier than the earliest evidence for implicature with quantifiers. In this study, children were asked to "find the friend with glasses" and were shown stylized faces with only glasses, a hat and glasses, or neither of the two. Even though the description was true of the face with hat and glasses, children chose the face with only glasses to be the friend. Presumably, they rejected the face with hat and glasses because it would have been better captured by an alternative description (friend with a hat, or friend with a hat and glasses). The performance of even younger children in this simplified task is heavily influenced by perceptual properties of the presented alternatives, suggesting again that inference per se is not the problem but rather the properties and availability of the alternatives it is based on (Yoon & Frank 2019). In sum, pragmatic inference critically relies on experience with the conventional use of expressions; without a full lexicon, specific inferences can be impossible to generate.

Using Pragmatics to Navigate the (Social) World

In addition to resolving ambiguities, pragmatic reasoning can allow children to learn from others. An adjacent body of work on nonlinguistic social learning phenomena suggests that 3- to 5-year-old children are remarkably good at learning from others' communicative actions (e.g., Bonawitz et al. 2011, Jara-Ettinger et al. 2016). This social learning can also be accomplished by using linguistic inferences. For example, Horowitz & Frank (2016) taught children the name of a novel object and commented on its property (e.g., "This is a small fep"). The contrastive use of the adjective implied that prototypical members of the category look different from the exemplar (they are bigger). When 3- to 5-year-olds were asked to identify such a prototype, they chose the object that differed from the exemplar in the property the speaker previously commented on.

Finally, pragmatic language provides a way for navigating the social world. From that perspective, overly ambiguous or inefficient language reflects a conflict of multiple social goals the speaker wants to achieve. A case in point is polite language. Polite language features words that have no informational value, and requests are often framed as questions even though they have an imperative core. For example, "Can you please open the window?" is a polite way of saying "open the window!" In addition to the goal of transmitting information (I want you to open the window), the speaker considers how the message would affect the listener's self-image or face (Brown & Levinson 1987). An imperative request might be perceived as a threat to the listener's freedom from imposition and could cause them to leave the interaction. Because communication is a cooperative endeavor, it requires the active participation of all interlocutors to achieve the joint goal of mutual understanding. By using polite language, the speaker signals benign intent and a willingness to cooperate (Clark 1996).

From 2.5 years of age onward, and increasingly with age, children start to use politeness markers such as "please" (Bates & Silvern 1977, Read & Cherry 1978). However, production of politeness markers alone does not show an understanding of the social function of polite speech; it could be a rule children follow to get what they want (Gleason et al. 1984). Yoon & Frank (2019) therefore asked children at 2, 3, and 4 years of age whether speakers who use markers like "please" or "can you" were more polite or more likely to achieve their goal. From 3 years of age onward, children judged speakers who say "please" as more polite, and from 4 years of age onward, they assumed that a speaker using polite language would be more likely to get what they want. Though this work is in its early stages, such social inferences appear to be described well using a slight extension to the RSA framework (Yoon et al. 2018).

DEVELOPMENTAL QUESTIONS ABOUT PRAGMATIC REASONING

With the help of the framework described above, we are now able to pose developmental questions about continuity and change much more effectively. (This is a specific instance of a general phenomenon—developmental theorizing is facilitated immensely by strong theories of the end state; see Tomasello 2000, Leslie et al. 1998). In particular, we can ask about developmental change in each posited psychological construct in our framework—linguistic knowledge/the lexicon, cooperative reasoning, and common ground—as well as about whether the broader framework applies equally to children and adults.

The developmental scope we are examining is quite broad, beginning just before the first birthday and ending—in our examination, though certainly not in the life of a child—around the beginning of formal education at the age of 5 to 6 years. In light of the literature reviewed above, we believe that the evidence is in favor of continuity, rather than separate developmental trajectories of language learning and social cognition. That is, from relatively early in development—perhaps 6–9 months of age—infants' view of language is communicative in nature (Waxman & Gelman 2009). The substance of this claim in our framework is that the basic constructs posited by our framework—including pragmatic inference, common ground, and the lexicon—are all in place by this early time and are being used interactively with one another in sophisticated ways. As we reviewed, this conceptualization stands in contrast with other views that have posited developmental shifts in how infants view early language. In particular, we do not believe that the evidence supports a shift from an earlier associative conceptualization of language—in which language is initially represented by stimulus-stimulus associations (e.g., Hollich et al. 2000, Sloutsky et al. 2017).

While we endorse the hypothesis that infants in the second half of their first year share the assumption that language is communicative, we remain agnostic about how early this continuity can be found. One possibility is that there is some innate adaptation for communication such that even early in infancy language is processed inferentially (e.g., Ferry et al. 2010), though evidence is relatively scant at this very young age. Another possibility, however, is that the communicative basis of language is discovered by infants through their observation of the social world. Although 6-month-olds may know very little about the specifics of language, an intriguing possibility is that they have already induced its broad function in manipulating human behavior. Such induction of framework hypotheses in the absence of specific supporting knowledge is known as the blessing of abstraction and has been posited for other framework theories such as the theory of causality (Goodman et al. 2011).

Regardless of the very early origins of communication, the broad developmental continuity that we have described here is often masked in children's observed behavior, owing to the truly transformational developmental changes that occur contemporaneously with the emergence of early language. Language itself is emerging—that is, children are learning the meanings of words and the ways they can be combined compositionally. Within the broad time period we considered, there is tremendous change in linguistic knowledge, from its very beginnings during the first year (Bergelson & Swingley 2012) through its ramification and exponential growth over subsequent years (Fenson et al. 1994). Trivially, without the ability to retrieve word meanings accurately and to interpret their composition, inferences that go beyond literal meaning are impossible. And language-processing speed changes dramatically during the early years of language learning (Fernald et al. 1998, 2006); thus, even if young children can interpret an utterance, they may not be able to do so with enough time to make a sophisticated inference (see, e.g., Huang & Snedeker 2009).

Further, a variety of social cognition skills adjacent to communication are being practiced extensively during early development. For example, infants are becoming more expert at action

prediction (e.g., Cannon & Woodward 2012, Falck-Ytter et al. 2006, Kanakogi & Itakura 2011), gaze following (Moore 2008), and processing directional actions as referential (Daum & Gredebäck 2011, Gredebäck et al. 2010). The ability to compute others' perspective (Sodian et al. 2007) and track what they experience also develops substantially after the first birthday (Moll & Tomasello 2007). Furthermore, children are getting better at explicitly reasoning about the relationship between beliefs, desires, and actions (Perner & Wimmer 1985, Wellman 2014) as well as about others' motives for action more broadly (Jara-Ettinger et al. 2016). We are deliberately agnostic about whether all pragmatic reasoning requires a fully fledged theory of mind in the sense of Premack & Woodruff (1978). While there is a wide variety of (conflicting) evidence on the question of whether infants can represent others' mental states (e.g., Onishi & Baillargeon 2005, Southgate et al. 2007; cf. Kulke & Rakoczy 2018), much of this evidence bears on the representation specifically of false beliefs. False belief understanding is not required for the communicative inferences we review here.

Finally, a wide variety of other abilities are themselves developing during this time period. During precisely the period in which we observe changes in children's communication abilities, children are also undergoing massive developmental changes in domain-general abilities such as working memory (Camos & Barrouillet 2018, Reznick et al. 2004), executive function (Diamond 2013, McGuigan & Núñez 2006), and general speed of processing (Kail 1991). The involvement of these abilities in early language processing is at present unknown, but an important goal for future research is understanding the extent to which developmental changes in pragmatic inference relate to these general developmental trends (cf. Yoon & Frank 2019).

CONCLUSION

We presented pragmatic inference as a pervasive theme in children's language, linking early communication based on social cues with word learning and language use. Further, we used the RSA framework as a theoretical beginning from which to argue for developmental continuity—the thesis that by 6–9 months of age, all of the ingredients of mature pragmatic inference are present. Developmental changes after this point are then attributed to the successive refinement of children's abilities—including their linguistic knowledge and their general processing abilities. We hope that this framework helps researchers in the area see the commonalities between the wide range of tasks and terminologies that are used to study early language from a pragmatic perspective.

One open developmental challenge for this perspective is understanding language development in children with neurodevelopmental disorders. A lot of research in this respect has focused on children diagnosed with an autism spectrum disorder (ASD). Language development (as measured via the Communicative Development Inventory) appears delayed in children with ASD compared with typically developing children (Luyster et al. 2007). In light of the account put forward here, this delay could be explained by pragmatic deficits commonly found in children with ASD (reviewed in Eigsti et al. 2011). Such a conclusion, however, would be premature. ASD is not a homogeneous phenomenon and does not constitute a social knockout (Jaswal & Akhtar 2019). Furthermore, some forms of pragmatic inference (for example, mutual exclusivity) can be found in children with ASD (de Marchena et al. 2011). More research is needed to elucidate the interplay between pragmatic abilities and word learning in children with neurodevelopmental disorders.

Perhaps the most severe limitation of this article and the theoretical framework it advocates for is its basis in data collected in Western, affluent, and urban settings. This systematic bias is widespread in (developmental) psychology and generally limits the scope of theorizing (Henrich et al. 2010, Nielsen et al. 2017). While we are optimistic that the communicative inference view would hold in non-Western settings, much research is needed to test whether this is actually the

case. The anthropological literature has hinted at differences in which and how pragmatic inferences are computed across cultures (Harris 1996, Le Guen 2018), but developmental work on cultural variation in early communication or linguistic pragmatics is still rare (cf. Fortier et al. 2018, Liszkowski et al. 2012, Salomo & Liszkowski 2013; S. Zhao, P. Zhou, J. Ren & M.C. Frank, manuscript in preparation). In principle, the modeling framework we presented offers a straightforward way to incorporate cross-cultural (and also interindividual) variation by assuming a universal model structure with a differential weighing of different information sources. For example, it might be that listeners all across the world consider gaze cues and linguistic information when interpreting an utterance, but the relative importance of the two differs across cultures. More broadly, we think that the use of explicit computational theories offers new possibilities to incorporate cross-cultural variation in unified theoretical frameworks.

We are continually astonished by the flexibility and efficiency of human communication. In the right circumstances, a seemingly ambiguous message can lead to a rich interpretation through a social inference about the goals of the speaker. The pragmatic viewpoint provides a way to explain this powerful ability. We have argued here that this viewpoint can be applied productively not just to apparent instances of pragmatic implicature in childhood but also to the communicative abilities of infants. We hope that this perspective inspires further studies elucidating both the origins of these abilities and their variability across cultures.

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