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Understanding the abstract role of speech in communication at 12 months

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ABSTRACT

Adult humans recognize that even unfamiliar speech can communicate information between third parties, demonstrating an ability to separate communicative function from linguistic content. We examined whether 12-month-old infants understand that speech can communicate before they understand the meanings of specific words. Specifically, we test the understanding that speech permits the transfer of information about a Communicator's target object to a Recipient. Initially, the Communicator selectively grasped one of two objects. In test, the Communicator could no longer reach the objects. She then turned to the Recipient and produced speech (a nonsense word) or non-speech (coughing). Infants looked longer when the Recipient selected the non-target than the target object when the Communicator had produced speech but not coughing (Experiment 1). Looking time patterns differed from the speech condition when the Recipient rather than the Communicator produced the speech (Experiment 2), and when the Communicator produced a positive emotional vocalization (Experiment 3), but did not differ when the Recipient had previously received information about the target by watching the Communicator's selective grasping (Experiment 4). Thus infants understand the information-transferring properties of speech and recognize some of the conditions under which others' information states can be updated. These results suggest that infants possess an abstract understanding of the communicative function of speech, providing an important potential mechanism for language and knowledge acquisition.

1. Introduction

Human adults recognize the communicative function of speech even when they cannot understand its content. For instance, when listening to a conversation in a foreign language, we know that the speaker is providing information to the listener. For adults, then, the communicative function and linguistic content of speech can be evaluated separately, such that the *very form of speech* can provide information. Here we ask whether infants have a similar understanding, realizing that speech is communicative in the abstract, that is, even when they do not yet understand the meaning of particular spoken words.

In principle, infants' understanding of the communicative function of speech could be either a product of or precursor to early language and knowledge acquisition (see e.g., Tomasello & Abbot-Smith, 2002, and Fisher, 2002, for a parallel debate on usage-based vs. generativist approaches to verb learning). One possibility is that infants do not grasp the abstract communicative role of speech until they have learned structural properties of language or meanings of words, and begin to talk themselves. They may begin by learning individual word-referent mappings (i.e., that individual units of speech provide information about individual referents) and eventually generalize to a more abstract appreciation that vocalizations that take the form of speech can provide information to others about the world. On this first view, early language acquisition would consist of

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learning specific mappings, with abstract principles of how language is used in the service of communication emerging as a product of accruing item-specific knowledge (e.g., Nazzi & Bertoncini, 2003; Smith, 2000). Alternatively, infants may understand that speech communicates before they acquire a large vocabulary and begin to speak. They may start with an early recognition that the form of speech (but not non-speech sounds) can transfer information, and use this abstract understanding to then help learn individual word meanings (e.g., Waxman, 2002). On this second view, infants' abstract understanding of the communicative function of speech could actually provide a mechanism for language and knowledge acquisition, independent of, and prior to, their knowledge of specific words. This understanding would dovetail with other mechanisms active in infancy such as statistical learning (e.g., Saffran et al., 1996), and pattern abstraction and generalization (e.g., Marcus, Vijayan, Bandi Rao, & Vishton, 1999) that drive language and knowledge acquisition.

In early language acquisition, speech is privileged for infants. From birth, infants respond differently to speech than non-speech (Butterfield & Siperstein, 1970; Peña et al., 2003; Spence & DeCasper, 1987; Vouloumanos & Werker, 2004, 2007). Within their first year, infants treat speech as functionally distinct from other sounds and actions for categorization (Balaban & Waxman, 1997; Ferry, Hespos, & Waxman, 2010; Fulkerson & Waxman, 2007), object individuation (Xu, 2002; Xu, Cote, & Baker, 2005), and word-object mapping (e.g., they associate objects with nonsense words like "fep", but not communicative sounds like "oooh" or consonantal sounds like "l"; MacKenzie, Graham, & Curtin, 2011). By 13 months, infants appreciate that language (i.e., a label) is likely to be shared between people while other behaviors (e.g., object preferences) are not (Buresh & Woodward, 2007; Graham, Stock, & Henderson, 2006). There is, however, also evidence that infants are still building their understanding of the functions of speech at the end of the first year. For instance, although infants understand that labels are object directed, they are permissive about the forms they will treat as labels, accepting spoken words as well as artificial sounds and gestures as object labels at 13 and 19 months (Campbell & Namy, 2003; Namy & Waxman, 1998; Woodward & Hoyne, 1999). Although infants show some understanding that speech functions differently than other sounds in categorization, individuation, and labeling, their understanding of the different functions of speech is not yet adult-like.

Do infants have an abstract understanding of the communicative function[2] of speech? Previous work has informed but not answered this question. By 6 months, infants recognize that speech is used in specific contexts that are potentially communicative: infants associate speech with its usual source, humans (and not other animals; Vouloumanos, Druhen, Hauser, & Huizink, 2009), and expect speech to be addressed toward other humans (rather than objects; Legerstee, Barna, & DiAdamo, 2000). By the end of their first year, infants use speech directed at them in ostensive communicative contexts differently than speech outside these contexts: when speech is accompanied by ostensive communicative cues (such as mutual eye gaze or infant-directed speech register), infants interpret this speech as providing generalizable knowledge, rather than episodic and context-specific information (reviewed in Csibra, 2010; Csibra & Gergely, 2009). Although infants are sensitive to some important elements of linguistic communication, the question of whether infants understand that the speech signal can transfer information from one person to another, even when the infants themselves do not know its meaning, has not been directly examined. Previous work has focused on infants' own ability to map specific speech forms (words) onto objects (or categories). However, appreciating the abstract communicative function of speech means understanding that a speaker can provide information to a recipient, and understanding that this information transfer occurs even when the utterance's specific content may be unknown to the observer. This abstract understanding may be constructed later as a product of language acquisition; alternatively, infants' understanding of speech as communicative may provide an important mechanism for language acquisition.

To examine whether infants have an understanding of the communicative function of speech, even in the absence of known meaning, we must ensure that infants are not responding based solely on their own comprehension of the meanings of particular words. In a typical experiment in which an experimenter communicates directly with the infant (e.g., asking for the "modi"), the infant's response could be based on his or her interpretation of the meaning of the word "modi" without requiring an abstract understanding of the communicative function of speech. To remedy this, we used a third-party scenario (e.g., Akhtar, Jipson, & Callanan, 2001; Song, Onishi, Baillargeon, & Fisher, 2008) in which a novel word is directed towards a second person instead of the infant, rendering the infant a third-party observer to the communicative exchange. Under these circumstances, for the infant to make sense of the second person's response to the word "modi" the infant must infer that the *second person* knows its meaning. In this third-party scenario, if infants do not know the meaning of the word "modi", but have some abstract understanding of the communicative function of speech, they might still be able to evaluate the second person's response to "modi", given infants' understanding that word uses are conventional between speakers (Buresh & Woodward, 2007; Graham et al., 2006). This third-party scenario, in which infants observed an interaction and evaluated the potential for transfer of information between two people, allowed us to examine whether infants understand that the form of speech is communicative.

Using a third-party scenario, we examined whether 12-month-old infants, like adults, treat speech forms as having the ability to transfer information from one person to

[2] Although in the biological literature any aspect of an organism's phenotype that influences the behavior of others (including, for example, size, coloring, etc.) can be considered communicative (Maynard Smith & Harper, 2003), we use communication to mean an exchange between individuals in which the Communicator produces flexible, intentional signals in order to influence the information state of the Recipient (akin to the "communicative signals" described in Tomasello, 2008). Here we use communication synonymously with information-transfer, although we recognize that information-transfer is only one of several key components of communication.

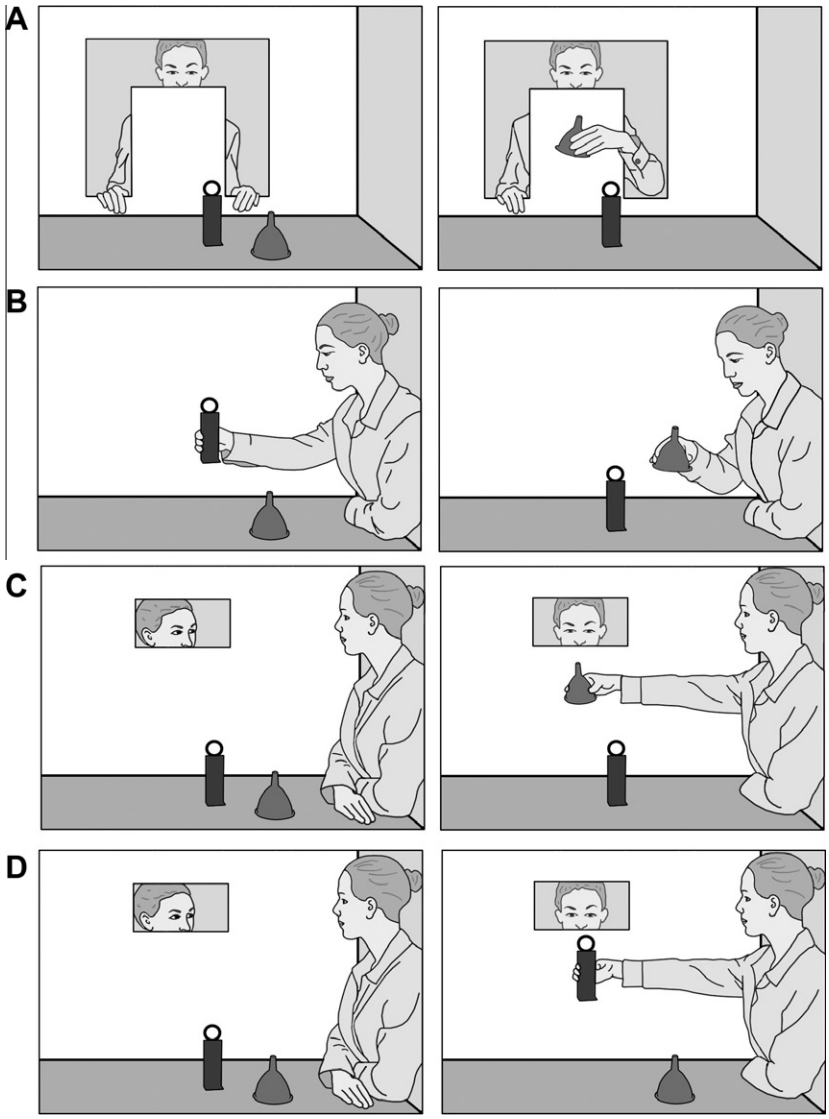

Fig. 1. Method. (A) Familiarization: The Communicator looked at two novel objects, and then grasped the target object. Here, the target object was the red funnel, placed on the right side (target object and object location were counterbalanced across participants). (B) Pretest: The Recipient interacted with both objects. (C and D) Test: The Communicator could no longer reach the objects. The Communicator turned toward the Recipient and produced a vocalization (in Experiment 2, the Recipient produced the vocalization instead). The Recipient then selected the target object (C), or the non-target object (D).

another–specifically, whether they understand that speech is a more effective means than other vocalizations for transferring information between individuals. Infants saw an actor (the Communicator), alone, repeatedly grasping one of two available novel objects (the target), indicating her preference without labeling either object (e.g., Luo & Baillargeon, 2007; Woodward, 1998). This observation provided infants with the relevant information about the Communicator's target object without providing a name for it. Next, a second actor (the Recipient) was introduced, alone, and briefly interacted with both objects, demonstrating no preference. In the test scene, both actors were present, however, due to a change in the scene, the Communicator could no longer reach the objects whereas the Recipient could (see Fig. 1). From an adult perspective, the Recipient could subsequently select the Communicator's target only if the Communicator provided relevant information, for example, producing an informative vocalization such as speech, but not if she produced a non-informative vocalization such as coughing. We examined infants' looking time responses to the Recipient's object selection.

In our experiments, infants always knew which object the Communicator preferred (through their prior observation of the Communicator's selective grasping), but the Recipient only *sometimes* had the requisite information to select the target (through the Communicator's appropriate vocalization). If infants made inferences about the Recipient's ability to select the target from their *own* perspective

and not from the Recipient's,[3] the infants' evaluation of the Recipient's ability to select the target would sometimes be incorrect. If, however, infants understood that some vocalizations (speech) but not others (e.g., coughing) lead to successful communication, they would expect the Recipient to select the target object only when the Communicator vocalized appropriately.

In four experiments using the same general method, we tested whether infants understand the abstract communicative function of speech for transferring information by examining whether 12-month-olds recognize that speech (a nonsense word), but not non-speech (coughing), can communicate about a target object (Experiment 1). We further examined infants' understanding of important components that contribute to the success of communicative interactions: whether infants understand that communication requires the source of the speech to be an informed party, or whether they expect successful outcomes whenever speech is produced, even when the speaker lacks information about which object is the target (Experiment 2); whether they expect only speech to communicate or whether any familiar intentional vocalization would result in successful communication (Experiment 3); and whether they understand that the effectiveness of a communicative signal depends on the information states of the interlocutors (Experiment 4).

2. General method

2.1. Apparatus

Infants sat on a parent's lap facing a display with a floor at infant eye level. From the infant's point of view, the back wall contained a window permitting the Communicator to be visible, or not. The right wall had a large opening covered by a yellow curtain, permitting the Recipient to be visible, or not. On either side of the display were two panels which isolated the parent and infant, and allowed an online coder to see the infant while preventing the coder from seeing the events presented to the infant. The coder recorded infant looking behavior by pressing a button on a game pad attached to a computer running the Windows-based program Baby (Baillargeon & Barrett, 2005). Both the infant and the events in the display were recorded on video.

2.2. Stimuli

Two novel objects were used: a red funnel, 10.2 cm in diameter at its widest point and 10.8 cm tall, and a rectangular blue plank, 13.3 cm tall, 5.1 cm wide, and 1.0 cm thick, topped by a looped pipe cleaner.

[3] There is independent evidence that within their second year (Buttelmann, Carpenter, & Tomasello, 2009; Luo & Baillargeon, 2007; Luo & Johnson, 2009; Moll, Carpenter, & Tomasello, 2007; Onishi & Baillargeon, 2005; Sodian, Thoermer, & Metz, 2007; Surian, Caldi, & Sperber, 2007) and perhaps even earlier (Kovács, Téglás, & Endress, 2010; Luo, 2011) infants recognize that others' information states can differ from the infants' own.

2.3. Procedure

Each infant saw five trials: three familiarization trials, one pretest trial, and one test trial (see Fig. 1). A curtain hid the scene between trials. Each trial contained initial and main sections. During the initial section, the actors performed the informative actions (e.g., in familiarization trials, the Communicator reached for the target object, see Section 2.3.1. below). During the main section, the actors remained still, or performed a non-informative action to maintain the infant's interest (e.g., in familiarization trials, the Communicator tilted the object back and forth). The looking times that are reported were measured during the main section of the trials, after all informative actions had ceased. Trials ended when the coder signaled that the infant had looked away from the scene for two consecutive seconds after having looked for at least 2 s in the main section of the trial, or when the infant looked for the maximum duration for the main trial. Trial-specific actions were performed in time to a metronome clicking once per second. Object placement allowed the infant to see both objects and allowed both actors to see and reach both objects (except as noted). The identity (funnel or plank) and location (left or right) of the target object were counterbalanced across participants such that for half the infants within each condition the target was the funnel (and for half, the plank) and for half the infants the target was on the left (and for half, the right). In test trials, half the infants in each condition saw the Recipient offer the target object, and the other half saw the Recipient offer the non-target object.

2.3.1. Familiarization

When the curtain rose, the Communicator was visible in the back window, with the top of her face and her arms visible. For all Experiments, the Communicator first looked neutrally in the center (2 s), then looked briefly at one object (2 s), then the other object (2 s), looked at and reached for the target object (2 s), lifting it (1 s) and bringing it to a point just below and in front of her face (1 s). She then tilted the object back and forth (2 s). During the remainder of the trial (main section), which had a maximum length of 18 s, the Communicator looked at the target object while tilting it back and forth until the trial was ended (see trial-end criteria in Section 2.3, above). The familiarization trial was presented three times. For Experiments 1–3, only the Communicator was present during Familiarization. For Experiment 4, the Recipient was also visible through the side opening of the display, with her eyes following the actions performed on the target object by the Communicator (see Experiment 4 in Section 6, below).

2.3.2. Pretest

When the curtain rose, the Recipient was visible through the side opening. The Communicator was no longer present. The Recipient briefly looked center (2 s), at one object (2 s), then the other object (2 s). Next, she looked at the first object (1 s), grasped and lifted it (2 s), tilted it towards and away from herself once (2 s), put it down and withdrew her hand (2 s). This 7-s look-lift-tilt sequence was then performed with the second object, ending the

trial's initial section. During the remainder of the trial (main section), which had a maximum length of 15 s, the Recipient performed the 7-s sequence on each object again, stopping when the trial was ended (see trial-end criteria in Section 2.3, above). The pretest trial was presented once.

2.3.3. Test

When the curtain rose, both actors were present in their respective locations, however, the Communicator was unable to reach the objects as the window was now smaller, again revealing only the top of her face, but now obscuring her arms. After the infant looked for 2 s, the Communicator looked at each object (4 s), then turned to make eye contact with the Recipient and produced a vocalization which differed by Experiment (e.g., speech or cough in Experiment 1) twice (4 s), except as noted.[4] The Recipient then selected one of the two objects (2 s), raised and lifted it just below the Communicator's face (2 s), ending the initial section. During the remainder of the trial (main section), which had a maximum length of 40 s, both actors looked at the object until the trial ended (see trial-end criteria in Section 2.3, above). Each infant saw a single test trial. Looking times during the main trials were determined by an online coder blind to target object identity, target object location and test trial type (target or non-target). A second coder, also blind to target object identity and location and to test trial type verified that the trial ended correctly.

3. Experiment 1

To test whether 12-month-old infants have an understanding of the abstract communicative function of speech, we examined whether they recognize that a Communicator can inform a Recipient about her target object by using speech but not non-speech. Since infants understand that speech can refer to objects and that words are shared between individuals (as discussed in Section 1), we examined whether infants would expect the Recipient to select the target when the Communicator produced a novel speech token ("koba"; speech condition), but not when she produced a physiological coughing vocalization ("xhm-xhm-xhm"; cough condition).

We predicted that infants in the speech condition would evaluate the Communicator's speech vocalization as successfully conveying information to the Recipient about the target object and therefore would look longer when the Recipient selected the non-target object (non-target trials) than the target object (target trials; Baillargeon, Spelke, & Wasserman, 1985; Wang, Baillargeon, & Brueckner, 2004). Since in the current scenario, a coughing vocalization could not indicate which object was the target, we predicted that infants in the cough condition should not evaluate the Communicator's vocalization as conveying information about the target to the Recipient; as a result, the Recipient would be equally likely to select either object. Thus, we predicted equal looking times to non-target and target trials.

3.1. Participants

Thirty-two healthy, full-term infants (mean age = 12 - months, 6 days; range = 11, 22 to 13, 09) participated, 16 in the speech condition (eight female), and 16 in the cough condition (seven female). Data from 11 additional infants were excluded from analysis due to fussiness or crying (5), inattentiveness (1), looking the maximum length on all trials (3), or experimenter or computer error (2).

3.2. Results and discussion

Infants evaluated the Communicator's speech, but not her coughing, as informing the Recipient about the target object. When the Communicator produced speech, infants looked significantly longer when the Recipient selected the non-target object ($M_{\text{non-target}} = 20.3$ s), than the target object ($M_{\text{target}} = 11.9$ s; one-way fixed-factor analysis of variance [ANOVA], $F(1,14) = 5.34$, $p = .037$, $r = .53$; see Fig. 2). When the Communicator coughed, infants looked equally when the Recipient selected either object ($M_{\text{non-target}} = 21.0$ s, $M_{\text{target}} = 24.6$ s; $F(1,14) = .73$). The difference between the speech condition and the cough condition was reliable (two-way fixed-factor ANOVA interaction, $F_{\text{interaction}}(1,28) = 4.70$, $p = .039$, $\eta^2 = .12$). When we ran the same one-way fixed-factor ANOVAs and two-way fixed-factor ANOVA on the sum of the trials before the test trial we found no differences in looking time, Fs $\leqslant 2.5$.

The pattern for the speech condition suggests that infants understood that the *form* of speech, even a nonsense word that had not been explicitly associated with a particular referent, communicated information about the target object to the Recipient. The pattern for the cough condition showed that infants did not evaluate the Communicator's coughing as conveying the same information. Just like adults listening to speakers converse in a foreign language, infants understand that the form of speech can communicate information from a speaker to a listener.

4. Experiment 2

For speech to transfer information between individuals, it is usually produced by the individual who has the relevant information. For example, in the current scenario, the Communicator has information about which object she previously grasped but the Recipient does not. Do infants understand that communication requires that the source of the speech be an informed party, that is, do they expect that for the Recipient to identify the target object, information must be provided by the Communicator? Or do they expect speech to result in the selection of a previously highlighted (e.g., grasped) object and a successful outcome regardless of the source of the speech? If infants had the latter expectation, they might not be reasoning about information transfer at all, but merely be responding

[4] We tested 16 infants on a silent version of the experiment in which no vocalization was produced. Infants looked equally whether the Recipient selected the non-target ($M_{\text{non-target}} = 24.8$ s) or the target object ($M_{\text{target}} = 22.5$ s; one-way fixed-factor ANOVA, $F(1,14) = .19$), demonstrating that in the absence of a vocalization, infants had no expectation about which object the Recipient should select.

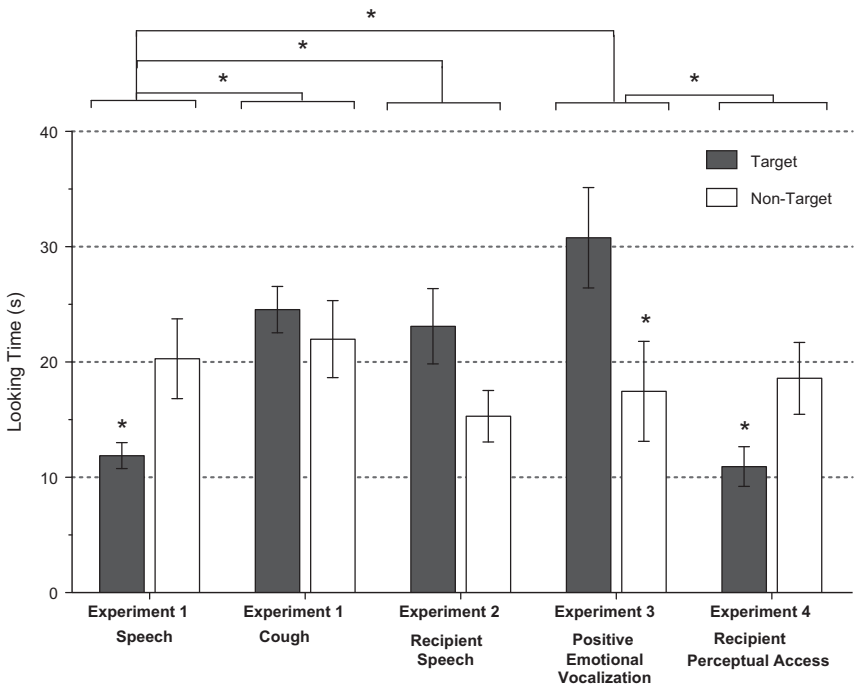

Fig. 2. Results. Mean looking time (in s) ± SEM across infants for each test trial type (target, non-target) for each Condition. An asterisk (∗) represents significance at $p < .05$.

to an association between speech and a recently highlighted object.

There is evidence that infants show sensitivity to the source of information in some situations. They accept a label from a human but not a stereo speaker (Koenig & Echols, 2003) and are more likely to link speech to an object that is looked at and pointed to when the speech and pointing seem to come from the same source (Gliga & Csibra, 2009). If provided with different information about two people (e.g., about their object preferences or the activities they engage in) infants react differently to the same behavior from each person (Liebal, Behne, Carpenter, & Tomasello, 2009). There is also evidence that infants recognize directionality in interactions between individuals. For instance, they dishabituate to a display when a chaser and chasee, or a giver and a taker, suddenly reverse roles (Rochat, Striano, & Morgan, 2004; Schoeppner, Sodian, & Pauen, 2006). Here we examine whether infants use this source sensitivity to evaluate whether the source of speech matters for information transfer.

In Experiment 2, we presented infants with the original scenario, except that in the test phase, the Recipient, rather than the Communicator, said "koba" and then selected one of the two objects. In this case, from an adult perspective, there is no reason to infer that the word "koba" uttered by the Recipient refers to the target object preferred by the Communicator, since the Recipient is uninformed about this preference. If infants consider that successful communication requires the source of the utterance to be informed, they should not evaluate the Recipient's speech as providing information about the target object. In this case, we predicted that infants would look equally at the two types of test trials (target and non-target). In contrast, if infants rely on simple associations between speech and behavior toward objects (e.g., Smith, 2000), then infants should look longer when the Recipient selects the non-target than the target, as in the speech condition of Experiment 1.

4.1. Participants

Twenty-eight (14 female) healthy, full-term infants (mean age = 12 months, 8 days; range = 11, 25 to 12, 22) participated. Data from 14 additional infants were excluded from analysis due to fussiness or crying (3), inattentiveness (4), looking the maximum length on all trials (1), parental interference (1), difficulty seeing the infant's eyes (1), and experimenter or computer error (4).

4.2. Results and discussion

Infants did not evaluate the Recipient's speech as being informative about the target object. After the Recipient spoke, infants looked equally when she selected either object ($M_{non\text{-}target} = 15.3$ s, $M_{target} = 23.1$ s; $F(1,26) = 3.88$, $p = .060$, $r = .36$), differing from the speech condition of Experiment 1 in which the Communicator spoke ($F_{interaction}(1, 40) = 7.45$, $p = .009$, $\eta^2 = .15$). The same analyses on the trials before the test trial revealed no differences in looking time, Fs < 1.

Infants were sensitive to the source of the speech utterance: when speech was produced by the Recipient rather than the Communicator, infants did not expect the Recipient to select the target object. This demonstrates that infants did not merely associate the presence of speech with either highlighted objects or successful outcomes, instead suggesting that infants recognize that for successful

communication, speech should be produced by an informed individual rather than an uninformed one. The numerically longer looking to the target than non-target outcome may reflect infants' understanding that, while speech is generally communicative, in the current scenario speech is unable to specify the target object for the Recipient. We discuss this possibility further in Section 7.

5. Experiment 3

Speech is often produced intentionally with the goal of communicating information and can be *object directed*, that is, reflect the fact that there is a relationship between the speaker and the object (Buresh & Woodward, 2007). In contrast, coughing is typically produced unintentionally for physiological reasons, and is not object directed. Is it only speech that can communicate about objects for infants, or might any intentionally-produced, object directed vocalization do so? In Experiment 3, we presented 12-month-old infants with the original scenario, except that during the test phase the Communicator produced a positive emotional vocalization ("Oooh"), a non-speech vocalization (MacKenzie et al., 2011; Tincoff, 2001) which, like speech, can be object directed (Phillips, Wellman, & Spelke, 2002; cf. Vaish & Woodward, 2010). Although the valence (positive, negative) of emotional vocalizations can be shared across individuals (Sauter, Eisner, Ekman, & Scott, 2010), an emotional vocalization alone is not specific enough to allow the Recipient to select the target object in the current scenario without additional contextual support, such as common ground between the individuals (Clark, 1996), or a co-referring action such as eye gaze directed at the target object (Moses, Baldwin, Rosicky, & Tidball, 2001; Repacholi, 1998).

If infants treat a positive emotional vocalization as similar to speech, relying on its object-directedness and shared valence between individuals, then they should look longer when the Recipient selects the non-target than the target object. If, in contrast, infants understand that an emotional vocalization is not specific enough to inform the Recipient about the target object, they should look equally when the Recipient selects the target or non-target object.

5.1. Participants

Sixteen (eight female) healthy, full-term infants (mean age = 12 months, 5 days; range = 11, 27 to 12, 19) participated. Data from 10 additional infants were excluded from analysis due to inattentiveness (5), looking the maximum length on all trials (1), parental interference (1), and experimenter or computer error (3).

5.2. Results and discussion

Unlike their evaluation of speech, infants did not evaluate the Communicator's positive emotional vocalization as informing the Recipient about the target object. When the Communicator produced a positive emotional vocalization, infants looked reliably longer when the Recipient selected the target object (M_{target} = 30.8 s) than the non-target object ($M_{\text{non-target}}$ = 17.5 s; $F(1,14) = 4.71$, $p = .048$, $r = .50$), a significantly different response than when the Communicator produced speech ($F_{interaction}(1,28) = 9.27$, $p = .005$, $\eta^2 = .22$). The same analyses on the trials before the test trial revealed no differences in looking time, $Fs \leqslant 2.1$.

Infants' response in this experiment clearly differed from their response to speech in Experiment 1, and their looking time pattern was not reliably different from their response to coughing in Experiment 1 ($F_{interaction}(1, 28) = 1.76$, $p = .195$), consistent with our conclusion that infants understand that speech, but not non-speech vocalizations, can transfer information.

Despite the general consistency of these findings, the results in this experiment differed from our predictions. Whereas we had predicted that if infants did not expect the Recipient to select the target after an emotional vocalization they would look equally in target and non-target trials, infants actually looked longer when the Recipient selected the *target*. A possible explanation for this unexpected result—that is consistent with results when the Recipient spoke in Experiment 2—is that infants construed the emotional vocalization as a communicative attempt on the part of the Communicator, but as unable to specify the target object for the Recipient, and thus found it unexpected when the Recipient succeeded in selecting the target anyway. Sixteen-month-olds showed a similar looking pattern in a labeling study, looking longer when an individual correctly labeled objects that she could not—rather than could—see (Koenig & Echols, 2003). Perhaps in the cough condition of Experiment 1 infants simply did not construe the Communicator's vocalization as a communicative attempt at all, and thus had no expectation for how the Recipient should respond.

An alternative explanation for the difference is that infants may have construed the Communicator's emotional vocalization as directed toward the non-target object to which she had previously paid less attention (as in "Oooh, I didn't play with this one before"), thus expecting the Recipient to hand over the non-target (Tomasello & Haberl, 2003). This alternative possibility is considered further in Experiment 4.

6. Experiment 4

The data of Experiments 1–3 suggest that infants were tracking the actors' information states separately, additionally recognizing that they (the infants) and the Recipient initially had access to different information about the Communicator's preference. Infants were always privy to the Communicator's preference because they saw her repeatedly grasping her target object. But, despite always having this knowledge, infants did not assume that the Recipient shared this knowledge; if they did make this assumption, they might have expected the Recipient to select the target object regardless of the Communicator's vocalization (speech, coughing, or emotional), and even when the Recipient produced the vocalization herself.

In Experiment 4 we directly examined whether infants take into account the Recipient's information state in evaluating the communicative function of vocalizations. We

presented infants with a scenario in which the Communicator produced the same underspecified emotional vocalization as in Experiment 3, but this time the Recipient was *present* during familiarization trials and thus had perceptual access to the Communicator's grasping of the target. This gave the Recipient information about the Communicator's preference (Song et al., 2008). If infants accurately evaluated the Recipient's information state, they should now recognize that the Recipient can correctly select the target even if the Communicator's vocalization is underspecified, and thus look longer if the Recipient selects the non-target object. If, in contrast, infants did not consider the Recipient's information state when evaluating the success of the Communicator's vocalization, then infants should behave as in Experiment 3, and not expect the Recipient to correctly select the target if the Communicator's vocalization is underspecified.

6.1. Participants

Sixteen (eight female) healthy, full-term infants (mean age = 12 months, 9 days; range = 12, 01 to 12, 24) participated. Data from three additional infants were excluded from analysis due to fussiness or crying (2), or looking the maximum length on all trials (1).

6.2. Results and discussion

Infants considered the information state of the Recipient when evaluating her response to a potentially communicative vocalization. When the Communicator produced a positive emotional vocalization and the Recipient had previously seen which object was her target, infants looked longer when the Recipient offered the non-target object ($M_{\text{non-target}} = 18.6$ s) than the target object ($M_{\text{target}} = 10.9$ s; $F(1,14) = 4.61$, $p = .050$, $r = .50$), differing reliably from their looking times in Experiment 3 when the Communicator produced an emotional vocalization but the Recipient had *not* previously seen her grasp the target during familiarization ($F_{interaction}(1,28) = 8.73$, $p = .006$, $\eta^2 = .20$). The same analyses on the trials before the test trial revealed no differences in looking time, $Fs \leqslant 2.5$.

Infants recognized that the Recipient's perceptual access to the Communicator's prior object selection allowed the Recipient to correctly select the target even when the Communicator's vocalization was underspecified. Thus infants expect that speech on its own may be sufficient to communicate information between individuals, while non-speech vocalizations may require additional contextual support.

The results of Experiment 4 also rule out the possibility that infants construe the positive emotional vocalization as directed toward the non-target object, leading them to expect the Recipient to offer the non-target (a possibility we considered in the discussion of Experiment 3). If infants had construed the vocalization in this fashion they should again have expected the Recipient to offer the non-target, as in Experiment 3. Instead, infants may have recognized that the positive emotional vocalization could not transfer information to the Recipient that would allow her to select the target object, but that speech or the Recipient's prior information about the Communicator's preferences could do so. These results are consistent with findings that 10-month-olds interpret an actor's ambiguous actions differently depending on their own prior knowledge of the actor's preferences (Sommerville & Crane, 2009). The current experiment shows that infants take into account another person's prior knowledge when interpreting that person's response to a potentially communicative vocalization.

7. General discussion

Twelve-month-old infants familiarized with a Communicator grasping a target object expected a Recipient to select that object in some situations, but not in others. Specifically, they expected the Recipient to select the target when the Communicator used a nonsense word, but not when she coughed or emoted positively unless, in this latter case, the Recipient had previously witnessed the Communicator grasping the target. Furthermore, they expected only speech produced by the Communicator (not speech produced by the Recipient) to inform the Recipient about the target, showing sensitivity to the source of speech in communicative interactions. Thus by 12 months, infants understand the communicative function of speech, taking into account its conventionality and referential specificity, as well as the source of the communicative signal and the information states of interlocutors, to evaluate the outcome of a third-party communicative interaction.

Infants expect that speech should lead to successful communication in at least one situation in which an emotional or physiological vocalization should not. This is consistent with the adult perspective that speech is often a more efficient means of communication than other vocalizations, identifying particular objects in a wider range of contexts. For instance, if a child wants a cookie and says "Cookie!" you will know which dessert to give her. If she vocalizes with positive emotion, "Mmmm!" you will be less likely to select the dessert she wants unless you have additional information, such as her concurrent pointing or your prior knowledge of her dessert preferences. Thus, by 12 months, infants not only privilege the speech signal in their listening preferences and inferences in enumerating, labeling, and categorizing the physical world (e.g., Balaban & Waxman, 1997; Mackenzie et al., 2011; Vouloumanos & Werker, 2004; Xu, 2002), but they have some understanding of the communicative function of speech, specifically its functional role in conveying information.

The finding that infants expected a nonsense word to identify the target object for the Recipient suggests that 12-month-olds can construe speech—in addition to reaching, pointing, and gazing—as an object directed behavior (Bíró & Leslie, 2007; Johnson, Ok, & Luo, 2007; Phillips & Wellman, 2005; Phillips et al., 2002; Sodian & Thoermer, 2004; Vaish & Woodward, 2010; Woodward, 1998, 2003; Woodward & Guajardo, 2002). The capacity to interpret speech as directed towards objects may serve as a foundation for understanding that speech can also refer to absent or abstract entities, such as mental states, and thus be used to inform others about aspects of the world beyond those

that are directly observable (Ganea & Saylor, 2007; Ganea, Shutts, Spelke, & DeLoache, 2007; Saylor, 2004; Saylor & Baldwin, 2004). This understanding in turn, would provide infants with a channel for learning about aspects of the world beyond their immediate experience.

The current studies are equivocal regarding infants' interpretation of the novel word "koba". "Koba" had the form of a word, while coughing and the emotional vocalization "oooh" had less canonical word forms (MacKenzie et al., 2011; Tincoff, 2001) and the latter was produced in our experiments with a prosodic contour typical of emotional utterances (Trainor, Austin, & Desjardins, 2000). While "koba" was clearly object directed, it might be interpreted as a label for the target, or a description (e.g., it might mean "the one on the right/left" or "the red/blue one"). If infants interpreted it as a label, they might, for example, themselves reach for the target if asked to find the "koba". Although the current experiments leave open infants' specific interpretation of "koba", the results demonstrate that infants understood the speech as directed towards the object and that they linked the Communicator's grasping behaviors with her subsequent speech even in the absence of an overtly ostensive context (paralleling results in ostensive contexts with concurrent speech and pointing gestures in 13-month-olds; Gliga & Csibra, 2009).

While we did not directly test infants' interpretation of the word "koba", they must have inferred that the *Recipient* knew the meaning of the word "koba" to make sense of the Recipient's response. The assumption that speech has the same meaning for the Communicator and Recipient is consistent with data from 19- and 24-month-olds who also assume the conventionality of language (Graham et al., 2006; Henderson & Graham, 2005). The current results build on our knowledge of infants' assumption of conventionality and ability to track others' knowledge states, showing in addition that infants expect the *form* of speech (a novel speech token not yet associated with any established meaning) to allow a Communicator to transfer information to a Recipient. This would not be an uncommon situation for 12-month-old infants, as many of the words spoken around them would be novel to them.

Infants showed different expectations for two types of non-speech sounds, an emotional vocalization and a physiological coughing vocalization. Why might infants have interpreted the two non-speech vocalizations differently? It is possible that infants evaluated the Recipient's behavior not only based on whether the vocalization was likely to convey information but also on whether the vocalization was interpreted as an attempt to communicate at all. Coughing is rarely used to communicate (and is usually not directed toward specific objects), and it is unlikely that infants would ever have experienced others using it in a communicative manner. If infants in our experiments did not interpret the cough as a communicative attempt, they may have construed the scenario as a situation in which there was no attempt to communicate on the part of the Communicator, and thus would have had no reason to expect the Recipient to select the target. Emotional vocalizations on the other hand, are frequently used communicatively to direct attention to objects (in conjunction with actions such as pointing which more specifically indicate the object of interest). Infants seem to recognize that others' positive emotional vocalizations can be directed toward specific objects, since they take the valence of these vocalizations into account when deciding which objects to approach or in which box to search (Moses et al., 2001; Repacholi, 1998). If infants interpreted the positive emotional vocalization as a communicative attempt, they may have looked longer when the Recipient offered the target object because the vocalization was underspecified. This general pattern of longer looking at the target outcome was also observed when the Recipient rather than the Communicator spoke, generating an underspecified communicative attempt. It is possible that in situations in which infants do not detect a communicative attempt, they would consider target and non-target outcomes as equally likely, but when a communicative attempt is made, infants evaluate whether that attempt allows a Recipient to select the target. Further work will be needed to examine these alternatives.

In addition to providing novel insight into infants' expectations about the abstract information-transferring properties of speech forms, our results add to a growing body of evidence that young infants understand that individuals, including the infants themselves, may have differential access to information (e.g., Onishi & Baillargeon, 2005; Surian et al., 2007). In our study, despite the fact that infants always knew which object the Communicator preferred, they did not assume that others would also have this information. Instead, they had specific expectations about the conditions under which the information states of others can be updated: hearing speech or witnessing previous relevant actions provided the necessary information to select the target object. Thus infants had to reason about how the different vocalizations would influence the *Recipient's* knowledge—and not their own knowledge—in order to predict the Recipient's response. Our results are thus consistent with recent studies demonstrating that infants expect an agent's behavior to be guided by its knowledge state (Buttelmann et al., 2009; Onishi & Baillargeon, 2005; Scott & Baillargeon, 2009; Southgate, Chevallier, & Csibra, 2010; Surian et al., 2007) and to be updated by relevant information from an interlocutor (Song et al., 2008), as well as demonstrations that infants adjust their communicative attempts in a context specific manner (Grosse, Behne, Carpenter, & Tomasello, 2010; Shwe & Markman, 1997). However, beyond this, our results show that infants track different information states in order to interpret communicative attempts even when the infants themselves are merely observers. The ability to track different information states and the conditions under which they can be updated may be a precursor to understanding the importance of common ground in communication (Clark, 1996); even ambiguous communicative behaviors can be informative if interlocutors have relevant shared background.

The current results suggest that understanding that speech is communicative is a precursor to early knowledge acquisition, and thus, that this abstract understanding of speech as a tool for transferring information could contribute to at least three aspects of early development. First, to language acquisition: infants' assumption that speech

communicates before they know the meanings of many words might drive language acquisition. For example, by attending to communicative interactions and observing their outcomes, infants might more easily detect the referents of novel words (Akhtar et al., 2001) or syntactic constructions (Gleitman, 1990). Contrary to a view in which early language abilities are limited to item-specific knowledge (e.g., about nouns, Nazzi & Bertoncini, 2003; Smith, 2000; or verbs, Tomasello & Abbot-Smith, 2002), our experiments suggest that 12-month-old infants understand that the presence of speech indexes a potential communicative interaction. This understanding of speech as a tool for information-transfer could contribute to language acquisition by allowing infants to make inferences beyond the set of words whose meanings they already know (see also Waxman, 2002, for inferential processes used in conceptual development).

Second, infants' understanding of the abstract communicative function of speech might provide infants with an important mechanism for knowledge acquisition: if infants recognize that speech is a tool for transferring information, this might also provide evidence to infants that the speech channel is a means of *acquiring* information for themselves. Hearing speech in the context of a communicative interaction could cue infants that there is information to be learned from this interaction, for instance about the speakers' goals or the functions of objects. Even before infants understand the meanings of words, they would treat speech as indexing an opportunity for acquiring knowledge(Gelman, 2009).

Third, infants' appreciation that speech transfers information could contribute to social cognition: this appreciation could lead to an understanding of the intentions underlying the use of speech, namely that a speaker uses speech with the intention of transferring information to another person (Grice, 1957), and that, as a consequence, a listener's information state can be updated by another person's speech.

8. Conclusion

The current experiments demonstrate that for 12-month-old infants, a vocalization that takes the form of speech, even without any previously established meaning, can communicate to others by updating their information states and thus influencing their behavior. Even before knowing many words, infants consider how different vocalizations, vocalization source, and information states contribute to the success of communication and thus have some understanding of critical components of communicative interactions (Vouloumanos & Onishi, in press). An abstract understanding of the communicative function of speech would help infants extract important linguistic and epistemic information from the interactions of others as well as to engage in these interactions themselves. Our findings suggest that even in this early phase of language acquisition, infants already have a powerful tool at their disposal for interpreting specific speech utterances based on the outcomes of communicative interactions, and for assessing others' information states and future behaviors.

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