Journal of Experimental Child Psychology 162 (2017) 149–162

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

You changed your mind! Infants interpret a change in word as signaling a change in an agent's goals

Kyong-sun Jin, Hyun-joo Song *

Department of Psychology, Yonsei University, Seoul 120-749, Republic of Korea

ARTICLE INFO

Article history:
Received 7 November 2016
Revised 1 May 2017
Available online 9 June 2017

Keywords:
Infancy
Psychological reasoning
Goal understanding
Verbal information
Communication
Mutual exclusivity

ABSTRACT

Language provides information about our psychological states. For instance, adults can use language to convey information about their goals or preferences. The current research examined whether 14- and 12-month-old infants could interpret a change in an agent's word as signaling a change in her goals. In two experiments, 14-month-olds (Experiment 1) and 12-month-olds (Experiment 2) were first familiarized to an event in which an agent uttered a novel word and then reached for one of two novel objects. During the test trials, the agent uttered a different novel word (different-word condition) or the same word (same-word condition) and then reached for the same object or the other object. Both 14- and 12-month-olds in the different-word condition expected the agent to change her goal and reach for the other object. In contrast, the infants in the same-word condition expected the agent to maintain her goal. In Experiment 3, 12-month-olds who heard two distinct sounds instead of the agent's novel words expected the agent to maintain her goal regardless of the change in the nonlinguistic sounds. Together, these results indicate that by 12 months of age infants can use an agent's verbal information to detect a change in her goals.

* Corresponding author. Fax: +82 2 365 4354.
E-mail address: hsong@yonsei.ac.kr (H.-j. Song).

http://dx.doi.org/10.1016/j.jecp.2017.05.001
0022-0965/

Introduction

Language is a powerful tool that enables us to communicate our psychological states. For instance, imagine an adult who hears someone say at a farmer's market, "I want to buy some blueberries. And, oh, look at those peaches! I will buy some peaches, too." The listener may easily infer that the goals of the speaker's actions will change over time (she will pick up blueberries first and then peaches) from only the brief linguistic experience. The current research sought new evidence that at the start of the second year of life infants already understand that language can provide such information about others' internal states.

Recent evidence suggests that infants appreciate the communicative function of language in their psychological reasoning (e.g., Buresh & Woodward, 2007; Chen & Waxman, 2013; Cheung, Xiao, & Lai, 2012; He et al., 2016; Henderson & Woodward, 2012; Martin, Onishi, & Vouloumanos, 2012; Song, Baillargeon, & Fisher, 2014; Vouloumanos, Martin, & Onishi, 2014). In Vouloumanos et al. (2014), for example, 6-month-old infants first received three familiarization trials in which Agent 1 selectively reached for one of two objects, signaling that she had a preference for the target object. Next, infants received a pretest trial in which Agent 2 reached equally for each of the two objects in Agent 1's absence, demonstrating that Agent 2 had no preference between them. Finally, in the test trial, the objects were manually accessible to Agent 2 but not to Agent 1; Agent 1 looked at Agent 2 and said a novel word, "Koba! Koba!" Agent 2 then picked up either the target object (old-object event) or the nontarget object (new-object event) and lifted it just below Agent 1's window, as though presenting her with the object. Infants looked longer if shown the new-object event as opposed to the old-object event. This effect disappeared in a control condition where Agent 1 coughed instead of saying the novel word, suggesting that infants understood that her coughing no longer conveyed the information about her goal object. These results demonstrate that by 6 months of age infants understand the communicative nature of language and use linguistic information to reason about which of two objects interlocutors are likely to select.

The findings mentioned above, however, focused on a situation in which an agent uses only one word. Thus, it remains unknown whether infants have more sophisticated abilities to use verbal information—and particularly changes in verbal information—when reasoning about an agent's mental states. Can infants interpret a change from one word to another as signaling a change in an agent's goals?

Several considerations suggest that around their first birthday infants might already possess some precursors of such understanding. First, even 6- and 7-month-olds distinguish the referents of a few common nouns such as *banana* versus *hair,* and 14-month-olds show a substantial improvement in the speed and accuracy of linking familiar words to their referents (Bergelson & Swingley, 2012; Bergelson & Swingley, 2013). Second, 9- to 12-month-olds can use distinct novel words in object individuation; for example, if an experimenter produces two different words (e.g., "I see a wug! I see a dak!") while peering into a box, they conclude that at least two objects are in the box (e.g., Dewar & Xu, 2007; Xu, Cote, & Baker, 2005). Third, although a mutual exclusivity assumption (i.e., different words refer to different objects; Liittschwager & Markman, 1994) has been considered to appear at around 17 to 19 months of age (e.g., Byers-Heinlein & Werker, 2009; Byers-Heinlein & Werker, 2013; Halberda, 2003; Houston-Price, Caloghiris, & Raviglione, 2010; Suanda & Namy, 2013; White & Morgan, 2008), Mather and Plunkett (2010) reported evidence that novel words guide 10-month-olds' attention to a novel object over a familiar object. Fourth, 12-month-olds successfully form a novel category if they hear the same novel word applied consistently to all distinct objects from a single category (e.g., "Look at the keeto! Look at the keeto! . . ."), but they do not do so if they hear a different word applied to each object (e.g., Look at the keeto! Look at the bookoo! . . .") (e.g., Ferguson, Havy, & Waxman, 2015; Waxman & Braun, 2005).

Although 12-month-old infants are still at the early stage of vocabulary acquisition (e.g., Dale & Fenson, 1996), the research reviewed above suggests that they can use different words to attend to the distinction between their referents. These findings raised the question of whether infants at this age could also use different words in their psychological reasoning, for example, to infer a change in an agent's mental states. Using a violation-of-expectation paradigm, a recent piece of evidence

demonstrated that 12-month-olds possess some understanding that different words signal a possible change in an agent's goals (Song et al., 2014). In the experiments, 12-month-olds first received four familiarization trials in which they saw an agent sitting (with only her arms and torso visible) behind two novel objects. In the same-word condition, at the start of each familiarization trial, infants heard a novel word ("A dax!") spoken twice in a female voice and saw the agent reach for one of the two novel objects. During the display trial, infants saw the objects in switched positions; the agent was present sitting in front of the objects. Finally, infants received a single test trial in which they heard the same novel word ("A dax!") twice at the start of the test trial and saw the agent reach for either the target object in its new position (old-object event) or the nontarget object (new-object event). The different-word condition was identical to the same-word condition except that infants heard a different novel word ("A pilk!") at the start of the test trial. The infants in the same-word condition looked reliably longer if shown the new-object event as opposed to the old-object event, suggesting that they expected the agent's goal to be maintained. In contrast, the infants in the different-word condition looked about equally at the new-object and old-object events. These and the control results suggest that the infants in the different-word condition (a) noticed the change in word and (b) canceled their initial expectation that the agent would pursue the same goal object, but (c) could not yet establish a specific expectation about which object she would choose.

Why did the 12-month-old infants in the different-word condition in Song et al. (2014) fail to form an expectation about the agent's new goal? One possibility is that the 12-month-olds could recognize the change from one novel word to another, but their fragile mutual exclusivity assumption did not allow them to build the firm expectation that the new word signaled the agent's new goal. This possibility seems likely given that infants aged 17 months and older start to reliably show the mutual exclusivity bias, for example, by linking a novel word to a novel object when faced with a familiar object and the novel object (e.g., Byers-Heinlein & Werker, 2009; Byers-Heinlein & Werker, 2013; Halberda, 2003; Houston-Price et al., 2010; Suanda & Namy, 2013; White & Morgan, 2008; but see Mather & Plunkett, 2010, for results with younger infants), and it is not until several months later that infants show evidence of retention of the link between a novel word and a novel object after a minimal delay (Bion, Borovsky, & Fernald, 2013; Horst & Samuelson, 2008).

Another possibility (albeit not mutually exclusive) is that 12-month-old infants' failure in the different-word condition in Song et al. (2014) might have stemmed from other factors such as high task demands. For example, Song and colleagues might not have offered infants sufficient time to process the novel words in their reasoning about the agent's goals. Specifically, in the experiments, at the start of each familiarization and test trial, infants heard the novel words only twice, once per second, without a pause; as a result, there was only a 2-s gap between the onset of the first word and the beginning of the agent's actions. Considering infants' slow speech perception and word identification (e.g., Fernald & Hurtado, 2006; Werker & Yeung, 2005), it seems reasonable that 12-month-olds would require more time to use the verbal information in their reasoning about the agent's goals.

In addition, in Song et al. (2014), it is possible that the source of the verbal information was ambiguous for the infants. In each of the familiarization and test trials, the agent sat behind the back wall (which entirely blocked her face and showed only her torso and arms) and silently acted on the objects; the infants heard the novel words played from the speakers hidden behind the back wall. In this situation, adults would likely assume that the agent whose face was not visible uttered the words. However, operating on such assumptions could be challenging for 12-month-olds. Prior research indicates that the source of verbal information can influence infants' understanding of others' linguistic behaviors (e.g., Gliga & Csibra, 2009; Koenig & Echols, 2003). For example, in Gliga and Csibra (2009), 13-month-olds could infer an object's location when an actor uttered the name while looking and pointing at where it was hidden. Interestingly, this effect was eliminated when the object was named in a voice that did not match the actor's gender. These results suggest that infants would more readily integrate linguistic and action information if they were clearly originated from the same source. Thus, it is possible that showing the agent's articulatory movement would support infants' understanding of the events, in particular, their integration of the agent's verbal information and goal-directed actions.

We addressed the above possibilities by testing whether 14- and 12-month-old infants could interpret a change in an agent's word as signaling a change in her goals (a) when they were provided with

additional time to process novel words and (b) in a context where the source of verbal information was clear. On each familiarization and test trial, an agent repeated a novel word three times (once per second) and paused 1 s between words, so there was a 6-s gap between the onset of her first word and the beginning of her actions (a duration 3 times longer than in Song et al., 2014). In addition, an agent sat behind a large window with an opening that showed her face and upper body (Fig. 1); therefore, infants were able to watch her utter words. In Experiment 1, we chose to test 14-month-olds to confirm whether the current procedure helped slightly older infants use verbal information to infer a change in an agent's goals. Using the same procedure, Experiment 2 extended the investigation to 12-month-olds, who did not succeed in the different-word condition in Song et al. (2014), to investigate whether infants at this age could build the expectation that an agent would change her goal object on hearing a change in her word.

In Experiments 1 and 2, infants were assigned to a same-word or different-word condition. In the same-word condition, infants first received four familiarization trials in which they saw a female agent sitting at a window in the back wall of an apparatus. In front of the agent, there were two distinct objects: a toy box and a toy cylinder. During the familiarization trials, the agent uttered a novel word ("Papu!") three times, with 1-s pauses between the words, and then grasped, lifted, and tilted the target object (box) until the trial ended. Next, during the display trial, the agent was present sitting in front of the objects that now appeared in switched positions. Finally, during the test trials, the agent uttered the same novel word ("Papu!") three times and grasped, lifted, and tilted the target object in its new position (old-object event) or the nontarget object (new-object event). The procedure in the different-word condition was identical with one critical exception, namely that the agent uttered a novel word ("Modi!") in each familiarization trial and then uttered a different novel word ("Papu") in the test trials.

Our predictions were as follows. First, if infants in the same-word condition interpreted the agent's word as referring to her intention of reaching for the goal object, then they should expect her to reach for the same object in the test trials; as a result, in line with prior findings from two-object experiments (e.g., Guajardo & Woodward, 2004; Woodward, 1998; Woodward, 1999), they should look reliably longer at the new-object event than at the old-object event. Second, if infants in the different-word condition (a) detected the change in the agent's word in the test trials and (b) interpreted it as signaling a change in her goal, then they should expect her to reach for the other object (the one she had not reached for previously); as a result, they should look longer at the old-object event than at the new-object event.

In addition, in Experiment 3, we tested 12-month-old infants in a different-sound condition to further confirm the nature of the verbal information. One might offer alternative and much simpler interpretations that infants would succeed in the current research, for example, simply by associating the auditory information with the objects without appreciating the communicative nature of the verbal information. However, consistent with prior findings suggesting that speech (vs. nonspeech sounds) plays a distinctive role in various kinds of infants' conceptual or social reasoning tasks, including their object categorization (e.g., Balaban & Waxman, 1997; Ferry, Hespos, & Waxman, 2010; Fulkerson & Waxman, 2007), object individuation (Xu, 2002; Xu et al., 2005), word–object mapping (MacKenzie, Graham, & Curtin, 2011), and goal understanding (e.g., Martin et al., 2012; Vouloumanos et al., 2014), here we also predict that infants would not use nonverbal sounds (not produced by the agent) as communicative signals indicating the agent's goals. The design of Experiment 3 was identical to that of the different-word condition in Experiments 1 and 2 except that infants heard two distinct sounds (computer-generated ding-dong and squeaky sounds) instead of the agent's words; the agent silently performed the actions. Such sounds, although clearly distinct, again were unlikely to provide communicative information about the agent's goals. If infants indeed considered these sounds to be irrelevant to the agent's goals, then they should expect the agent to maintain her goal regardless of the change in sounds; accordingly, consistent with previous goal-reasoning tasks (e.g., Guajardo & Woodward, 2004; Woodward, 1998; Woodward, 1999), they should look longer at the new-object goal than at the old-object goal.

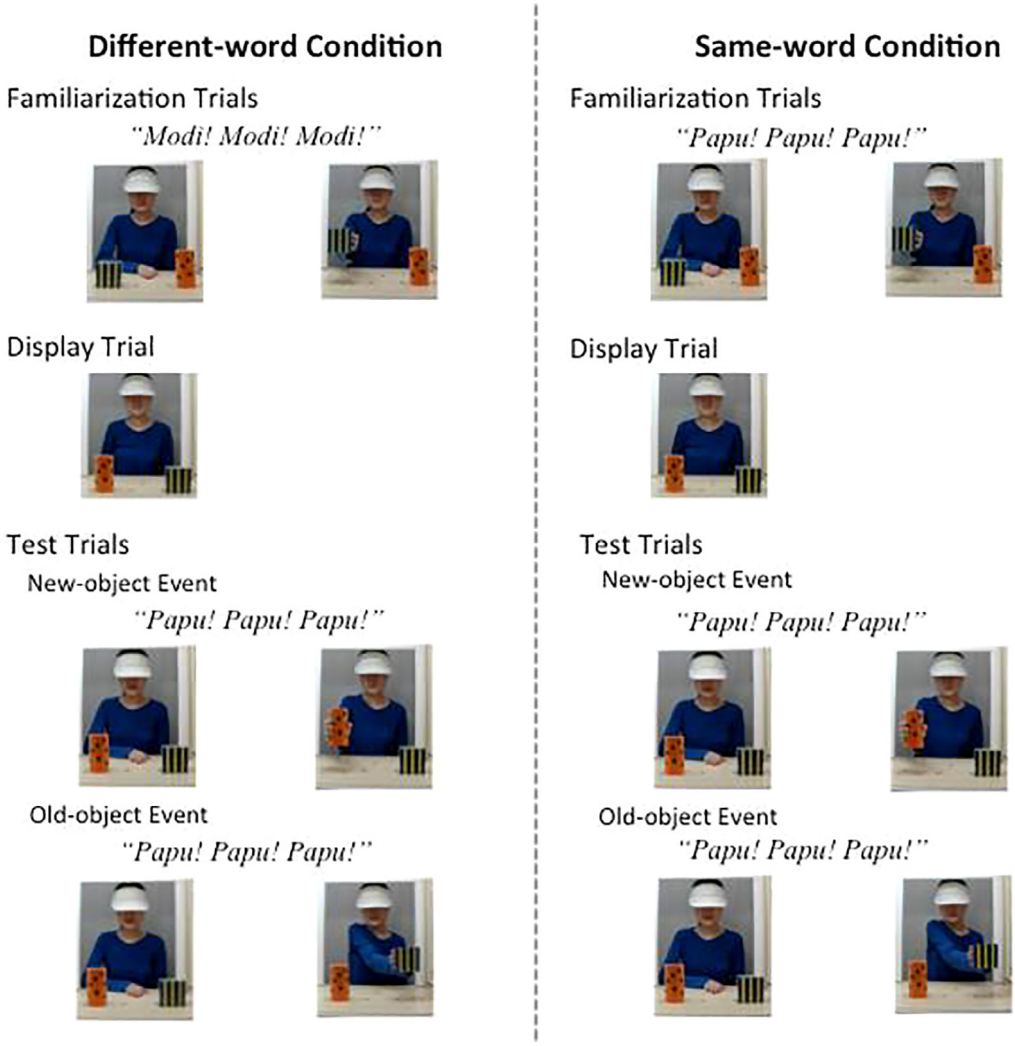

Fig. 1. Events presented in Experiments 1 and 2 by condition.

Experiment 1

Do 14-month-old infants possess a sophisticated ability to use verbal information to reason about others' goals? Building on prior work by Song et al. (2014), Experiment 1 examined whether 14-month-olds interpret a change in an agent's word as signaling a change in her action goals (a) when given additional repetitions and time to process novel words and (b) when the source of verbal information was clear.

Method

Participants

Participants were 36 healthy full-term infants (18 male; age range = 13 months 3 days to 16 months 0 days, *M* = 14 months 12 days). Another 12 infants (8 from the different-word condition

and 4 from the same-word condition) were excluded; of these infants, 9 were overly fussy (7 did not complete the experiment due to fussiness and 2 completed the experiment but were rated as fussy or crying by two observers who were naive about the test events), 1 was distracted (e.g., by the bib), 1 had a looking time difference at the two test events greater than 3 standard deviations from the condition mean, and 1 had parental interference. Equal numbers of infants (n = 18) were randomly assigned to the same-word or different-word condition.

Participants were recruited in Seoul, Korea, and surrounding areas and were acquiring Korean as their native language. The infants in this experiment and the subsequent experiments were recruited through the posting of recruitment advertisements on online parenting communities and the distribution of leaflets at a public health center. Parents were offered reimbursement for their transportation expenses but were not compensated for their participation. Written informed consent was obtained from each infant's parent prior to the test session, and all protocols were approved by the Yonsei University institutional review board.

Apparatus and stimuli

The events were presented on a brightly lit display booth (200 cm high, 95 cm wide, and 64 cm deep) mounted 75 cm above the floor. The infant faced a large opening (53 × 88 cm) in front of the apparatus; between trials, a supervisor lowered a curtain in front of this opening. The floor of the apparatus was covered with pastel apricot-colored paper, and the sidewalls were covered with white muslin. The back wall was made of white foam core; a window (50 × 46 cm) extended from its lower edge, 6 cm from the right wall.

The experimenter was a female native Korean speaker. She sat on a chair centered behind the window, through which an opening showed her upper body and face. Unlike in Song et al. (2014), this setup permitted us to provide infants with a clear source of verbal information; it was clear for infants that the experimenter uttered the words. The experimenter wore a solid blue T-shirt and an ivory visor covering her eyes.[1] A muslin screen behind her hid the testing room.

On the apparatus floor, 20 cm in front of the window, there were two distinct objects, a toy box and a toy cylinder, whose centers were 18.5 cm apart. The box (9 × 9 × 9 cm) was made of cardboard and was blue with yellow vertical stripes. The cylinder (13 cm high and 7 cm in diameter) was made of cardboard and was orange with green dots.

The agent produced novel words ("Modi!" and "Papu!" in the different-word condition and "Papu!" in the same-word condition) at a comfortable listening level (range = 68–73 dB, measured with a handheld sound level meter).

Procedure

The infants sat on their parents' lap centered in front of the apparatus; parents were instructed to close their eyes and to remain silent during the testing session. Two naive observers hidden on either side of the apparatus monitored each infant's looking behavior, and looking times were computed using the primary observer's responses; the observers could not determine whether the agent in the test trials reached for the new object or the old object. Agreement between the two observers was calculated for each trial by dividing the number of 100-ms intervals in which the two observers agreed on whether the infant was or was not looking at the event by the total number of intervals in the trial. Interobserver agreement was calculated for 34 infants (only one observer was present for 2 infants) and averaged 96% per trial per infant.

Infants in the different-word condition received four familiarization trials, a display trial, and a pair of test trials. Each familiarization trial had a pretrial and a main trial. At the start of the 10-s pretrials, the agent sat at the window with her bare right hand resting on the apparatus floor, centered between and 22 cm behind the box and cylinder. After a 2-s silent pause, the agent said a novel word ("Modi!") three times, once per second, and after each utterance there was a 1-s pause (6 s). Next, the agent reached for and grasped the box (1 s), and then lifted it about 12 cm above the apparatus floor (1 s).

[1] The primary goal of the current research was to investigate the effect of verbal information on infants' goal understanding; thus, we wanted to control the influence of other social cues such as eye gaze.

During the main trial, the agent tilted the object gently left to right, changing orientation once per second, until the trial ended. During the entire session, the agent (who wore the visor) looked at a mark on the apparatus floor centered between the two objects.

Prior to the display trial, the objects' positions were switched. During the display trial, the infants saw the objects in their new positions; the agent sat at the window with no hands on the apparatus floor. This trial was static and silent and had only a main trial.

Finally, infants received a pair of test trials. Each of the two test trials again consisted of a 10-s pretrial followed by a main trial. As in the familiarization trials, at the start of the pretrials the agent sat at the window with her bare right hand resting on the apparatus floor. After a 2-s silent pause, the agent said a different novel word ("Papu!") three times, once per second, with a 1-s pause after each word (6 s). Next, the agent reached for, grasped, and lifted up the cylinder (new-object event) or the box (old-object event) (2 s). During the main trials, the agent tilted the object (box or cylinder) left to right until the trial ended. Half of the infants saw the new-object event first, and the other half saw the old-object event first.

The procedure of the same-word condition was identical to that of the different-word condition except that the agent uttered the same novel word ("Papu!") in the familiarization and test trials.

Looking times during the pretrials and main trials of the familiarization and test trials were computed separately. Across conditions, infants were highly attentive during the pretrials of the familiarization trials and looked, on average, for 9.6/10 s. The main trial of each familiarization trial ended when the infants either (a) looked away for 2 consecutive seconds after having looked for at least 2 cumulative seconds or (b) looked for a maximum of 60 s.

The display trial (which had only a main trial) ended when the infants either (a) looked away for 2 consecutive seconds after having looked for at least 4 cumulative seconds or (b) looked for a maximum of 60 s. The 4-s minimum value ensured that infants had the opportunity to see the change in the objects' positions before the trial could end.

Across conditions and events, the infants were highly attentive during the pretrials of the test trials and looked, on average, for 9.5/10 s. Each test trial ended when infants either (a) looked away for 2 consecutive seconds after having looked for at least 6 cumulative seconds or (b) looked for a maximum of 60 s. The 6-s minimum value was chosen to give infants sufficient time after the agent reached for the object to process the event and determine whether it was consistent with their expectations.

Preliminary analyses of the test data revealed no significant interaction of condition and event with infant's sex or which test event was presented first, all Fs(1, 32) < 1.93, ps > .17; therefore, the data were collapsed across these latter two factors.

Results and discussion

Infants' looking times during the main trials of the four familiarization trials (Table 1) were averaged and subjected to a single-factor analysis of variance (ANOVA) with condition (different-word or same-word) as a between-participants factor. The main effect of condition was not significant, $F(1, 34) < 1$, suggesting that infants in the two conditions looked about equally during the familiarization trials.

Infants' looking times during the display trial were analyzed as above. Again, the main effect of condition was not significant, $F(1, 34) < 1$, suggesting that infants in the two conditions looked about equally during the display trial.

Infants' looking times during the main trials of the test trials (Fig. 2) were analyzed by a 2 × 2 ANOVA with condition (different-word or same-word) as a between-participants factor and event (new-object or old-object) as a within-participant factor. The results revealed no significant main effects of condition or event, both Fs(1, 34) < 1.28, ps > .26. However, a significant Condition × Event interaction was observed, $F(1, 34) = 15.70$, $p < .001$, $\eta_p^2 = .32$. Paired-sample t tests within each condition were conducted. In the different-word condition, infants looked reliably longer at the old-object event ($M = 27.7$, $SD = 12.6$) than at the new-object event ($M = 20.0$, $SD = 11.3$), $t(17) = 2.60$, $p = .02$, $d = 0.61$. In contrast, in the same-word condition, infants looked reliably longer at the new-object event ($M = 33.5$, $SD = 18.5$) than at the old-object event ($M = 23.9$, $SD = 14.3$), $t(17) = 2.99$, $p = .01$, $d = 0.73$.

Table 1
Mean looking times (and standard deviations) during the main-trials of familiarization and display trials, separately per experiment and condition.

	Familiarization trials	Display trial
Experiment 1 (14-month-olds)		
Different-word	29.1 (12.6)	19.3 (15.9)
Same-word	29.2 (11.0)	23.7 (13.8)
Experiment 2 (12-month-olds)		
Different-word	31.1 (15.1)	21.4 (12.0)
Same-word	30.9 (9.2)	20.8 (10.3)
Experiment 3 (12-month-olds)		
Different-sound	28.4 (12.6)	19.7 (12.2)

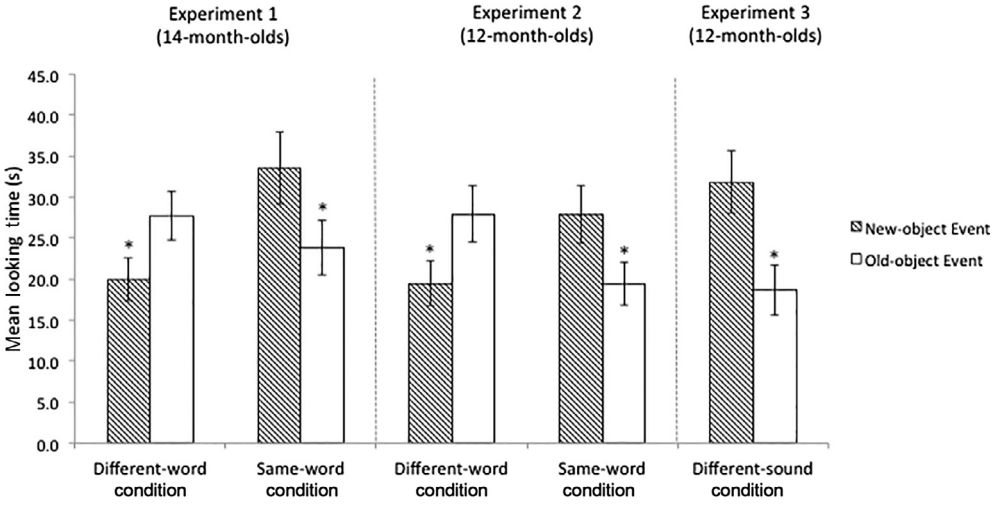

Fig. 2. Mean looking times in each experiment by condition during the main trials of the test trials. Error bars represent standard errors. An asterisk denotes a significant difference ($p < .025$ or better).

Inspection of infants' individual responses yielded similar results. In the different-word condition, 13 of the 18 infants looked longer at the old-object event than at the new-object event (nonparametric Wilcoxon signed-rank test, $Z = 2.37$, $p = .02$). In the same-word condition, in contrast, 16 of the 18 infants looked longer at the new-object event than at the old-object event ($Z = 2.59$, $p = .01$).

In conclusion, in Experiment 1 14-month-old infants (a) used the agent's novel words in reasoning about her action goals and (b) interpreted the change from one novel word to another as signaling a change in which object the agent would choose next. Unlike 12-month-old infants in Song et al. (2014), 14-month-olds in the current experiment successfully used verbal information to build a specific expectation that the agent would change her goals. Why did infants in the current experiment succeed, whereas 12-month-olds in Song et al. failed, at such understanding? One possibility is that the changes we made to the procedure facilitated infants' processing of the verbal information and events. A second possibility is that there is a developmental change between 12 and 14 months of age as infants obtain more linguistic and social experiences. To address these possibilities, in Experiment 2 we tested 12-month-olds using the same procedure.

Experiment 2

The goal of Experiment 2 was to further investigate 12-month-old infants' ability to use verbal information in reasoning about others' goals. Recall that infants at this age in the previous research

(Song et al., 2014) failed at building a specific expectation about an agent's new goal even though they noticed the change in word. The procedure was the same as in Experiment 1.

Method

Participants

Participants were 32 healthy infants (17 male; age range = 10 months 27 days to 12 months 27 days, M = 11 months 28 days). Another 17 infants (9 from the different-word condition and 8 from the same-word condition) were excluded; of these infants, 13 were overly fussy (10 did not complete the experiment due to fussiness and 3 completed the experiment but were rated as fussy or crying by two naive observers), 1 was distracted, 2 looked for the maximum amount of time allowed (60 s) in both test trials, and 1 had parental interference. Equal numbers of infants (n = 16) were randomly assigned to the different-word or same-word condition.

Apparatus and stimuli

The apparatus and stimuli were identical to those in Experiment 1.

Procedure

The procedure was identical to that of Experiment 1. Interobserver agreement averaged 95% per trial per infant. Infants were highly attentive during the pretrials, looking on average for 9.7/10 s in familiarization trials and for 9.4/10 s in test trials.

Preliminary analyses of the test data revealed no interaction of condition and test event with infants' sex or which test event was presented first, all Fs(1, 28) < 1; therefore, the data were collapsed across these latter two factors.

Results and discussion

Infants' looking times were analyzed as in Experiment 1. The main effect of condition was not significant during the main trials of the familiarization and display trials, Fs(1, 30) < 1. Infants in the two conditions looked about equally during the familiarization and display trials (Table 1).

Analyses of infants' looking times during the main trials of the test trials (Fig. 2) yielded a significant Condition × Event interaction, $F(1, 30) = 16.40$, $p < .001$, $\eta_p^2 = .35$. Neither the main effect of condition nor the main effect of event was significant, Fs(1, 30) < 1. Paired-sample t tests revealed that infants in the different-word condition looked reliably longer at the old-object event (M = 28.0, SD = 13.7) than at the new-object event (M = 19.5, SD = 10.9), $t(15) = 3.26$, $p = .01$, $d = 0.84$, whereas infants in the same-word condition looked reliably longer at the new-object event (M = 27.9, SD = 14.1) than at the old-object event (M =19.4, SD = 10.5), $t(15) = 2.58$, $p = .02$, $d = 0.67$.

Inspection of infants' individual responses yielded similar results. In the different-word condition, 13 of the 16 infants looked longer at the old-object event than at the new-object event ($Z = 2.69$, p = .01). In the same-word condition, in contrast, 14 of the 16 infants looked longer at the new-object event than at the old-object event ($Z = 2.53$, $p = .01$).

In Experiment 2, we replicated and extended the findings of Experiment 1 to 12-month-old infants. These results indicate that 12-month-olds are already capable of interpreting a change in word as signaling a change in an agent's goals when given sufficient time to process words and actions and when the source of verbal information is clear. On hearing the same word, infants expected the agent to pursue the same goal object as she did in the familiarization trials. However, when the agent changed her word from one to another, infants expected her to reach for the other object. Together, Experiments 1 and 2 suggest that by 12 months of age, infants understand not only that words are selected for communicative purposes but also that a change in an agent's word signals a change in her mental states.

Experiment 3

Could weaker interpretations be offered for the positive results of the different-word condition in Experiments 1 and 2? An alternative interpretation could be that infants in the different-word condition might have used low-level strategies, for example, simply by encoding the words as mere auditory information and associating the sounds with the objects without appreciating the communicative nature of the words. To rule out this alternative interpretation, in Experiment 3 we tested 12-month-old infants in a different-sound condition. The procedure of Experiment 3 was identical to that of the different-word condition in Experiments 1 and 2 except as follows. The two novel words were replaced by two distinct prerecorded sounds, which were played from the hidden speakers. The duration of the two computer-generated sounds was about the same (each 1 s) as that of the novel words used in Experiments 1 and 2. The agent performed the same actions as in the preceding experiments but did not utter any words.

At the start of each of the four familiarization trials, infants heard ding-dong sounds three times with a 1-s pause in between and then saw the agent reach for one of the two distinct objects (box) on the apparatus floor. During the display trial, the agent was present sitting in front of the objects that now appeared in switched positions. Finally, at the start of each of the two test trials, infants heard squeaky sounds (resembling a rubber duck sound) and then saw the agent reach for the box (old-object event) or the cylinder (new-object event).

The predictions were as follows. If infants in Experiment 3 (a) interpreted the agent's repeated actions in the familiarization trials as directed toward the goal of obtaining the box, consistent with previous findings from goal-reasoning tasks (e.g., Guajardo & Woodward, 2004; Woodward, 1998; Woodward, 1999), and (b) understood that, unlike the agent's words, the background sounds that happened to precede the agent's actions did not necessarily signal her underlying mental states, then infants should expect the agent's goal to be maintained regardless of the shift in sounds (from ding-dong to squeaky). Thus, we predicted that infants should detect a violation when the agent changed her goal object after the mere change in sounds and, hence, should look longer at the new-object event than at the old-object event. Such a result would help to rule out low-level alternative interpretations of the positive results in the different-word condition in the preceding experiments (e.g., infants looked longer at the old-object event because they simply associated the agent's words with the objects without necessarily understanding the communicative function of words).

Method

Participants

Participants were 16 healthy term 12-month-old infants (8 male; age range = 11 months 2 days to 12 months 27 days, *M* = 11 months 28 days). Another 4 infants were excluded because they did not complete the experiment due to fussiness.

Apparatus and stimuli

The apparatus and stimuli were identical to those of the different-word condition in Experiments 1 and 2 except as follows. Two distinct ding-dong (1 s) and squeaky (1 s) sounds were created and normalized by a computer program. The volume (70 dB) of these sounds was approximately similar to that of the agent's words in the preceding experiments. These sounds were prerecorded on an MP3 player to repeat three times with a 1-s pause in between (so that each soundtrack lasted for 6 s) and were played through the hidden speakers behind the wall of the apparatus.

Procedure

The procedure of Experiment 3 was similar to that of the different-word condition in Experiments 1 and 2 with the following exceptions. First, at the start of each familiarization trial, after a 2-s silent pause, a hidden supervisor played the ding-dong sounds through the MP3 player connected to the hidden speakers. Infants heard the ding-dong (1 s) sounds three times; after each ding-dong sound, there

was a 1-s pause (6 s). Second, at the start of each test trial, after a 2-s silent pause the infants heard the squeaky (1 s) sounds three times; again with a 1-s pause between each sound (6 s).

Interobserver agreement was calculated for 15 infants (only one observer was present for 1 infant) and averaged 96% per trial per infant. Infants were highly attentive during the pretrials, looking on average for 9.0/10 s in the familiarization trials and for 8.8/10 s in the test trials.

Preliminary analyses of the test data revealed no significant interaction of event with infant's sex or which test event was presented first, all Fs(1, 14) < 1; therefore, the data were collapsed across these latter two factors.

Results and discussion

Infants' looking times during the main trials of the test trials (Fig. 2) were analyzed by a paired-sample t test. This analysis revealed that infants looked reliably longer at the new-object event (M = 31.8, SD = 15.2) than the old-object event (M = 18.7, SD = 12.3), $t(15) = 3.48$, $p = .00$, $d = 0.88$. Inspection of infants' individual responses yielded a similar result, with 14 of the 16 infants looking longer at the new-object event than at the old-object event ($Z = 2.74$, $p = .01$).

We further analyzed infants' looking times during the main trials of the test trials by a 2 × 2 ANOVA with condition (different-word in Experiment 2 or different-sound in Experiment 3) as a between-participants factor and event (new-object or old-object) as a within-participant factor. Preliminary analyses of the test data revealed no significant interaction of condition and event with infant's sex or which test event was presented first, all Fs(1, 28) < 1; therefore, the data were collapsed across these latter two factors. The main effects of condition and event were not significant, both Fs(1, 30) < 1.1, ps > .32, but the Condition × Event interaction was significant, $F(1, 30) = 22.22$, $p < .001$, $\eta_p^2 = .43$.

Recall that in Experiment 2, 12-month-old infants in the different-word condition looked longer at the old-object event than at the new-object event, indicating that they expected the agent to reach for the new object when she uttered the new novel word. However, it might be suggested that the infants in the different-word condition showed the positive result based on low-level associations such as a simple link between the sounds and the objects. The results in Experiment 3 ruled out this alternative interpretation; the 12-month-olds in Experiment 3 did not expect the agent to change her goal when they simply heard the change in nonverbal sounds in the test trials. These results suggest that they perceived the nonverbal sounds as irrelevant to the agent's goals and, hence, expected her goal to be maintained regardless of the change in sounds. One might still argue that the results of Experiment 3 do not rule out a possibility that infants associate any *human vocalization*, either verbal or nonverbal, with an agent's goal-directed objects. This possibility seems unlikely given prior evidence that 12-month-olds understand words, but not nonverbal vocalization (e.g., coughing), can communicate about an agent's intentions (e.g., Martin et al., 2012). Nevertheless, it remains possible that in our testing context infants might interpret a change in nonverbal vocalization (e.g., coughing to humming) perhaps as some changes in an agent's goals. Future experiments will explore this possibility.

General discussion

The current research examined whether 14- and 12-month-old infants could use verbal information to reason about a change in an agent's goals. In the same-word condition, when an agent produced a novel word three times and reached for one of two distinct objects in multiple familiarization trials, infants assumed that the agent's same word communicated that the agent would reach again for the same object in test. In contrast, in the different-word condition, when the agent changed her word in test, infants understood that the change in her word communicated that she would now reach for the other object. In the different-sound condition, when 12-month-olds heard two distinct sounds instead of the agent's two different words, they expected the agent's goal to be maintained regardless of the change in sounds, suggesting that they did not evaluate the sounds as conveying the same information as the agent's words. Although numerous reports have presented evidence that infants can attribute to agents' motivational states such as goals and dispositions

(e.g., Csibra, Biró, Koós, & Gergely, 2003; Johnson, Ok, & Luo, 2007; Luo & Baillargeon, 2005; Woodward, 1998; Woodward, 1999; for reviews, see Baillargeon, Scott, & Bian, 2016; Baillargeon et al., 2015), this is the first evidence that infants as young as 12 months can infer a change in an agent's goals using verbal information.

The current findings extend prior research by Song et al. (2014) indicating that 12-month-old infants were not yet able to form a specific expectation that an agent would change her goal despite noticing the change of word. To facilitate infants' processing of verbal information, the current research additionally provided infants with more repetition of the novel words, more time to process the words, and the opportunity to clearly observe the agent produce the words. Rather than attempting to tease apart the roles of those factors here, we reserve this question for future research and emphasize the importance of providing the relevant information to support infants' subtle and context-sensitive psychological reasoning. Future research can also explore whether additional communicative information such as eye gaze would help infants to reason about a change in an agent's goals. Communicative contexts are complex, and infants may fail in using communicative information because of task demands or nuanced differences in contexts.

It is important to note that the situations presented in the current research are closely related to mutual exclusivity in word learning, which has been suggested to arise at 17–19 months of age (e.g., Byers-Heinlein & Werker, 2009; Byers-Heinlein & Werker, 2013; Halberda, 2003; Houston-Price et al., 2010; Suanda & Namy, 2013; White & Morgan, 2008). The current findings add to a small set of experimental reports suggesting precursors of mutual exclusivity well before infants implement it in word-learning experiments. First, 9- to 12-month-olds can use distinct novel words in object individuation (e.g., Dewar & Xu, 2007; Xu et al., 2005) and object categorization (e.g., Althaus & Westermann 2016). Second, Mather and Plunkett (2010) reported evidence that under some conditions even 10-month-olds preferentially looked at a novel object over a familiar object after they heard a novel label. Together, these results suggest that infants around their first birthday might already be sensitive to the mutual exclusivity assumption.

This possibility leads us to wonder whether infants in the current research mapped words to objects in the situations presented. The findings from the delayed-word condition in Song et al. (2014) suggest that this is unlikely. The procedure of the delayed-word condition in Song et al. was identical to that of the different-word condition in the study with one exception, namely that infants heard the words "A dax!" (familiarization) or "A pilk" (test) *after,* rather than before, the agent reached for the toy. If the infants simply mapped words onto the objects, both the infants in the delayed-word condition and those in the different-word condition should not detect a violation when the agent reached for the new object regardless of when a new word was uttered. Thus, the infants in the two conditions should look about equally at the new-object test event. However, the results provided evidence against the possibility; the infants in the delayed-word condition looked reliably longer at the new-object test event than did those in the different-word condition. Song and colleagues interpreted these results to suggest that because the words in the delayed-word condition were not available to infants, at the moment when they reasoned about the agent's upcoming actions, they held the expectation that she would maintain her goal and, hence, looked longer at the new-object event.

Infants in the current research appeared to be sensitive to the communicative significance of verbal information. Unlike the infants in Experiments 1 and 2, the 12-month-olds in Experiment 3 ignored the change in sounds and expected the agent to maintain her goal. These results suggest that verbal information may play a substantial role in infants' reasoning about others' internal states. The distinctive role of linguistic information might be guided by early-emerging biases toward language. For example, even newborns show a preference for human speech over nonspeech stimuli (Vouloumanos & Werker, 2007). Within their first year of life, infants use language, but not tones, to promote object categorization (e.g., Balaban & Waxman, 1997; Ferry et al., 2010; Fulkerson & Haaf, 2006; Fulkerson & Waxman, 2007) and object individuation (Xu, 2002; Xu et al., 2005). Moreover, by 6 months of age, infants recognize that words (e.g., "koba"), but not nonverbal sounds (e.g., coughing), can communicate information about which object an agent wants to refer to (e.g., Vouloumanos et al., 2014). Interestingly, a recent study showed that 6-month-olds accept tones to support object categorization if they are trained in a situation where a human actor produces the tones to converse with another who speaks the infants' native language (Ferguson & Waxman,

2016). Future research can explore whether infants in the current contexts also benefit from such communicative use of nonlinguistic information (e.g., an agent "produces" ding-dong or squeaky sounds).

Another remaining question is how exactly the infants in the current research interpreted the novel words. As adults, we may easily appreciate the agent's referential intention, interpret the novel word as referring to her goal object, and even generalize the label to another object of the same kind. However, it is unknown whether infants here also interpreted the novel words (presented in isolation without any sentence-structural information; cf. Booth & Waxman, 2009; Waxman & Booth, 2001) as object labels. It is possible that they interpreted the novel words differently, for example, as referring to the corresponding spatial position (e.g., *the one on the left*), object features (e.g., *the striped box*), descriptions of actions (e.g., *acting on the box*), or psychological states (e.g., *She likes the box*) (for a similar argument, see Martin et al., 2012). In fact, this question has arisen in previous studies that used similar paradigms in which an agent produced object-directed words (e.g., Buresh and Woodward, 2007; Chen and Waxman, 2013; Henderson and Woodward, 2012; Martin et al., 2012; Vouloumanos et al., 2014). Future research can investigate infants' interpretations of novel words in such contexts by adding a post-word-learning or word-extension task.

In conclusion, the current research provides new evidence that 12- to 14-month-old infants have sophisticated abilities to use verbal information to reason about others' goals. In particular, by 12 months of age, infants can interpret a change from one novel word to another as signaling a change in which object an agent will choose next. These results also provide further evidence supporting the possibility that 12-month-olds already possess a precursor to the mutual exclusivity assumption that different words refer to different objects. This basic understanding may lay the foundation for infants' language acquisition and communicative development.

Acknowledgments

This research was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2015S1A3A2046711). We thank Lin Bian, Cynthia Lukyanenko, and Maayan Stavans for their suggestions on the manuscript, and we thank the parents and infants who participated in the research.

References

Althaus, N., & Westermann, G. (2016). Labels constructively shape object categories in 10-month-old infants. *Journal of Experimental Child Psychology, 151*, 5–17.

Baillargeon, R., Scott, R. M., He, Z., Sloane, S., Setoh, P., Jin, K., ..., Bian, L. (2015). Psychological and sociomoral reasoning in infancy. In M. Mikulincer & P. R. Shaver (Eds.), E. Borgida & J. A. Bargh (Assoc. Eds.), *APA handbook of personality and social psychology*, Vol. 1: *Attitudes and social cognition* (pp. 79–150). Washington, DC: American Psychological Association.

Baillargeon, R., Scott, R. M., & Bian, L. (2016). Psychological reasoning in infancy. *Annual Review of Psychology, 67*, 159–186.

Balaban, M. T., & Waxman, S. R. (1997). Do words facilitate object categorization in 9-month-old infants? *Journal of Experimental Child Psychology, 64*, 3–26.

Bergelson, E., & Swingley, D. (2012). At 6–9 months, human infants know the meanings of many common nouns. *Proceedings of the National Academy of Sciences of the United States of America, 109*, 3253–3258.

Bergelson, E., & Swingley, D. (2013). The acquisition of abstract words by young infants. *Cognition, 127*, 391–397.

Bion, R. A. H., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: Disambiguation of novel word–object mappings in relation to vocabulary learning at 18, 24, and 30 months. *Cognition, 126*, 39–53.

Booth, A. E., & Waxman, S. R. (2009). A horse of a different color: Specifying with precision infants' mappings of novel nouns and adjectives. *Child Development, 80*, 15–22.

Buresh, J. S., & Woodward, A. L. (2007). Infants track action goals within and across agents. *Cognition, 104*, 287–314.

Byers-Heinlein, K., & Werker, J. F. (2009). Monolingual, bilingual, trilingual: Infants' language experience influences the development of a word-learning heuristic. *Developmental Science, 12*, 815–823.

Byers-Heinlein, K., & Werker, J. F. (2013). Lexicon structure and the disambiguation of novel words: Evidence from bilingual infants. *Cognition, 128*, 407–416.

Chen, M. L., & Waxman, S. R. (2013). "Shall we blick?" Novel words highlight actors' underlying intentions for 14-month-old infants. *Developmental Psychology, 49*, 426–431.

Cheung, H., Xiao, W., & Lai, C. M. (2012). Twelve-month-olds' understanding of intention transfer through communication. *PLoS ONE, 7*(9), e46168.

Csibra, G., Biró, S., Koós, O., & Gergely, G. (2003). One-year-old infants use teleological representations of actions productively. *Cognitive Science, 27*, 111–133.

Dale, P. S., & Fenson, L. (1996). Lexical development norms for young children. *Behavior Research Methods, Instruments, & Computers, 28*, 125–127.
Dewar, K., & Xu, F. (2007). Do 9-month-old infants expect distinct words to refer to kinds? *Developmental Psychology, 43*, 1227–1238.
Ferguson, B., Havy, M., & Waxman, S. R. (2015). The precision of 12-month-old infants' link between language and categorization predicts vocabulary size at 12 and 18 months. *Frontiers in Psychology, 6*. http://dx.doi.org/10.3389/fpsyg.2015.01319.
Ferguson, B., & Waxman, S. R. (2016). What the [beep]? Six-month-olds link novel communicative signals to meaning. *Cognition, 146*, 185–189.
Fernald, A., & Hurtado, N. (2006). Names in frames: Infants interpret words in sentence frames faster than words in isolation. *Developmental Science, 9*, F33–F40.
Ferry, A. L., Hespos, S. J., & Waxman, S. R. (2010). Categorization in 3- and 4-month-old infants: An advantage of words over tones. *Child Development, 81*, 472–479.
Fulkerson, A. L., & Haaf, R. A. (2006). Does object naming aid 12-month-olds' formation of novel object categories? *First Language, 26*, 347–361.
Fulkerson, A. L., & Waxman, S. R. (2007). Words (but not tones) facilitate object categorization: Evidence from 6- and 12-month-olds. *Cognition, 105*, 218–228.
Gliga, T., & Csibra, G. (2009). One-year-old infants appreciate the referential nature of deictic gestures and words. *Psychological Science, 20*, 347–353.
Guajardo, J. J., & Woodward, A. L. (2004). Is agency skin deep? Surface attributes influence infants' sensitivity to goal-directed action. *Infancy, 6*, 361–384.
Halberda, J. (2003). The development of a word-learning strategy. *Cognition, 87*, B23–B34.
He, J., Jin, X., Li, Z., Zheng, L., Sun, Z., Zhang, M., & Shen, M. (2016). Infants' understanding of information transmission in the context of communication involving multiple agents. *Infancy, 21*, 228–240.
Henderson, A. M., & Woodward, A. L. (2012). Nine-month-old infants generalize object labels, but not object preferences, across individuals. *Developmental Science, 15*, 641–652.
Horst, J., & Samuelson, L. (2008). Fast mapping but poor retention by 24-month-old infants. *Infancy, 13*, 128–157.
Houston-Price, C., Caloghiris, Z., & Raviglione, E. (2010). Language experience shapes the development of the mutual exclusivity bias. *Infancy, 15*, 125–150.
Johnson, S. C., Ok, S. J., & Luo, Y. (2007). The attribution of attention: 9-Month-olds' interpretation of gaze as goal-directed action. *Developmental Science, 10*, 530–537.
Koenig, M. A., & Echols, C. H. (2003). Infants' understanding of false labeling events: The referential roles of words and the speakers who use them. *Cognition, 87*, 179–208.
Liittschwager, J. C., & Markman, E. M. (1994). Sixteen- and 24-month-olds' use of mutual exclusivity as a default assumption in second-label learning. *Developmental Psychology, 30*, 955–968.
Luo, Y., & Baillargeon, R. (2005). Can a self-propelled box have a goal? Psychological reasoning in 5-month-old infants. *Psychological Science, 16*, 601–608.
MacKenzie, H., Graham, S. A., & Curtin, S. (2011). Twelve-month-olds privilege words over other linguistic sounds in an associative learning task. *Developmental Science, 14*, 249–255.
Martin, A., Onishi, K. H., & Vouloumanos, A. (2012). Understanding the abstract role of speech in communication at 12 months. *Cognition, 123*, 50–60.
Mather, E., & Plunkett, K. (2010). Novel labels support 10-month-olds' attention to novel objects. *Journal of Experimental Child Psychology, 105*, 232–242.
Song, H., Baillargeon, R., & Fisher, C. (2014). The development of infants' use of novel verbal information when reasoning about others' actions. *PLoS ONE, 9*(3), e92387.
Suanda, S. H., & Namy, L. L. (2013). Young word learners' interpretations of words and symbolic gestures within the context of ambiguous reference. *Child Development, 84*, 143–153.
Vouloumanos, A., Martin, A., & Onishi, K. H. (2014). Do 6-month-olds understand that speech can communicate? *Developmental Science, 17*, 872–879.
Vouloumanos, A., & Werker, J. F. (2007). Listening to language at birth: Evidence for a bias for speech in neonates. *Developmental Science, 10*, 159–164.
Waxman, S. R., & Booth, A. E. (2001). Seeing pink elephants: Fourteen-month-olds' interpretations of novel nouns and adjectives. *Cognitive Psychology, 43*, 217–242.
Waxman, S. R., & Braun, I. E. (2005). Consistent (but not variable) names as invitations to form object categories: New evidence from 12-month-old infants. *Cognition, 95*, B59–B68.
Werker, J. F., & Yeung, H. H. (2005). Infant speech perception bootstraps word learning. *Trends in Cognitive Sciences, 9*, 519–527.
White, K. S., & Morgan, J. L. (2008). Sub-segmental detail in early lexical representations. *Journal of Memory and Language, 59*, 114–132.
Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69*, 1–34.
Woodward, A. L. (1999). Infants' ability to distinguish between purposeful and non-purposeful behaviors. *Infant Behavior and Development, 22*, 145–160.
Xu, F. (2002). The role of language in acquiring object kind concepts in infancy. *Cognition, 85*, 223–250.
Xu, F., Cote, M., & Baker, A. (2005). Labeling guides object individuation in 12-month-old infants. *Psychological Science, 16*, 372–377.