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Infants Use Category Label Knowledge to Interpret Absent Reference

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This research investigated infants' (16 and 20 months) use of category information in responding to references to absent objects. Infants were asked to find an object in the box (e.g., "Find an apple!"). When allowed to search, they found either an object from the mentioned category (a plastic apple) or a different object. Infants in both age groups searched again in the box trying to find another object more often on nonreferent than on referent trials (Experiment 1). However, when nonreferents were categorically related to referents, only older infants detected a mismatch and searched again (Experiment 2). These findings suggest that infants use category knowledge when processing references to absent objects.

The ability to understand speech about absent or invisible entities is a pivotal accomplishment of early development. This ability not only expands the scope of possible conversations between children and adults, but also extends children's learning opportunities beyond the limits of present and observable things and phenomena. Absent reference comprehension opens the possibility of acquiring knowledge from testimony which to a great extent shapes children's cognitive development. At the same time, absent reference comprehension itself strongly depends on children's cognitive development. Children's ability to call the appropriate set of representations to mind and hold them in working memory in response to absent reference is a necessary skill that supports their understanding of language (Ganea & Saylor, 2013b). The focus of the current study is the role of category label knowledge in children's interpretations of references to absent objects.

Previous research on absent reference understanding shows that this skill emerges around 1 year of age (Ganea, 2005; Huttenlocher, 1974; Miller, Chapman, Branston,

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& Reichle, 1980; Saylor, 2004; Saylor & Baldwin, 2004). In a typical paradigm, infants play with an object, then the object is removed from view, and after a time delay, the object is mentioned again. Infants' ability to orient to the referent's location, point at it, or approach it has been taken as a sign of their comprehension of labeling an absent object. In a paradigm like this, infants as young as 11 months will turn around to look at the mentioned toy if it is close to them (Huttenlocher, 1974). Older, 13-month-old infants point, look, or walk toward the referent's hiding location (Ganea, 2005; Osina, Saylor, & Ganea, 2013, 2014), and at 16 months, infants also go and search for the referent in another room (Huttenlocher, 1974).

Across multiple studies, it has been shown that infants' absent reference understanding is influenced by their memory of the referent and its location. The youngest infants tested in laboratory settings (11–14 months) are best able to respond to requests about absent entities in contexts that support the retrieval and maintenance of the target representation (Ganea, 2005; Ganea & Saylor, 2013b; Saylor & Baldwin, 2004). For example, infants are most likely to respond to names of highly familiar absent referents (Gallerani, Saylor, & Adwar, 2009; Ganea & Saylor, 2013a), after short time delays (Ganea, 2005), and in the presence of reminders of the absent referents (Saylor, 2004). The youngest infants' comprehension is also limited to most proximal and accessible referents (Ganea, 2005; Huttenlocher, 1974). Thus, 11- to 14-month-old infants only attend to the mentioned referent if it is close and easily accessible (Ganea, 2005), and has not been moved from location to location (Huttenlocher, 1974; Osina et al., 2013, 2014). Infants' ability to respond to absent reference becomes increasingly independent of the properties of the referent's location in their second year of life (Miller et al., 1980; Saylor, 2004; Swingley & Fernald, 2002).

One question that arises from this research is what kind of representation supports infants' responding to the mention of absent referents. On the one hand, when hearing a label of a hidden object, infants may recognize it as potentially referring to multiple tokens of a given category and then think about the speaker's intention to refer to a particular one. On the other hand, infants may orient to the remembered location of the referent reflexively based on low-level associations between sound, object, and location. Previous research provides evidence in support of both of these explanations. To begin with, it has been shown that from early on, infants understand words in a more advanced way than simple associations between sounds, objects, and locations. Infants as early as 12 months recognize the communicative intention behind words and use words to build different kinds of expectations about the unobservable world. For example, in Gliga and Csibra (2009) infants expected to find an object at a particular location based on a label coupled with a deictic gesture produced by the same person. Infants did not do this when the label and the gesture came from two people. This suggests that infants do not just follow the gesture automatically. Moreover, 12-month-olds recognize that only speech, not other sounds, can be used to communicate about unobservable aspects of the world such as a person's intentions (Vouloumanos, Onishi, & Pogue, 2012). Infants also infer the number of objects in a box based on the number of nouns produced by the speaker (Xu, Cote, & Baker, 2005).

In addition to infants' intentional understanding of reference, many developmental findings demonstrate the link between common nouns and categories of objects. For example, naming several objects with the same common noun facilitates object categorization in 9-month-old infants (Balaban & Waxman, 1997). Twelve-month-old infants' ability to identify a referent of a category label (e.g., bird) is affected by how well the item represents its category (e.g., robin versus ostrich; Meints, Plunkett, & Harris, 1999). Finally, when objects are present, infants from as young as 6–9 months are able to identify a novel token of a familiar category as the referent of a spoken word (e.g., Benedict, 1979; Bergelson & Swingley, 2012; Reznick, 1990).

Despite all this evidence that infants understand the categorical nature of words and recognize communicative intent behind reference, there is still little evidence that this applies to situations when referents are absent. When infants hear words in the absence of their referents, they may still orient reflexively to the remembered location of a specific recently seen object without understanding the potential of the word to refer to a category of things. Research by Kirkham, Richardson, Wu, and Johnson (2012) demonstrates that infants as young as 6 months bind auditory, visual, and spatial information in complex multimodal events. They orient to the remembered location of an object when they hear a sound associated with that object, because the sound, the object, and its location are part of one complex multimodal event. Infants' responses in absent reference tasks might be explainable by a similar low-level process of spatially indexing absent objects and orienting to their locations in response to the associated sound forms.

In this study, we ask whether infants are sensitive to the categorical information contained in references to absent objects and whether they are able to use such information to identify correct referents. The task was designed such that infants could not use an active memory trace of a recent object in its specific location to understand the reference. Instead, they had to understand that common nouns refer to sets of similar objects rather than to one specific object and to identify a new object as belonging to the mentioned set or not. Infants first heard a name of an object hidden in a box and were asked to find it (e.g., "Find an apple!"), and then, they were allowed to reach inside and retrieve it [similar in some ways to methods used by Feigenson and Carey (2003, 2005) and Xu et al. (2005)]. On some trials, infants retrieved a referent object (a token of the mentioned basic category, e.g., an apple), while on other trials, they found a nonreferent object—an object from an unrelated category, like a shoe (Experiment 1), or from a related category, like a banana (Experiment 2). In this task, infants have to understand that common nouns are category labels that refer to a limited set of similar objects to recognize the referents and to reject the nonreferents. We tested 16-month-olds and 20-month-olds because in previous studies 16 months was the youngest age when infants displayed understanding of absent reference in situations where referents have not been seen for a long time or were not close nearby (Huttenlocher, 1974; Saylor & Baldwin, 2004). This suggests that at this age, infants' understanding of absent reference may become less restricted by a memory of a particular object in its specific location. We predicted that infants would reach back into the box to find another object more often on nonreferent than on referent trials. We also expected older infants to respond more robustly than the younger infants.

EXPERIMENT 1

Method

Participants

Participants were 32 healthy full-term infants with normal hearing and from English-speaking families. Half were 16 months old (range 14;19–18;3, mean 16;7; 9 girls), and half were 20 months old (range 19;1–21;18; mean 20;5; 8 girls). One additional 16-month-old child participated, but was omitted due to being too upset to engage with the researcher. Participants for this and all subsequent experiments were primarily Caucasian and from middle class families. They were recruited from the Greater Nashville area (southeastern United States) by phone from a database of interested families. This study was conducted according to Declaration of Helsinki guidelines, with written informed consent obtained from a parent or guardian for each child before any assessment or data collection. All procedures involving human subjects in this study were approved by the Vanderbilt University Institutional Review Board.

Materials

For the purposes of this research, we used a variation of a manual search method used in prior studies on infants' object individuation and working memory (e.g., Feigenson & Carey, 2003, 2005; Xu et al., 2005). Stimulus objects were hidden in a felt-covered box constructed from foam core. The box measured 35 (length) $\times$ 12 (width) $\times$ 8 (height) cm. There was an 8 $\times$ 4 cm opening on each side of the box to allow reaching in the box from the experimenter's and the infant's side without turning the box. The opening was covered with spandex with a horizontal slit running through its center (see Figure 1). Small graspable objects from familiar object categories were used during the study. The objects were a toy spoon, a car, a bottle, a shoe, an apple, a cup, a banana, a diaper, a toy plastic dog, toy keys, a rubber duck, and a ball (Figure 1). Parents were given a list of the names of these objects and were asked to indicate the ones their child understood best. Specifically, parents were asked about infants' comprehension of the words, not about production. Based on this report, four experimental objects were chosen such that the child knew the labels for both the referents and nonreferents and such that in each referent–nonreferent pair, the objects did not belong to the same category (like apple–banana) and did not start with the same sound (like dog and duck). Previous research suggests that perceptual similarity between referent and nonreferent objects inhibits infants' ability to correctly identify the named object (Arias-Trejo & Plunkett, 2010). For this reason, special care has been taken to assure that paired objects did not share any perceptual features such as color and shape. Infants in both age groups were reported to know a sufficient number of words to make such pairings. See Appendix A for the summary of items used in the two experiments.

The experiment was recorded with two cameras. One camera recorded infants from the front to enable coding looking behavior and facial expression. The second camera was positioned on the right of the infant 1 m above their head to enable coding reaching behavior (both hands were visible on the recordings).

Procedure

Infants were tested individually in the laboratory. They were seated on their parents' lap across the table from the experimenter. To assure that parents did not inadvertently influence their infants' behavior, parents were asked to wear a specially designed visor that prevented them from watching the experiment. An assistant sat on the floor to the left of the experimenter. The assistant's role was to put objects inside the box for the experimenter. This was necessary to avoid disruptions in the experimenter–child interaction and not to attract the child's attention to the bucket with the

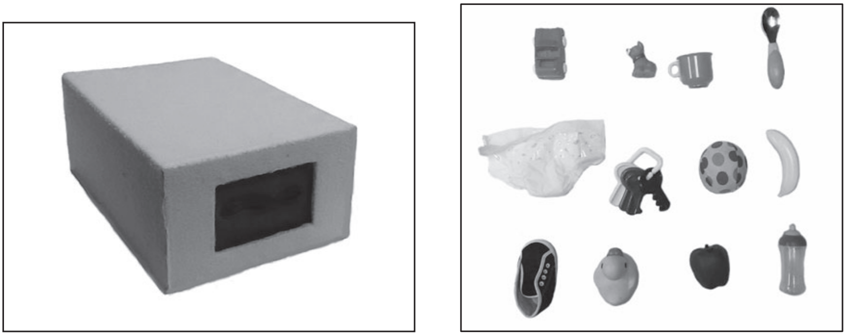

Figure 1 Stimuli used in Experiment 1.

objects that was hidden under the table. The assistant did not look at or interacted with the participants. If a child initially focused on the assistant, their attention was immediately taken by the experimenter as she started the study, and no infant was distracted by the assistant during the task.

Familiarization phase

Once everyone was seated, the experimenter began the *familiarization* phase. The purpose of this phase was to familiarize the child with the box and teach her or him to reach inside to find toys. During the familiarization, the experimenter first showed the box to the child, demonstrating that it had two openings and that one could reach inside. Then, she put the box on her lap where the child did not see it, saying "Let's see what's in the box!" The assistant put two objects in the box that were not going to be used during the experiment. The familiarization objects were from the pool of objects listed above, and they varied from child to child. The familiarization objects were never named by the experimenter to avoid overloading the child with object labels.

The experimenter put the box on the table, pushed it toward the child, and encouraged the child to reach inside to get a toy out by saying "Look, <child's name>, there is something in the box! Do you want to find it? Find a toy!" If the child did not reach on her own, the experimenter took one of the objects out through the child-facing opening. After the child had explored the object for some time (about 30 sec), the experimenter told the child that there was something else in the box and encouraged the child to find the other object. Most infants found the second object on their own. If they did not reach inside the second time, the experimenter took the object out herself. The child was allowed to explore the objects, put them back into the box, and take them out again. Either 3 min later or after the child lost interest in the first pair of objects, the experimenter took the objects from the child and put them on the floor under the table. She put the box on her lap again, and the assistant put two more objects in the box for the child to practice with. The procedure was repeated with the second pair of objects.

Test phase

At the end of the familiarization phase, the experimenter took the objects and the box from the child separately and gently shook the box to make sure the child understood that it was now empty. She put the objects under the table and put the box on her lap. At the beginning of the *test phase*, she said: "Let's see what else is in the box!" while the assistant was hiding the first experimental object (e.g., an apple) in the box. There was always only one object on each of the experimental trials. Once the object was inside, the experimenter put the box on the table, holding it close to herself to prevent the child from reaching, and said: "<Child's name>, I have an apple in there! Yes, an apple! Find the apple!" She pushed the box toward the child to allow her or him to reach inside. If the child did not reach inside, the experimenter repeated the request: "Find the apple!" If the child reached in but could not get the object herself, the experimenter helped the child either by inserting her hand in the box from her side and moving the object closer to the child's hand inside the box, or just by taking the object out of the box from the child-facing opening and giving it to the child. This happened on 40 trials equally distributed across the two experiments and age groups (representing 10% of all trials). These trials did not impact the overall pattern of results.

The experimenter then waited for 10–15 sec for the child to explore the object. This exploration period was the interval during which infants could choose to reach back into the box if they detected a mismatch between the object they retrieved and the item that they were told was in the box. This exploration period varied in length because some infants decided to reach back in the box before 15 sec was over. The main dependent measure was whether infants reached back in the box during the exploration period. The trials terminated in one of the following two ways: (1) An infant put an object in the box after having explored it and pushed the box back to the experimenter; and (2) after 10–15 sec of the exploration period, the experimenter terminated the trial by taking the box and the object from the child whether the child had reached back or not. At the end of the trial, the experimenter put the object under the table and put the box on her lap. The procedure was repeated with three other objects, resulting in four experimental trials total. For all infants, both referent objects were from unrelated categories (e.g., car and shoe) except for one 20-month-old (referents cup and bottle) and one 16-month-old (referents apple and banana).

During the experimental trials, the experimenter maintained eye contact with the child. She did not name the objects once they were visible and just smiled at the infant if he or she showed an object to her or named it. The duration of trials (from the moment an infant was allowed to reach in the box to the moment the experimenter took an object and the box away from the infant) varied from trial to trial and from infant to infant. This happened because sometimes infants terminated the trials themselves by putting the object in the box and pushing the box away, and such trials were therefore shorter, or because infants sometimes reached back into the box for another object after having found the first one, and as a result, these trials lasted longer. The analysis of trial length (from the end of the request to the moment the objects were taken from the infant) revealed that nonreferent trials were longer than referent trials in both age groups (see Table 1 for summary): 20-month-olds (31 trial pairs coded), paired t-test, $t(30) = 2.28$, $p < .01$; and 16-month-olds (30 trial pairs coded), $t(29) = 2.17$, $p < .05$.

To ensure that the difference in the durations of nonreferent and referent trials did not emerge because the experimenter waited longer on nonreferent trials for infants to reach back than on referent trials (the experimenter was not blind to trial type), but because infants were reaching back on nonreferent trials and this took extra time, we conducted the following coding. For the nonreferent trials on which infants reached back to find another object, we measured the duration of time from the onset of the

TABLE 1
Duration of Referent and Nonreferent Trials by Age Group (in Seconds). Standard Deviations are in the Parentheses

	Referent	*Nonreferent*
20-month-olds	18.5 (6.69)	24.4 (9.53)
16-month-olds	20.4 (8.05)	23.2 (9.97)

TABLE 2
Duration of Referent Trials and Latency of Reaching Back on Nonreferent Trials by Age Group (in Seconds). Standard Deviations are in the Parentheses

	Duration of referent trials	*Latency of reaching back on nonreferent trials*	*Paired t-test*
20-month-olds	18.5 (6.69)	12.7 (6.29)	$t(16) = 2.59$, $p < .05$
16-month-olds	20.4 (8.05)	14.1 (7.41)	$t(15) = 2.26$, $p < .05$

trial to the moment infants started reaching back. We compared this to the duration of the corresponding referent trials in the same trial blocks. We found that the duration of referent trials was significantly longer than the latency of reaching back on the nonreferent trials (see Table 2 for summary). This demonstrates that infants had enough time on referent trials to initiate reaching back.

To summarize, nonreferent trials lasted longer than referent trials not because the experimenter terminated the referent trials before infants could reach back, but rather because infants were reaching back for another object on nonreferent trials more often than on referent trials, and this took extra time.

Design

In both studies, the four experimental trials were blocked by label. Thus, each child heard two labels, each label occurring two times in a row. For each label, infants found the referent object once and a nonreferent once. We tested infants twice with the same label to keep word knowledge constant across paired referents and nonreferents. The purpose of not having more than two trials was to reduce the likelihood that infants would learn that there is always just one object in the box with repeated failed attempts to find another object in the box. The order of referent and nonreferent trials was counterbalanced for each label. Thus, each participant had two types of trial sequences: referent–nonreferent and nonreferent–referent. Which sequence came first was counterbalanced across participants.

Coding

In this and all subsequent experiments, the main measure was whether infants searched again in the box on nonreferent trials more often than on referent trials. If an infant took out one object, put it on the table, and then inserted her empty hand in the box, it was coded as searching again for another object. On two occasions, infants put aside the retrieved object, and instead of reaching with their hands, they peeked inside the box through the spandex opening. This was also coded as searching again for another object. On four trials, infants first put the retrieved object back into the box, then took their hand out, and reached back again. Such behavior is ambiguous and could be interpreted as reaching again to get the first toy out or reaching back to find another object. On two trials, infants took the first object out right after having put it back in the box, suggesting that they were just playing with the box and the toy. Such cases were not coded as reaching back. On the other two trials, the persistence of infants' search (how long they have been searching and how far they inserted their hand in the box) suggested they were trying to find a second object, because they left the first one right at the spandex opening. Such instances were coded as reaching back for another object. On seven trials, infants inserted their hand into the box holding the retrieved object and took their hand out without letting it go. Such occasions were not treated as searching again for another object. If a child reached out with her hand and touched the spandex cover on the box opening, but did not insert their hand any further, this was not coded as reaching back. Such variations in infants' responses occurred equally often on referent and nonreferent trials, and our coding choices did not matter for the overall pattern of results. The same coding decisions were made in Experiment 2.

Infants were scored "0" for trials on which they did not reach back and "1" for trials on which they reached back. Muted video recordings (90.6% of the trials) were analyzed by an independent coder blind to the trial type. Overall agreement on whether a search for another object occurred or not was high: 95.7% of the coded trials (Cohen's kappa = 0.91). Disagreements were resolved via discussion, and the concerted coding was used in the analyses below.

In addition to infants' rates of reaching back, we performed exploratory analysis of infants' spontaneous verbal and looking behavior. We recorded instances of infants' object label production when infants were reaching in the box and when they were exploring the objects. We also coded the duration of infants' initial look at the retrieved objects and instances of looking back at the experimenter after finding an object. There were no systematic differences in infants' verbal and looking behavior across the two experiments. Thus, we report this analysis for both experiments together after Experiment 2.

Results and discussion

The purpose of this experiment was to investigate the role of category knowledge in infants' understanding of references to absent objects. Infants first heard a reference to an object inside the box and then were allowed to retrieve an object. We predicted that infants would be more likely to search for another object on nonreferent trials (when they retrieved a different object than what the experimenter had mentioned) than on referent trials. Results are displayed in Figure 2. The effects of age and trial type on infants' search for another object were analyzed using GEE (generalized estimating equations), a type of linear model that accounts for covariance between repeated measures. A binomial probit model was chosen as the basis for GEE analyses.[1] Trial type and age were dummy-coded, first, with 20-month-olds and nonreferent trials as

[1]The data file and the code are shared via *GitHub* (https://github.com/MariaOsina/GEE-analisis/releases/tag/GEE).

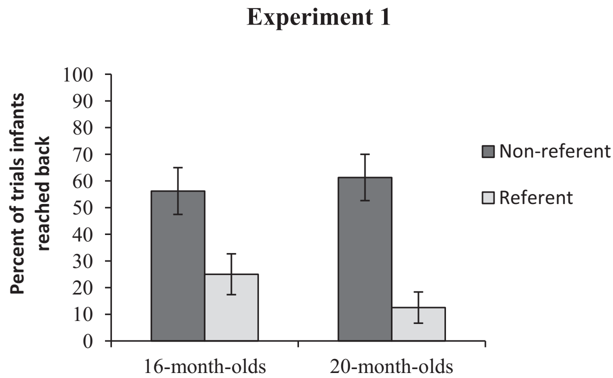

Figure 2 Percent of trials infants reached back into the box to find another object. Error bars represent standard errors.

reference categories, and second, with 16-month-olds and nonreferent trials as reference categories. The analysis showed that 20-month-old infants searched significantly more on nonreferent (61.29%) than on referent trials (12.9%; $(b_1) = 1.42$, $\chi^2(1) = 10.75$, $p = .001$, 95% CI [0.57; 2.26]). Similarly, 16-month-old infants reached back on 56.25% of nonreferent trials and on 25% of referent trials ($b_1 = 0.83$, $\chi^2(1) = 5.62$, $p < .05$, 95% CI [0.14; 1.52]). There was no significant difference in the rates of reaching back on nonreferent trials between 20- and 16-month-olds ($b_2 = -0.454$, $\chi^2(1) = 1.07$, $p < .30$, 95% CI [−1.31; 0.41]). The age-by-trial interaction was not significant, meaning that the difference in infants' performance on referent versus nonreferent trials was not smaller in the younger group compared to the older group ($b_3 = 0.59$, $\chi^2(1) = 1.11$, $p = .29$, 95% CI [−0.51; 1.68]). There were no item, sex, or order effects (see Appendix S1 for the corresponding analyses).

To guard against the possibility that differences in infants' behavior on referent and nonreferent trials were prompted by the experimenter's behavior, a coder naïve to trial type watched muted video recordings (90.6%) and tried to guess trial type based on the experimenter's behavior. The coder was told that each child had two referent and two nonreferent trials, but was naïve to the order of the trials. The coder could correctly guess trial type on 50.9% of the coded trials, which is not different from chance level (binomial test, $p = .9$). Whether the coder correctly guessed nonreferent trials was not related to whether a child reached back on those trials or not (logistic regression, $b = 0.34$, $Z = 0.76$, $p = .44$). This suggests that infants' behavior was not biased by the experimenter.

Higher rates of reaching back into the box to find another object on nonreferent trials than on referent trials suggest that infants were able to recognize objects they had never seen before as the correct referents and that they treated the nonreferent objects differently. This suggests that when infants process absent reference, they can activate categorical information relevant to referent identification. Infants' reaching again to find another object on nonreferent trials indicates that they were able to recognize the nonreferent objects as not belonging to the right set of referent objects.

To summarize, this experiment demonstrates that infants at 16 and 20 months are sensitive to the categorical information contained in common nouns when identifying the target of absent reference. Their language comprehension is sufficient to enable them to treat familiar but never-seen-before objects as referents (objects from the mentioned category) and sufficient for them to detect a mismatch between the processed word and nonreferents (objects from an unrelated category).

Previous research on infants' lexical development suggests that infants' lexicons are organized in a network with groupings based on taxonomic, perceptual, functional, and associational relationships from as early as 14 months (Friedrich & Friederici, 2005) and continue to develop into the second year of life (Arias-Trejo & Plunkett, 2009, 2010, 2013; Johnson & Huettig, 2011; Johnson, McQueen, & Huettig, 2011; Mani, Johnson, McQueen, & Huettig, 2013; Styles & Plunkett, 2009). Such clustering characterizes adult lexicons and may be considered a proper developmental achievement. However, this feature of lexicon may lead to temporary difficulties in production and comprehension in infants and toddlers. First, as suggested by numerous diary studies (e.g., Barrett, 1978; Rescorla, 1981), infants between 1 and 2 years of age frequently overextend words to categorically related objects. For example, they may use the word "doggie" to refer to other four-legged animals, or the word "car" for trucks and buses. Second, when nonreferents are taxonomically related to referents, infants have more difficulty identifying the right object than when nonreferents are unrelated (Arias-Trejo & Plunkett, 2010). In this study, the presence of a related nonreferent slowed down children's ability to fixate on referent objects in a visual search task.

In Experiment 2, we investigate infants' ability to reject nonreferent objects that are from the same superordinate category as the referents, but are dissimilar perceptually (e.g., apple–banana, bottle–cup). Based on previous research, we predict that infants will be affected by the categorical similarity of nonreferent objects to a set of potential referents of the mentioned word. Such similarity of nonreferent objects should inhibit infants' ability to detect a mismatch between the announced word and the retrieved object. This should decrease the frequency of infants' attempts to find the right object, and we should observe lower rates of reaching back here than in Experiment 1. We also compare 16- and 20-month-olds' performance to explore the developmental change of category label knowledge.

EXPERIMENT 2

Method

Participants

Seventeen 20-month-old infants (range 19;8–21;9; mean 20;4, 13 girls) and sixteen 16-month-old infants (range 15;24–16;14; mean 15;25, 10 girls) participated. Participants were recruited as in Experiment 1.

Materials and design

Six objects from the Experiment 1 set were used, and two new objects were added: an infants' sock and infants' pants to make four pairs of categorically related, but visually dissimilar items: apple–banana, bottle–cup, shoe–sock, and diaper–pants (see Figure 3). The paired objects were from the same superordinate category, but looked distinct from each other. For example, banana and apple are both fruit, but banana is long and yellow, while apple is round and red.

Figure 3 Stimuli used in Experiment 2.

Two pairs were selected for each child to be tested with, based on which words their parents reported as known. For three 16-month-olds, the list of words reported as "known best" by the parents did not include all words from our "matched nonreferent" set. When constructing nonreferent–referent pairs for these three infants, preference was given to their knowledge of referent labels (this occurred on five nonreferent trials total). For example, if a parent checked the word "banana" in the list, but not the word "apple," the child would be asked to find the banana, and the apple served as a nonreferent. Procedure, design, and coding were the same as in Experiment 1. Trial length analysis conducted in the same manner as for Experiment 1 revealed that the nonreferent trials lasted marginally longer than the referent trials for 20-month-olds (see Table 3 for summary): paired t-test, $t(30) = 1.84$, $p = .08$, while no significant differences were revealed for 16-month-olds: $t(31) = 0.55$, $p = .59$.

For 20-month-olds, the duration of referent trials was significantly longer than the latency of reaching back on the nonreferent trials: 20-month-olds, M(referent) = 16.1 sec., $SD = 7.96$, M(reaching back) = 9.25 sec., $SD = 4.13$, paired t-test $t(21) = 3.39$, $p < .01$. This suggests that trial length difference cannot be explained by the experimenter waiting longer on nonreferent trials than on referent trials for the infants to reach in.

Muted video recordings (94% of the trials) were analyzed by an independent coder blind to the trial type. Overall agreement on whether a search for another object occurred or not was high: 93.5% of the coded trials (Cohen's kappa = 0.87). Disagreements were resolved via discussion, and the concerted coding was used in the analyses below.

Results and discussion

The purpose of this experiment was to investigate whether infants can reject nonreferent objects that are categorically related, but perceptually dissimilar. Infants' performance in this task depends on their recognition that nonreferent objects are categorically related to referents of the announced words. If infants recognize the similarity between the retrieved nonreferent objects and the objects they were told to find

TABLE 3
Duration of Referent and Nonreferent Trials by Age Group (in Seconds). Standard Deviations are in the Parentheses

	Referent	*Nonreferent*
20-month-olds	16.1 (7.96)	18.9 (8.85)
16-month-olds	18.5 (8.55)	19.5 (8.38)

in the box, it should be more difficult for infants to reject such nonreferents. Thus, we should see lower rates of reaching back on nonreferent trials in this experiment.

The analysis of infants' rates of reaching back to find another object in this experiment confirmed the prediction, but only for the younger group of infants (see Figure 4). A probit regression-based GEE model was run following the same strategy as in Experiment 1.[2] Older, 20-month-old infants reached back on 67.7% of nonreferent trials and on 17.6% of the referent trials, which is significantly less than on nonreferent trials ($b_1 = -1.39$, $\chi^2(1) = 20.54$, $p < .0001$, 95% CI [−1.99; −0.787]). Younger, 16-month-old infants reached back on 31.2% of nonreferent trials, which is significantly less than 20-month-olds ($b_2 = -0.95$, $\chi^2(1) = 7.91$, $p < .01$, 95% CI [−1.6; −0.29]). This was also marginally less frequent than did 16-month-olds in Experiment 1 (56.2%, $b = -0.646$, $\chi^2(1) = 3.43$, $p = .064$, 95% CI [−1.33; −0.04]). There was a significant age-by-trial interaction ($b_3 = -0.95$, $\chi^2(1) = 7.91$, $p < .01$, 95% CI [0.33; 2.07]), meaning that the difference in rates of reaching back on nonreferent and referent trials was larger for 20-month-olds than for 16-month-olds. Indeed, 16-month-old infants' reaching back on nonreferent trials (31.2%) was not significantly more frequent than on referent trials (25%; $b_1 = -0.19$, $\chi^2(1) = 0.34$, $p = .56$, 95% CI [−0.82; 0.44]). There were no item, sex, or order effects (see Appendix S1).

To ensure that 20-month-old infants' behavior was not influenced by the experimenter, we asked a coder naïve to trial type to watch muted tapes (88% of the trials) and guess trial type based on the experimenter's behavior. The coder could correctly guess 53% of the trials, which is not more than predicted by chance (binomial test, $p = .7$). This suggests that infants' behavior cannot be explained by the experimenter's behavior.

To summarize, these results show that older, 20-month-old infants reached back on nonreferent trials significantly more often than on referent trials, like in Experiment 1. Younger, 16-month-old infants no longer showed this pattern. They reached on nonreferent trials much less often than 20-month-old infants, and not more often than on referent trials. To further investigate older infants' reaction to categorically matched nonreferents, we compared the latency of reaching back on nonreferent trials in Experiment 1 and Experiment 2 for 20-month-olds. We coded the duration of time between the moment infants retrieved an object from the box (it was in full view) and the

[2]Recall that in this experiment on five nonreferent trials, 16-month-olds retrieved objects whose labels were not indicated as known best by the infants' parents. To assess whether this affected Experiment 2 results, we excluded these nonreferent pairs and the corresponding referent trials (10 trials total) for these infants and reran the analyses. The new analyses agreed with the original analyses reported above and lead to the same conclusions about the effects of age and trial type. This suggests that testing three infants with not their best-known words did not affect the overall pattern of results found in Experiment 2.

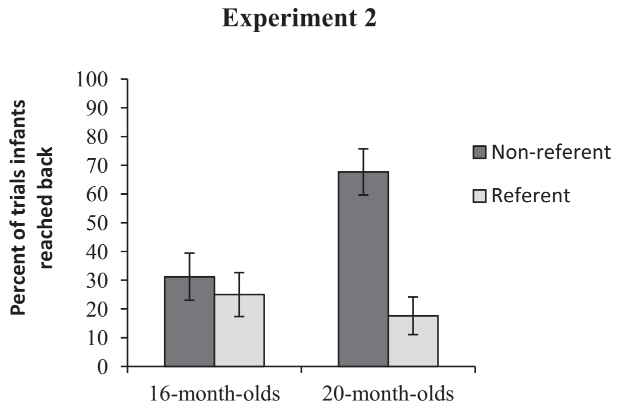

Figure 4 Percent of trials infants reached back into the box to find another object. Error bars represent standard errors.

moment they initiated reaching back (they raised their hand to reach in). This coding was performed only for the nonreferent trials on which infants reached back. Increased difficulty rejecting categorically matched nonreferents should be reflected in longer latency of reaching back in Experiment 2 compared to Experiment 1. This pattern was not found: *M*(Exp. 1) = 9.53 sec., *SD* = 5.72, *M*(Exp. 2) = 7.81, *SD* = 3.66, Welch *t*-test, two-sided, $t(27.7) = 1.1$, $p = .28$.

As shown above, younger infants in this experiment did not reach back on nonreferent trials more than on referent trials. This suggests that they detected the similarity of the nonreferent objects to the category of objects denoted by the experimenter's reference, and this made it difficult for them to reject the nonreferents and attempt to find another object inside. Older infants in this experiment showed the same pattern of responses as in Experiment 1: They reached back for another object more often on nonreferent trials than on referent trials. We assume that older infants are more advanced than younger infants in their category knowledge and word comprehension. In other words, they should be better able to understand that socks and shoes are related, as well as apples and bananas, and at the same time, they should be more likely to understand that the word "shoe" does not refer to a sock and the word "banana" should not be used to refer to apples. Therefore, it is unlikely that 20-month-old infants reached back on nonreferent trials more than on referent trials in this experiment because they did not detect that the nonreferents were categorically close to the referents. A more likely explanation is that they detected this, but were still able to reject categorically related objects as incorrect ones.

Age difference in understanding basic category labels found in this Experiment is in accord with previous research that indicates that global (superordinate) categories develop earlier than basic categories. For example, Mandler, Bauer, and McDonough (1991) showed that at 18 months, children have difficulty differentiating between members of the same basic categories (e.g., dogs versus horses or trucks versus cars), but showed evidence of possessing global category distinctions (dogs versus cars). By 30 months of age, children demonstrated the ability to differentiate at both levels of categorization. Our results indicate that infants' differentiation of word meanings at the basic and superordinate levels is consistent with the development of object categorization.

Altogether, Experiment 2 shows that 20-month-old infants' knowledge of category labels is robust enough for them to tell the difference between related objects. At the same time, 16-month-olds appear to have fuzzy category boundaries as they have more difficulty rejecting objects from the same superordinate category.

Exploratory analysis of infants' spontaneous verbal and looking behavior

In addition to our analysis of infants' reaching back for another object, we performed exploratory analyses of infants' spontaneous verbal and looking behavior. We coded all trials for 16-month-olds and 87.87% of trials for 20-month-olds (video recordings were not available for four 20-month-olds). We recorded instances of infants' labeling the retrieved objects. We also coded whether infants repeated the reference after the experimenter while reaching in the box. We coded instances of mislabeling nonreferent objects: It happened sometimes if infants were repeating the experimenter's reference after having retrieved a nonreferent object. Last, we coded whether infants were able to correct their mislabeling of a nonreferent object by producing the right label. To investigate infants' reaction to referent and nonreferent objects, we coded the duration of infants' first look at the retrieved objects. Finally, as a measure of infants' social behavior, we coded whether they looked back at the experimenter right after looking at the retrieved object.

There were no systematic differences in infants' spontaneous looking and verbal behavior across the two experiments. Thus, this coding is reported below for both experiments together (see summary in Table 4).

Verbal behavior (object label production)

Coding of infants' verbal behavior revealed that infants in both groups occasionally named the objects they found in the box. In the older group, naming occurred on 48 trials (42.1% of the coded trials) and often more than once on the same trial. Naming occurred 20 times on referent trials and 28 times on nonreferent trials. Most of the time infants labeled the objects after having retrieved them from the box. This occurred on 37.07% of all coded trials: 35 trials overall, 13 referent and 22 nonreferent. Less often infants rehearsed the label provided by the experimenter before seeing the object. This occurred on 11.4% of the coded trials: 13 trials overall (seven referent and six nonreferent trials).

Labels produced by infants on nonreferent trials sometimes were correct, and sometimes were not. The following naming patterns were observed on nonreferent trials:

1. Infants rehearsed the incorrect label after the experimenter and did not label the object after finding it (one time).
2. Infants repeated the label after the experimenter after having found an object, thus mislabeling it (six times).
3. Infants named the object correctly after having retrieved it from the box (11 times).
4. Infants rehearsed the label after the experimenter and kept repeating the wrong label after having found the object (three times).
5. Infants rehearsed the label after the experimenter, but correctly named the object after having retrieved it (five times).

TABLE 4
Exploratory Analysis of Infants' Verbal and Looking Behavior

	Naming object in hands	*Mislabeling on the nonreferent trials*	*Rehearsing the label while reaching*	*Looking back at the experimenter*
20-month-olds	37.07%	13.16%	11.4%	49.14%
16-month-olds	10.9%	1.6%	3.13%	87.50%

6. Infants rehearsed the label produced by the experimenter after having found one object while reaching back in the box (three times).

The following example demonstrates the last two patterns of naming. The experimenter said there was an apple inside, but a child found a shoe and said "Apple! Apple! No… Shoe!" Then, she reached in the box saying "Apple, where are you?"

In the younger group, naming occurred less often, only on 14.1% of the trials: 18 trials overall, 11 referent and seven nonreferent trials. Most of such instances occurred when infants were already exploring the retrieved object (14 times: nine referent and five nonreferent), while on only four trials infants repeated the label after the experimenter before seeing the object. Two of such rehearsal instances occurred on nonreferent trials; however, infants did not produce the correct label after having retrieved the object.

Overall, infants' verbal behavior provides additional evidence that they often recognized objects for what they were, and their reaction to the retrieved objects was often guided by their word comprehension.

Looking behavior

To investigate infants' immediate reaction at the retrieved objects, we coded the duration of infants' initial look at the retrieved objects. We expected that infants may be surprised at finding wrong objects on nonreferent trials which will be manifested in longer looking at the nonreferent objects than at referent objects. We did not find this difference with 16-month-olds (see Table 5 for summary). With 20-month-olds, however, we found the opposite pattern: Infants' initial look at nonreferent objects was quicker than their look at the referent objects. One potential explanation for this is that infants concentrated on exploring the objects when there was no mismatch, while they looked back at the experimenter and engaged in further reaching when they detected a mismatch between the provided label and the retrieved object.

Further investigation of infants' looking patterns revealed that infants in both age groups often looked back at the experimenter after their initial look at the object (very rarely they looked at their parent instead of the experimenter). This behavior was observed on 49.14% of trials in the older group and on 87.5% of trials in the younger group, and equally often on referent and nonreferent trials. This suggests that infants in both age groups were sensitive to the social component of the interaction and often reestablished eye contact with the experimenter after having initially explored the retrieved objects.

To summarize, exploratory coding of infants' verbal and looking behavior suggests that infants often spontaneously provided labels for the retrieved objects, older infants

TABLE 5
Duration of Infants' Initial Look at the Retrieved Object (in Seconds) by Age Group and Experiment. Standard Deviations are in the Parentheses

		Referent	*Nonreferent*	*Paired t-test*
16-month-olds	Experiment 1	4.37 (2.4)	4.55 (4)	$t(31) = 0.28$, $p = .78$
	Experiment 2	3.58 (3.29)	3.39 (2.68)	$t(31) = 0.37$, $p = .71$
20-month-olds	Experiment 1	5.09 (3.5)	4.04 (1.9)	$t(31) = 1.74$, $p = .09$
	Experiment 2	5.71 (3.1)	3.87 (3.29)	$t(27) = 2.35$, $p < .05$

more often than younger infants. Infants sometimes rehearsed the labels provided by the experimenter while reaching in the box. Along with our main measure of reaching back for another object, infants' verbal behavior provides additional evidence that by 20 months, infants have sufficient vocabularies to comprehend and produce absent reference. Infants' looking patterns (reestablishing eye contact with the experimenter after having retrieved an object) suggest that they are sensitive to the social component of the interaction. Altogether, the qualitative description of infants' verbal and looking reactions during our experimental tasks adds important information to the developmental profile of 20- and 16-month-olds. It broadens our main findings regarding infants' reaching behavior and gives a more detailed picture of what infants can do at this age.

GENERAL DISCUSSION

The purpose of the current research was to investigate infants' use of categorical information contained in references to absent objects. Sixteen- and 20-month-old infants first heard a reference to an object hidden in the box, and then, they were allowed to reach in and retrieve it. On referent trials, they retrieved an object that matched the experimenter's reference, and on nonreferent trials, they retrieved a different object—not the one mentioned previously by the researcher. Infants' ability to recognize a mismatch on nonreferent trials and reach back to find another object, while accepting referent objects as correct referents, demonstrates their use of category knowledge in responding to names for absent objects. In Experiment 1, when nonreferent objects were unrelated to referents, 16- and 20-month-old infants reached back into the box on nonreferent trials more often than on referent trials. In Experiment 2, when nonreferent objects were from the same superordinate category as the referents, but looked different, 20-month-olds, but not 16-month-old infants, searched again for another object on nonreferent trials more than on referent trials.

The Experiment 1 findings suggest that infants at both ages were able to recognize novel tokens of familiar categories as the correct referents. Thus, infants' absent reference comprehension does not seem to be solely based on their ability to recall a particular object in its specific location (see also Ganea & Saylor, 2007). If it were the case, they should not have been able to accept referent objects as the targets of the experimenter's request. Infants also were often not satisfied at finding wrong objects and searched again in the box. Thus, word comprehension at this age is more complex than just associations between a word and one specific object. Infants are able to understand words as referring to particular categories of objects and do not extend them to objects from other unrelated categories. Therefore, we conclude that infants of at least 16 months can rely on their knowledge of nouns as category labels to interpret absent reference.

The Experiment 2 results are consistent with the possibility that infants may activate a network of categorically related objects in response to experimenter's reference. When the nonreferent objects were drawn from the same superordinate category as the referent objects, but were perceptually dissimilar, 16-month-old infants had difficulty detecting a mismatch between the experimenter's request and the retrieved object. This can happen only if infants recognize that the retrieved object is close in categorical space to a group of objects that are the right referents of the mentioned word. Older, 20-month-old infants did not have difficulty rejecting categorically related nonreferent objects.

Age difference found in Experiment 2 can be explained in a number of ways. First, 16-month-olds had difficulty rejecting categorically related nonreferents because they have less precise word knowledge and vague category boundaries than 20-month-olds. This idea parallels parental naming practices described in Mervis and Mervis (1982). As this work shows, parents are sensitive to infants' knowledge, and for infants around 13 months old, they prefer not to use exact labels for different members of a given basic category. For example, parents prefer to use the word "kitty" to talk about leopards, cougars, and lions. Thus, parents may be inadvertently suppressing infants' attention to differences between different members of the category and encouraging overgeneralization. Another possibility is that our task was cognitively demanding, and the development of general cognitive skills can explain the difference. Keeping in mind the experimenter's request while searching in the box, then matching the retrieved object to that request, and finally, on nonreferent trials, rejecting the object as a potential target draws heavily on working memory and inhibitory control which is more developed at 20 than at 16 months.

The finding that categorically related nonreferents are more difficult for infants to reject than unrelated nonreferents is consistent with previous research on toddlers' language comprehension. For example, in Arias-Trejo and Plunkett (2010) 21- to 24-month-old toddlers' ability to look at the picture of the mentioned object was impaired when the distracter was drawn from the same superordinate category and was also perceptually similar. The authors conclude that "early representations of meaning are linked not only to their original referent, but also to related concepts sharing ontological status" (Arias-Trejo & Plunkett, 2010, p. 78). This conclusion was also reached in priming–interference studies. For example, in Styles and Plunkett (2009) 24-month-old toddlers' target recognition was more robust after hearing a semantically related word (e.g., cat–dog) than after hearing an unrelated word (plate–dog; see also Arias-Trejo & Plunkett, 2009; Johnson et al., 2011). Preferential listening studies also showed that 24-month-old toddlers are sensitive to the semantic (and visual) relatedness of referents in the absence of visual input (Willits, Wojcik, Seidenberg, & Saffran, 2013; Wojcik & Saffran, 2013). In these studies, toddlers' detection of referent relatedness was reflected in differences in their listening times to related and unrelated pairs of words. In the current research, these findings were extended to younger ages (16 and 20 months). Our findings also suggest that infants' lexically derived representations not only affect their looking and listening behavior (i.e., visual search for a target picture and attention to auditory stimuli), but also quite often influence their decisions for actions (i.e., reaching back to find another object). This shows that lexical representations and linguistically induced expectations about the world at this age are robust enough to support not only looking, but motor behavior as well which is more cognitively demanding than listening and looking.

It is important to note that items in Experiment 2 were not only categorically related to each other. They also often appear together in the same contexts. For example, shoes are usually put on socks, and pants are put over diapers. Therefore, referents and nonreferents were also related in the associative way. Teasing apart these two possible contributions to infants' performance is problematic because most categorically related objects are also contextually associated as well. Nevertheless, future studies can investigate the role of purely associative connection between objects in infants' understanding of absent reference by testing them with a set of categorically unrelated, but associated objects.

In the current task, infants reached back in the box more on nonreferent than on referent trials. One question is what cognitive processes underlie infants' decision to reach back or not. One possibility is that infants do not need to understand the experimenter's reference and only need to know what the retrieved object is called—a process similar to mutual exclusivity reasoning. For example, if infants find a banana when asked to find a shoe, they might realize that the experimenter is asking for something else, because the object in hands is the banana. Importantly, infants do not have to understand what exactly they are supposed to find when deciding to reach back. Another possibility is that infants do not need to know the label for the retrieved object and do not need to retrieve categorical information contained in the experimenter's reference. All they need to do is bring to mind a long-term representation of one specific object associated with the label and assess the degree to which the retrieved object resembles it. We do not favor these explanations because they are inconsistent with the Experiment 2 results. The fact that categorically related nonreferents elicited different response than unrelated nonreferents (Experiment 1) suggests that infants were processing experimenter's reference, not just bringing to mind the label for the retrieved object. Otherwise, we would not have expected them to detect categorical similarity between the retrieved object and the experimenter's reference. Additionally, infants would not be able to detect the categorical match based on visual matching alone because the categorically related items were not perceptually similar. Therefore, we favor the interpretation that at the time of hearing the absent reference, infants accessed some perceptual information that indicated category membership of the labeled object. Future research could further manipulate object and label familiarity to disentangle what is important for infants—representing a familiar token of the experimenter's reference, knowing labels of the retrieved objects, or both.

Another question that remains unanswered is the time course of activating perceptual information in the process of absent reference comprehension. One possibility is that infants' search in the box is guided by a reference-elicited representation of what the experimenter told them to find. In other words, they access a representation associated with the mentioned category label before finding an object. Another possibility is that infants bring such representation to mind only after having found an object in the box. It is possible that they initially search in the box without having a clear idea of what is in it. Only after having found an object, they call to mind a long-term semantic representation associated with the experimenter's reference and use it to decide whether the object in hand matches this representation or does not. In case it does not, they assume that there must be a different object in the box and reach back to find it.

Previous research on toddler word comprehension provides evidence that toddlers bring to mind the prototypical color of an object when hearing a word. For example, in Johnson and Huettig (2011) 3-year-olds fixated on color-matched distracter (red plane) after hearing a word (strawberry) more than at an unrelated distracter (yellow plane). Johnson et al. (2011) also clarified with 2-year-old participants that color label comprehension is not required for this effect. On the other hand, in a similar experiment (Huettig & Altmann, 2010), adult participants were more likely to fixate on color-associated distracters than at other distracters only when the pictures were presented in color. When the stimuli were presented in black and white or in line drawings, participants were not more likely to fixate on color-associated distracters (e.g., spinach as a distracter for the word "frog"). This suggests that the stored color information may be brought to working memory only at the stage of visual search. The possibility that infants in the current study may not retrieve a representation of a referent when reaching in the box and rather do it at the stage of looking at the retrieved object is in accord with this finding.

The Huettig and Altmann (2010) findings do not exclude the possibility, however, that subjects activated categorical information other than color. Color is rarely a feature that defines object category membership and is rarely related to object function (see also Mani et al., 2013). Therefore, infants in our study may retrieve other perceptual information that is relevant to the referent's category membership (e.g., the prototypical shape). This possibility is not ungrounded because bringing to mind category-related perceptual information only at the time of visual search would limit children's word comprehension to situations where they have something to look at. Clarifying when and what exactly infants represent in the process of word comprehension is an exciting question for future research.

Altogether, the current study presents an initial attempt to look at how infants' long-term semantic representations of word meanings may influence their perception of visible objects and, importantly, their subsequent actions. Our findings suggest that infants as young as 16–20 months rely on their understanding of words as category labels when interpreting absent reference, and their understanding is not restricted by remembering a particular recently seen object and its specific location. Between 16 and 20 months, infants develop a more precise understanding of basic category labels and thus become less prone to overgeneralizations. This research contributes to our understanding of how cognitive development and language development interact and how they navigate infants' reasoning and actions in social situations.

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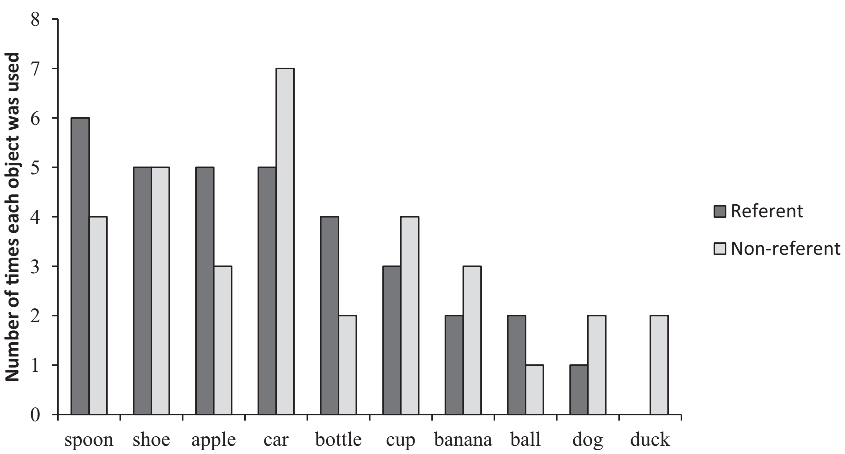
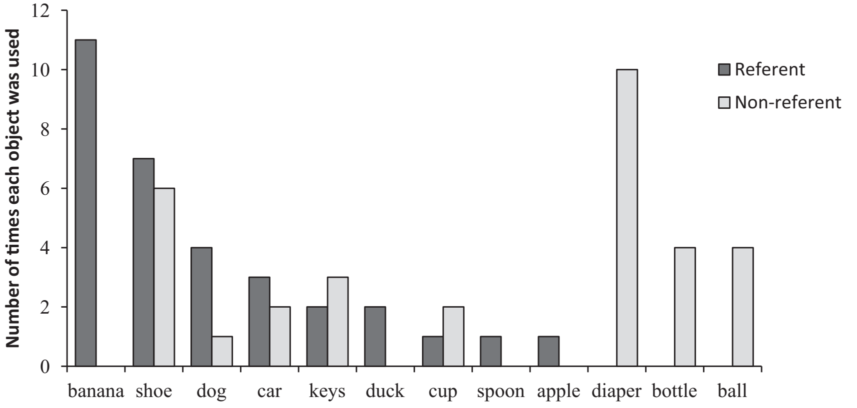
APPENDIX A
Items used as referents and nonreferents by age group and experiment

A1. Objects used in Experiment 1 with 20-month-old infants. In this and other experiments, nonreferent objects were never labeled by the experimenter. Here and in other graphs, *Y*-axis represents total number of times each object was used.



A2. Objects used in Experiment 1 with 16-month-old infants.



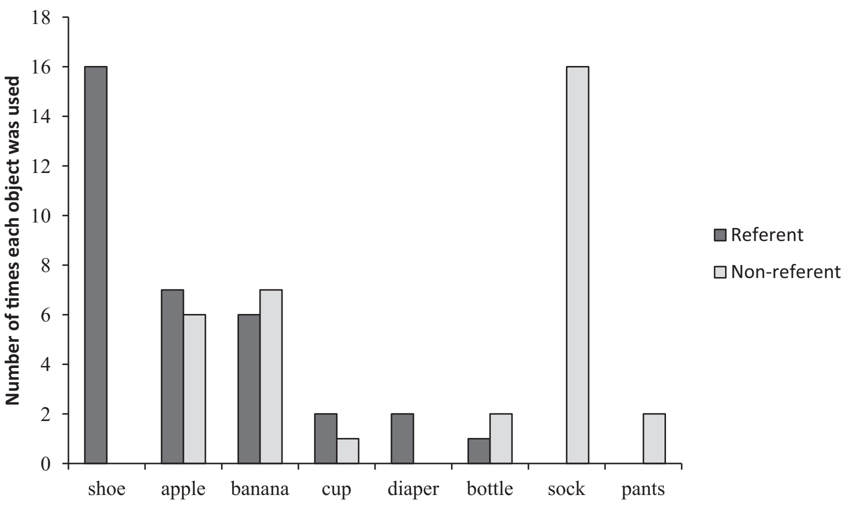
A3. List of referent–nonreferent pairs used in Experiment 1 with 20-month-olds.

Referent	*Nonreferent objects*	*Frequency*
Spoon	Car	4
	Shoe	1
	Banana	1
Shoe	Bottle	2
	Apple	1
	Car	1
	Dog	1
Apple	Cup	3
	Shoe	1
	Duck	1
Car	Spoon	4
	Banana	1
Bottle	Shoe	2
	Car	2
Cup	Apple	2
	Banana	1
Banana	Shoe	1
	Cup	1
Ball	Dog	1
	Duck	1
Dog	Ball	1

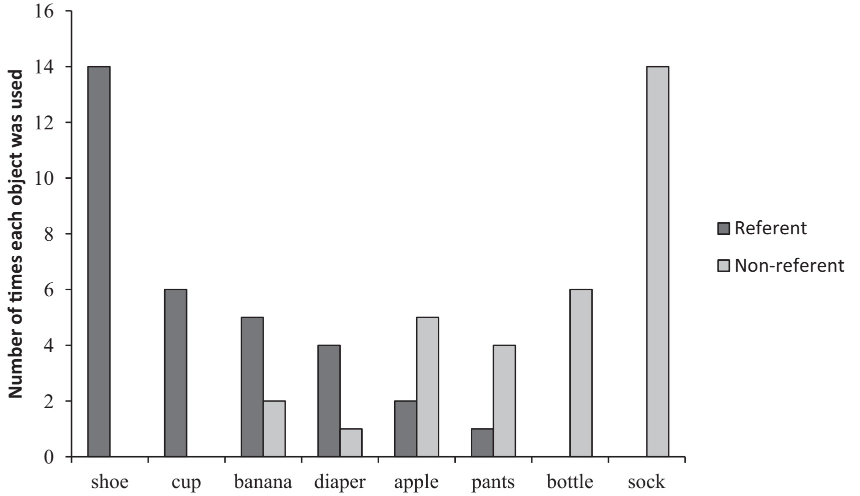
A4. List of referent–nonreferent pairs used in Experiment 1 with 16-month-olds.

Referent	*Nonreferent objects*	*Frequency*
Spoon	Car	1
Shoe	Bottle	4
	Cup	1
	Ball	1
	Dog	1
Apple	Cup	1
Car	Shoe	3
Cup	Shoe	1
Banana	Diaper	8
	Shoe	2
	Keys	1
Dog	Keys	2
	Diaper	1
	Car	1
Duck	Ball	2
Keys	Ball	1
	Diaper	1

A5. Objects used in Experiment 2 with 20-month-old infants.



A6. Objects used in Experiment 2 with 16-month-old infants.



SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article:

Appendix S1. Experiment I: Order, sex and item effects analyses.