Infants' use of category labels and intonation in reference resolution

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To my wonderful children, Sergei and Alexander,

and

To my beloved husband, infinitely patient and supportive

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CHAPTER I

INTRODUCTION

Human language, although a powerful source of communication, is not a perfect, error-free, way of conveying meaning. There is much room for referential ambiguity. For example, in situations when referents are absent, the listener must rely on his or her long-term knowledge of a mentioned concept to understand what a word means. Often, concepts differ across people, especially between children and adults, and this may lead to misunderstandings. For example, as shown in Mervis & Mervis (1982), 13-month-old infants may not be able to distinguish between different types of cars or between leopards and kitty cats, and mothers adjust their object labeling accordingly to avoid misunderstanding (Mervis & Mervis, 1982). Additionally, in English, and most other languages of the world, common nouns denote categories of objects, entities and events, rather than individual tokens. For example, the word "dog" can refer to a German shepherd, to a Scotch terrier, or to a child's stuffed animal. Therefore, when a speaker uses a common noun in speech it can potentially refer to any token of the corresponding category. Speakers must therefore determine which of several possible items to which a person is referring. In a similar vein, people use pronouns like "it", "that", and "one" to refer to objects. Phrases like "Can you bring me the cup" or "Can you give it to me?" are potentially ambiguous when the speaker does not specify which particular cup is meant or what is meant by "it".

An important concept that helps explain how understanding can be achieved between different people is the concept of common ground (Clark, 1996). Common ground includes "…mutual knowledge, beliefs and assumptions shared by the speaker and the addressees" (Clark, Schreuder, & Buttrick, 1983). Several sources of information are available to adults for establishing and using common ground. One such source is shared linguistic evidence, which is what conversational partners experienced or are experiencing being said (Clark & Wilkes-Gibbs, 1986). This source can be meaningful only if the speaker and the listener have access to the shared conventional meanings of words, and references used in the conversation elicit comparable sets of representations in the speaker's and the listener's mind. Another important source is shared perceptual evidence, or what two people jointly experienced or are experiencing at the moment. This source of information requires that people track each other's perceptual

experiences and understand that one's awareness of an object in the perceptual common ground depends on one's prior or current perceptual contact with that object.

In the current research we investigate young children's ability to access and use these two sources of information in ambiguous communicative situations. Children can have access to shared linguistic evidence only if they understand words in their conventional sense as referring to categories of related objects rather than to individual tokens. In previous research infants demonstrated their understanding of the categorical nature of words from a very young age (9-12 months), but mostly when the referent objects were in full view. However, much less is known about young infants' understanding of words as category labels when referents are out of view. The purpose of the first study is to investigate children's use of the categorical nature of words when interpreting references to absent objects.

The purpose of the second study is to test children's understanding of the intonation of a request when interpreting ambiguous references to objects. Previous research has shown that infants as young as 14-18 months are sensitive to another person's experience with objects. Infants know what's new (Moll & Tomasello, 2007; Tomasello & Haberl, 2003) and what's old to the speaker (Saylor & Ganea, 2007), and use that information in reference resolution. Infants also can take into account the previous linguistic context, or what the speaker has been saying previously, to interpret ambiguous pronouns like "it" (Ganea & Saylor, 2007). Infants as young as 12 months are able to use the direction of the speaker's voice when the speaker is not visible to infer which of the 2 possible referents she is attending to (Rossano, Carpenter & Tomasello, 2012). In study 2 of the current dissertation we investigate if infants can take into account whether a person is excited or not to understand if she is asking about an old or a new object.

Infants' use of category label to interpret reference

Previous research on children's word learning demonstrated that children acquire categorical understanding of words at a very young age. There are indications that children may initially overgeneralize or undergeneralize words, but very quickly they correct their initial mapping errors and accept conventional word meanings. For example, Bloom (1973) reports that her 9-month-old used the word "car" only for moving cars seen from the living room. Barrett (1986) reports that a 13-month-old used "dog" for a few weeks solely in response to an eliciting question about a picture on his bib. At the same time, Huttenlocher and Smiley (1987) demonstrate that overgeneralizations and undergeneralizations disappear quickly after 13

months, and most instances of infants' word production they recorded were appropriate for the adult categories.

Infants' early understanding of the categorical nature of words has been demonstrated in a number of studies. One study reports that 9-11-month-old infants can group objects named with the same word into one category (Balaban & Waxman, 1993; Waxman & Leddon, 2011). They do not group objects in the same way when they are not named or when they are accompanied by a simple tone. Older children extend the meanings of newly learned words based on different perceptual information depending on the objects' ontological kinds (e.g., animate or inanimate) (Booth & Waxman, 2003). Booth and Waxman (2003) demonstrated that preschoolers use shape alone or both, shape and texture to extend new words depending on whether they believe the objects are animate or inanimate. Children in this study relied on conceptual information to extend words even if it was put in conflict with perceptual information (e.g., an object had eyes but was described as inanimate). Altogether, these studies reflect children's understanding that common nouns are used symbolically to refer to categories of objects.

All studies described above tested children's word meanings in situations where referents were perceptually available to children. It is not clear if children can rely on their understanding of the categorical nature of words when referents are out of view. For example, when a child hears the word "dog" she might be able to understand that this must be about one of many hairy barking four-legged domestic animals. Alternatively, the child can just think of one specific dog that is most active in her memory and fail to recognize that the speaker might mean something different. The child's ability to access the right set of representations that are relevant to the mentioned category is a first step in understanding absent reference. If a child does not take into account multiple potential referents of the announced word comprehension may not be successful.

To investigate infants' use of category knowledge in reference resolution, in Study I of the current investigation, we test infants' ability to rely on the provided label when searching for hidden objects. Infants first hear a word that refers to an object hidden in a box, then they are allowed to reach in and find an object that is either the target (a token of the mentioned basic category) or one of the three distractor objects (an unrelated object, a token of the same superordinate category, or a perceptually similar object). If infants understand absent reference at

the categorical level they should be able to recognize target objects as the correct referents (they will stop searching after having found the target) and reject distractor objects as incorrect ones (search again for another object after having found something wrong). We predict that it will be more difficult for infants to reject distractors that match the target objects categorically or perceptually.

Infants' understanding of ambiguous requests for objects

The focus of the second study in this research is infants' ability to track people's experiences with objects and to use the intonation of the request to infer if the speaker means to refer to a new or a familiar object. Previous investigations of infants' behavior in ambiguous reference situations (two or more objects are potential referents of a verbal request) indicate that infants beginning at 12 months are able to keep track of people's experiences with objects and rely on this information to identify the target (Saylor & Ganea, 2007; Saylor, Ganea & Vazquez, 2011). However, in some studies infants infer that the ambiguous request is about a familiar object, while in other studies, on the opposite, they interpret the request as about a new object. For example, in Saylor and Ganea (2007) two experimenters played one at a time with 14-18-month-old infants, each with her own ball. At test, when both balls were present, one of the experimenters came back and asked the child ambiguously "Give me the ball". Most children picked the ball that the experimenter previously played with. In comparison to this, in a similar ambiguous reference situation in Tomasello and Haberl (2003) 12- and 18-month-old infants selected a new object over the familiar one as the intended referent. In this study, infants played with two experimenters with two toys. A third toy was introduced to them while one of the experimenters was absent. At test, while all three toys were on the tray, the experimenter who did not see the third toy showed great excitement (Oh, wow! Look at that! Look at that!) and asked the infants ambiguously "Give it to me, please!" Infants selected the toy that the experimenter had not seen before assuming she wants the new object. Why did infants pick the familiar object in one study and the new object in the other?

In Study 2 we investigate the possibility that this discrepancy may be explained by infants' understanding of the intonation of the request. If children can switch from picking an old object to picking a new object depending on whether the speaker is excited or not this would suggest that in addition to tracking the speaker's experience with objects they can also rely on the speaker's intonation to interpret ambiguous reference.

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CHAPTER II

WORD COMPREHENSION GUIDES INFANTS' SEARCH FOR HIDDEN OBJECTS

Introduction

Adult linguistic communication to a large extent consists of discussing topics that are not physically manifested in the conversational context. Adults often exchange information about the past and the future, about the non-visible, hypothetical or non-existent. Young children's ability to understand references to absent or invisible entities is a pivotal accomplishment as it extends 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. 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, et al., 1980; Saylor & Baldwin, 2004; Saylor, 2004). In a typical paradigm, infants play with an object, than it is removed from view, and after a time delay it is mentioned again. Infants' ability to orient to the referent's location, point at it or approach it is taken as a sign of their comprehension of labeling an absent object. In a paradigm like this, infants as young as 10.5-11 months can turn around to look at the mentioned toy if it's close to them. Older, 14-month-old infants can point, look or walk towards the referent's hiding location. At 16 months, infants can go and search for the referent in another room.

Across multiple studies, it has been shown that infants' absent reference understanding may be influenced by their memory of the referent and its location. The youngest infants are best able to respond to requests about absent entities in contexts that support the retrieval and maintenance of the target representation. Infants are more likely to respond to names of highly familiar absent referents, after short time delays and in the presence of reminders of the absent

referents. For example, infants show comprehension of references to absent familiar people before for absent objects. In Gallerani et al. (2009), 11-month-old infants showed understanding of their parent's name when the parent played with them in the lab and then stepped out of the testing room. When the absent person was mentioned (e.g., "Where is the daddy?") infants looked, pointed or approached the door. They did not show similar comprehension behaviors for familiar objects (e.g., a ball or phone). In other studies, 13-14 months have been shown to engage in the same type of behaviors in response to references to absent objects (Ganea, 2005; Saylor, 2004). Infants are also more likely to understand references for familiar versus unfamiliar people. In Ganea & Saylor (2012), 13-month-old babies responded to a familiar person (a sibling), but not to an unfamiliar absent person they recently met.

Infants' comprehension is also affected by the length of time the referent had been away. In Ganea and Saylor (2013) 13-month-old infants were able to respond to the name of a familiar person when he/she was absent for 2 minutes, but not when for 16 minutes. Older, 16-month-old infants were able to respond after both a 2-minute and 16-minute delays. In a different study, Ganea (2005) found that 13-14-month-old infants responded to the mention of an absent toy by searching for it if it had been absent for 5 minutes, but they were less likely to do so if the toy had been absent for 15 minutes.

Several findings suggest that infants' comprehension can be supported by reminding them of the referent during the delay by different visual and verbal means. In Ganea (2005), 13-14-month-old infants were introduced to a stuffed animal and taught its name. Infants who during the delay listened to a story containing the toy's name looked, pointed or searched for the target object more often than infants who listened to a story containing a different name. In Saylor (2004), both, 12- and 16-month-old infants revealed their comprehension of absent reference by looking and gesturing more to the referent's prior location than to the distractor object's location if the locations were marked by the displays matching the colors of the absent objects.

Young infants are also more likely to respond to absent reference if the referent is associated with the conversational context. If infants see the referent in the context where they are later asked about it, different elements of the context can remind them of the absent referent and support their comprehension. Contextual associations are very important to infants, and when infants are asked about an absent familiar entity that they had never seen in the testing

environment, they are unlikely to show comprehension. In Saylor & Baldwin (2004) infants younger than 15 months did not display any comprehension of the mention of their absent parent (e.g., daddy) when the parent did not accompany them to the lab. However, in Gallerani et al. (2009) and Ganea & Saylor (2012) a family member was taken to the lab, and infants of 11 and 13 months displayed comprehension by searching for them when they were mentioned while being absent.

In previous absent reference research infants' successful responding required them not only to bring to mind the mentioned hidden object, but also to remember the referent's location. Hence, many studies demonstrate that the characteristics of the referent's hiding location do appear to play a significant role in infants' ability to display comprehension. For example, the youngest infants' comprehension is limited to most proximal and accessible objects and people (Huttenlocher, 1974; Ganea, 2005). In Ganea (2005), 14-month-old infants were less likely to respond to the name of an absent object when its location was not immediately visible and accessible (a toy in the basket behind a couch) compared to when the object's location was accessible and in full view (a toy in the basket in front of the couch). Older infants become increasingly able to search for more distal referents located in a different room or in a different building (Huttenlocher, 1974; Saylor & Baldwin, 2004). It is only by age 2 that their comprehension expands to topics free of physical locations and embodied existence (Miller et al., 1980; Saylor, 2004; Swingley & Fernald, 2002).

The importance of location information in infants' absent reference understanding is suggested by a number of other studies, exploring both, comprehension and production (Adamson & Bakeman, 2006; Morford & Goldin-Meadow, 1997; Osina, Saylor & Ganea, 2013, 2014; Sachs, 1983; Snow et al., 1996). For example, older children (16-19 months) who already can refer to and respond to the names of not immediately available referents still depend on their memory for the referent's location when understanding absent reference. Huttenlocher (1974) observed that infants who can go to a different room to search for a mentioned object mostly do it for large pieces of furniture that occupy permanent locations. The stability of the referent's location helps infants remember where the referent is and this appears to support their comprehension abilities. Objects' locations ("e.g., "where is the <…>?") remain the main topic of infants' own talk about the absent at this stage as well (Morford & Goldin-Meadow, 1997; Sachs, 1983).

A special role of object location in children's communication about the absent is also suggested by observations of deaf children. This research suggests that referents' habitual locations can be used in a symbolic way, to stand for the target object. For example, the deaf child whose displaced communication is described in Butcher, Mylander & Goldin-Meadow (1991) could point at the location associated with the intended referent to bring the referent to the listener's mind. The child pointed at the chair where his dad usually sits to refer to the absent dad or at the corner where they usually put a Christmas tree to convey something about celebrating Christmas. Location as a symbol, or a placeholder for an absent object, can be also used by young hearing children to request a desired object that is associated with that location (Liszkowski et al., 2009).

Altogether, these findings provide strong evidence for the role of infants' memory of the concrete object and its location in their comprehension. What is not clear from the previous research is whether infants truly understood the word as potentially referring to multiple tokens of the target category and then made an inference about which one they were being asked about, or they simply oriented reflexively to the remembered location of the specific recently seen object. Research by Kirkham et al. (2012) demonstrated that infants as young as 6 months can 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 all parts of one complex multimodal event. Infants' responses in absent reference tasks can be explained by a similar low-level process of spatially indexing absent objects and orienting to their locations in response to the associated sound forms.

In the current study, we investigate infants' ability to use category labels when interpreting references to absent objects. The task was designed such that infants cannot use an active memory trace of a recent object in its' specific location to understand the reference. They have to use their categorical understanding of words knowledge to appropriately respond to absent reference. Infants first hear a name of an object hidden in a box and are asked to find it, and then they are allowed to reach inside and retrieve it. On some trials they retrieve a target object (a token of the mentioned basic category), while on other targets they find a distractor object. We expected infants to reach back into the box to find another object more often on

distractor trials than on target trials. Infants' long-term categorical knowledge of the mentioned words is required for them to recognize the targets and to reject the distractors.

To further investigate infants' use of category labels in reference resolution we compare their performance with different types of distractors: unrelated objects, related objects (tokens of the same superordinate category) and perceptually similar objects. Previous research on toddler language comprehension (18-24 months) suggests that it is more difficult for children to reject distractor objects that are related categorically or perceptually to the targets because they likely activate categorical and perceptual information when hearing words (Arias-Trejo & Plunkett, 2009; Arias-Trejo & Plunkett, 2010; Johnson & Huettig, 2011; Johnson, McQueen & Huettig, 2011; Mani, et al., in press; Styles & Plunkett, 2009). Therefore, it is possible that infants in the current study have a harder time rejecting distractors that are close categorically or similar perceptually to the targets.

Experiment I

Method

Participants

Participants were 32 healthy full-term infants with normal hearing and from English-speaking families. Half were 16 months old (range 14 months 19 days – 18 months 3 days, mean 16 months 7 days; 9 girls) and half were 20 months old (range 19 months 1 day – 21 months 18 days; mean 20 months 5 days; 8 girls). One additional 16-month-old child participated, but was omitted due to being upset and refusing to participate. Participants for this and all subsequent experiments were primarily Caucasian and from middle class families. They were recruited from the Greater Nashville area by phone from a database of interested families.

Materials

Stimulus objects were hidden in a felt covered box measuring 35x12x8 cm with an 8x4 cm. opening on each side covered by spandex. 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. Parents were given a list of the names of these objects and were asked to choose which their child understood most well. Based on this report, 4 experimental objects were chosen such that the child knew the labels for both the targets and distractors, and such that in each distractor-target

pair the objects do not share any perceptual features like color and shape, did not belong to the same category (like apple-banana), and did not start with the same sound (like dog and duck). 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 Experiments 1-3.

The experiment was recorded from 2 viewpoints using 2 cameras. One camera recorded infants from the front to enable coding looking behavior and facial expression. The second camera recorded the experiment from the child's right side to enable coding reaching behavior.

Procedure

In this and all subsequent experiments the procedure was as follows. Infants were tested individually in the lab. 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 objects that was hidden under the table.

Familiarization phase

Once everyone was seated, the experimenter began the first phase of the experiment - *familiarization.* The purpose of this phase was to familiarize the child with the box and teach her/him to reach inside to find toys. During the familiarization, the experimenter first showed the box to the child, demonstrating that it had 2 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 2 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 has explored the object for some time (about 30 seconds), the experimenter told the child that there was

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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 minutes 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 2 more objects 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 to make sure the child understood that the box 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 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 towards the child to allow her/him to reach inside. If the child did not reach inside, the experimenter repeated the request: "Find the apple!" On 29 trials (equally distributed across the three experiments and age groups) a child would not reach inside at all or reached, but could not find the object if it rolled too far back or sideways. The experimenter then helped the child find it 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 took the object out of the box from the child-facing opening and gave it to the child.

She then waited for the child to explore the object. This exploration period was also 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. The main dependent measure was whether infants' reached back in the box during this period. The trials terminated in one of the following 2 ways: 1) an infant put an object in the box after having explored it and pushed the box back to the experimenter; 2) the experimenter waited for the child to explore the object and reach back for another one, and then took the box and the object from the child whether the child had reached back or not. At the end of the trials the experimenter put

the object under the table and put the box on her lap. The procedure was repeated with 3 other objects, making it 4 experimental trials total.

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 (s)he 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 such trials lasted longer for this reason. An average trial length across the 3 experiments was 19.86 seconds (SD = 8.43 sec). We return to a discussion of trail length after Experiment 3.

Design

In this and all subsequent experiments, the 4 experimental trials were blocked by label. Thus, each child heard 2 labels, each label occurred 2 times in a row. For each label, infants once found the target object and once a distractor. For example, the experimenter said there was a spoon inside and a child found a spoon on the target trial. Once the spoon was taken from the child and out of view and the assistant put in a distractor object, the experimenter said again there was a spoon inside and the child found a different object (e.g., a toy car). The order of target and distractor trials was counterbalanced for each label. Thus each participant had two types of trial sequences: target-distractor, and distractor-target. Whether the target-distractor or the distractor-target sequence came first was counterbalanced across participants.

Coding

 1. *Searching for another object*

In this and all subsequent experiments, the main measure was whether infants searched again in the box on distractor trials more often than on target 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 2 occasions (Experiment 1) 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 8 trials (5 distractor and 3 target trials), infants first put the retrieved object back into the box, then took their hand out, and

reached back again (Experiment 1, 2 in each age group, Experiment 2, 2 in the 20-month-old group and 1 in the 16-month-old group, and 1 in Experiment 3). 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 some occasions 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. On some occasions they would take the first object out right away suggesting they were just playing with the box and the toy. Such ambiguous instances were coded as searching back for another object or not based on the coder's impression of what infants were doing. On 21 trials evenly spread across all experiments (both distractor and target, representing 6.7% of all 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 back for another object. If a child reached out with her hand, touched the spandex cover on the box opening, but did not insert their hand any further this was not coded as searching back.

Infants were scored "0" for trials on which they did not reach back and "1" for trials on which infants searched back. Muted video recordings were analyzed by an independent coder blind to the trial type: 90.6% of the trials from Experiment 1 (both age groups), 94% from Experiment 2 (both age groups), and 100% in Experiment 3. Overall agreement on whether a search for another object occurred or not was high: on 95.7% of the trials in Experiment 1 (Cohen's kappa = 0.91), on 93.5% in Experiment 2 (Cohen's kappa = 0.87), on 90% in Experiment 3 (Cohen's kappa = 0.77).

2. *Exploratory analysis of infants' behavior*

In addition to the main measure of infants' word comprehension we performed the following exploratory analyses of infants' reaction to the experimenter's reference and to the retrieved objects.

1) *Verbal behavior (object label production)*

We coded the following instances of infants' labeling the objects during the experimental trials. First, we were interested in whether infants repeated the reference after the experimenter while initially reaching in the box. We also coded if infants named the objects after having found them. Next, we coded instances of mislabeling distractor objects: it happened sometimes if infants were repeating the experimenter's reference after having retrieved a distractor object.

Last, we coded if the infants were able to correct their mislabeling of a distractor object by producing the right label.

2) Object exploration

We coded the actions infants produced on the retrieved objects, specifically, the actions that corresponded to the object's function and category membership (category-specific actions). Some examples of category-specific actions include rolling the car, drinking from the bottle, trying to bite the apple etc. General actions like mouthing the objects or dropping them on the floor that could be done with any kind of toy were not recorded. We report the actions that reflected infants' recognition of the objects' functions and category membership.

3) Looking behavior

To investigate infants' reaction at the target and distractor objects we coded the duration of infants' first look at the retrieved objects. As a measure of infants' social behavior we also coded whether they looked at the mom or at the experimenter right after looking at the retrieved object.

Results and discussion

1. Searching for another object

The purpose of this experiment was to investigate infants' ability to use a category label in interpreting 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 again in the box to find another object on distractor trials (when they retrieved a different object than what the experimenter had mentioned) than on target trials. Results are displayed in Figure 1. A Generalized Estimating Equation model with probit link was run predicting infants' reaching back from trial type, age and their interaction. Trial type and age were dummy coded first, with 20-month-olds and distractor trials as reference categories, and second with 16-month-olds and distractor trials as reference categories. The analysis showed that 20-month-old infants searched on 59.4% of distractor trials ($b_0 = 0.24$, $\chi^2(1) = 0.83$, $p = 0.36$, 95% CI [-0.27; 0.75]). They were significantly less likely to reach back on target trials (46.9%) than on distractor trials ($b_1 = -1.39$, $\chi^2(1) = 10.89$, $p < 0.001$, 95% CI [-2.21; -0.56]). There was no significant difference in the rates of reaching back on distractor trials between 20 and 16-month-olds ($b_2 = -0.08$, $\chi^2(1) = 0.05$, $p = 0.82$, 95% CI [-0.784; 0.624]). The age by trial interaction was not significant, meaning that the difference in infants' performance on target vs.

distractor trials was not smaller in the younger group comparing to the older group ($b_3 = 0.56$, $\chi^2(1) = 1.03$, $p = 0.31$, 95%, CI [-0.518; 1.629]).

Next, to investigate 16-month-old infants' performance on distractor vs. target trials we changed the reference category from 20-month-olds to 16-month-olds. Sixteen-month-old infants reached back on 56.2% of distractor trials ($b_0 = 0.1573$, $\chi^2(1) = 0.4$, $p = 0.5253$, 95% CI [-0.328; 0.643]). They were significantly less likely to search back on target trials (31.2%) than on distractor trials ($b_1 = -0.83$, $\chi^2(1) = 5.62$, p < 0.05, 95% CI [-1.519; -0.144]). There were no sex or order effects.
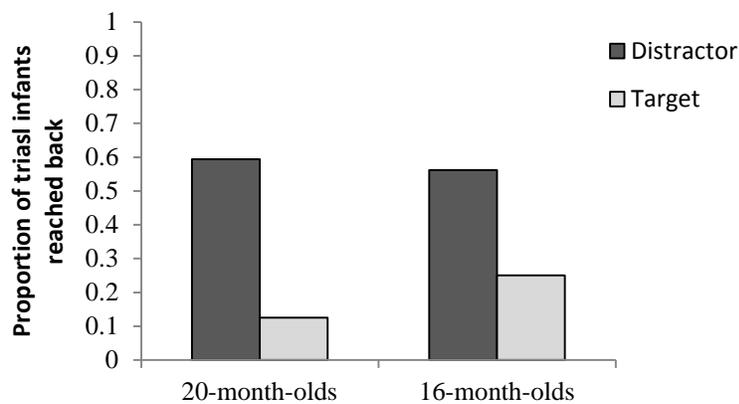

Figure 1. Proportion of trials infants reached back into the box to find another object.

To guard against the possibility that differences in infants' behavior on target trials and distractor trials was 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 2 target trials and 2 distractor 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, $p = 0.9$). Whether the coder correctly guessed distractor trials was not related to whether a child reached back on those trials or not (Logistic regression, $b = 0.34$, $Z = 0.76$, $p = 0.44$). This suggests that infants' behavior was not biased by the experimenter.

Higher rates of reaching back into the box to find another object on distractor trials than on target trials suggest that infants were able to recognize target objects they had never seen before as the correct referents and that they were able to recognize the distractor objects as not

belonging to the right set of referent objects. This suggests that infants are able to use category label to interpret absent reference, and their understanding does not require a memory of a particular token in its specific location.

2. *Exploratory analysis of infants' behavior*

To further investigate infants' reaction to the announced words and their reaction to the retrieved objects we coded 100% of trials for 16-month-olds and 94% of trials for 20-month-olds (the experiment was not taped for 1 participant) with respect to various verbal and non-verbal behaviors infants produced during the experimental trials. See summary in Table 1.

1) *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 45% of the trials (often more than once on the same trial), about equally often on target and distractor trials. In the younger group, naming occurred less often, only on 12.5% of trials, and all but one on target trials. On rare occasions (17% of trials in the older group and 4.7% in the younger), infants rehearsed the label provided by the experimenter either during the initial search in the box or during the secondary search after having realized they found something wrong. Interestingly, on 43.8% (7 out of 16) of the distractor trials on which labeling occurred older infants repeated the label produced by the experimenter when already exploring the retrieved object and this actually lead them to mislabeling the object in hands. On 3 occasions of mislabeling infants corrected themselves. For example, when the experimenter said there was an apple inside and a child found a shoe instead, she said "Apple! Apple! Apple! No… Shoe!" In the younger group mislabeling on distractor trials occurred only once. Infants' verbal behavior provides additional evidence that infants often recognized objects for what they were, and their reactions to the retrieved objects was guided by their word comprehension.

2) *Object exploration*

Coding of infants' object exploration showed that infants sometimes produced category-specific actions when exploring the toys they found in the box. Some examples of such actions include rolling the car, drinking from the cup and the bottle, shaking the bottle, bouncing the ball, trying to bite the banana and the apple, eating or digging with the spoon. Such behaviors occurred on 37% of the coded trials in the older group (both target and distractor) and on 12.5% of the coded trials in the younger group (both target and distractor). Such behavior may suggest

that many infants were mostly able to recognize objects for what they were. However, it's important to point out that such behavior could have been driven by object affordances and not reflect infants' higher-level understanding of what the objects were. Additionally, we can not be sure that infants who did not produce this behavior were not able to recognize the objects. It's possible that they just did not want to play with these objects. Despite the uncertainty about the interpretation of such behavior it can be used to compare infants' object exploration across the 3 experiments.

3) 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 the distractor trials which will be manifested in longer looking at the distractor objects than at target objects. In the older group, we found the opposite: 20-month-old infants' initial look at distractor objects tended to be quicker than their look at the target objects, although the difference was only marginally significant (M(target) = 5.09 sec., SD = 3.5 sec., M(distractor) = 4.04 sec., SD = 1.9 sec., paired t-test, $t(31) = 1.74$, $p = 0.09$). One potential explanation for this is that older infants quickly recognized the mismatch between the experimenter's reference and the retrieved objects on distractor trials, while they concentrated on exploring the objects longer on target trials. In the younger age group this difference did not emerge (M(target) = 4.37 sec., SD = 2.4, M(distractor) = 4.55 sec., SD = 4, paired t-test, $t(31) = 0.28$, $p = 0.78$).

Further investigation of infants' looking patterns revealed that infants 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 57% of trials in the older group and on 93% of trials in the younger group, and equally often on target and distractor 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.

Table 1. Exploratory analysis of infants' behavior.

	Naming object in hands	Mislabeling on the distractor trials	Rehearsing the label while reaching	Object exploration	Duration of 1st look	Looking back at the experimenter
20 months	45%, both T and D trials	43.8% of the D trials where the naming occurred (7/16)	17%, both on T and D trials	37% of T and D trials	Mean T = 5.09(3.5) Mean D = 4.04(1.9)	57% of T and D trials
16 months	12.5%, mostly on T trials	1.56% only 1 instance	4.7%, both on T and D trials	12.5% of T and D trials	Mean T = 4.37(2.4) Mean D = 4.55(4.0)	93% of T and D trials

To summarize, this experiment demonstrates that infants at 16 and 20 months are able to understand absent reference based on their knowledge of category labels and without relying on their memory of a particular recently seen token of the category and its specific location. Their language comprehension is sufficient for them to recognize familiar but never seen before objects as targets and to reject distractors as objects not belonging to the category mentioned by the researcher. In addition, at both ages they showed some understanding of the social aspect of communication. First, infants frequently looked back at the experimenter after having found an object to check on her reaction. Second, they were able to make an inference that there must be a different object inside the box if they did not find the object the experimenter was referring to on distractor trials.

In the next two experiments we investigate infants' ability to reject distractor objects that are similar to the target objects categorically (Experiment 2) and visually (Experiment 3). Arias-Trejo and Plunkett (2010) suggest that perceptual similarity and category membership of distractor objects interfere with referent identification both in toddlers and adults. In their study, target identification was slower and less accurate when the distractor was similar perceptually or categorically, or both, compared to when it was unrelated and visually dissimilar. Additionally, research on adults' factual error detection shows that people are more prone to accept incorrect statements if the incorrect entity is conceptually related to the correct entity (e.g., Moses instead of Noah as a person who build the arc, Erickson & Mattson, 1981). In the next 2 experiments

infants are tested with distractor objects drawn from the same global category, but visually dissimilar (Experiment 2), and with perceptually similar distractors, but not related to targets categorically (Experiment 3).

Experiment 2

Method

Participants

Seventeen 20-month-old infants (range 19 months 8 days – 21 months 9 days; mean 20 months 4 days, 13 girls) and 16 16-month-old infants (mean = 15 months 25 days, range 15 months 24 days – 16 months 14 days; 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 4 pairs of categorically related, but visually dissimilar items: apple-banana, bottle-cup, shoe-sock and diaper-pants (see pictures in Appendix B). The paired objects were from the same global 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.

Two pairs were selected for each child to be tested with based on which words their parents reported as known. For 16-month-olds occasionally the list of words reported as "known best" by the parents did not include all words from our "matched distractor" set. On such cases preference was given to infants' knowledge of target labels in constructing distractor-target pairs. 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 distractor. Procedure, design and coding were the same as in Experiment 1.

Results and discussion

1. *Reaching back for another object*

The purpose of this experiment was to investigate if infants can reject distractor objects that are categorically related, but perceptually dissimilar. Infants' performance in this task depends on their recognition that distractor objects are categorically related. If infants recognize

the similarity between the retrieved distractor objects and the objects they were told were in the box it should be more difficult for infants to reject such distractors. Thus we should see lower rates of reaching back 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 2). A GEE model (probit link) was run following the same strategy as in Experiment 1. Older, 20-month-old infants searched back on 67.7% of distractor trials ($b_0 = 0.458$, $\chi^2(1) = 3.97$, $p < 0.01$, 96% CI [0.007; 0.9]). They were significantly (50.1%) less likely to search on target trials ($b_1 = -1.39$, $\chi^2(1) = 20.54$, $p < 0.0001$, 95% CI [-1.99; -0.787]). Younger, 16-month-old infants, were significantly (36.5%) less likely to reach back on distractor trials than 20-month-olds ($b_2 = -0.95$, $\chi^2(1) = 7.91$, $p < 0.01$, 95% CI [-1.6; -0.29]). Finally, there was a significant age by trial interaction ($b_3 = -0.95$, $\chi^2(1) = 7.91$, $p < 0.01$, 95% CI [0.33; 2.07]) meaning that the difference in rates of reaching back on distractor and target trials was larger for 20-month-olds than for 16-months-olds. Indeed, 16-month-old infants reached back on 31.2% of distractor trials ($b_0 = -0.49$, $\chi^2(1) = 3.96$, $p > 0.05$, 95% CI [-0.97; -0.007]). They were not much less likely to reach back on target trials ($b_1 = -0.19$, $\chi^2(1) = 0.34$, $p = 0.56$, 95% CI [-0.82; 0.44]). There were no sex or order effects.
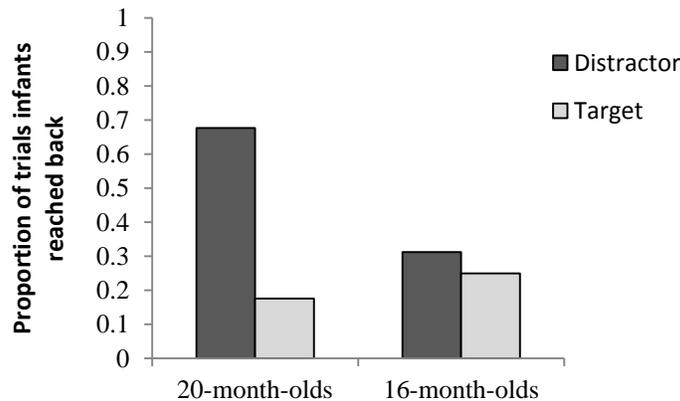

Figure 2. Proportion of trials infants reached back into the box to find another object.

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, $p = 0.7$). 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 distractor trials significantly more often than on target trials, like in Experiment 1. Younger, 16-month-old infants no longer showed this pattern. They reached on distractor trials much less often than 20-month-old infants, and not more often than on target trials. To further investigate older infants' reaction to categorically matched distractors we compared the latency of reaching back on distractor 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 moment they initiated reaching back (they raised their hand to reach in). This coding was performed only for the distractor trials on which infants reached back. Although the latency of reaching back in Experiment 1 tended to be larger comparing to that in Experiment 2, the difference did not reach significance (M (Exp. 1) = 9.53 sec., SD = 5.72, M (Exp. 2) = 7.81, SD = 3.66, Welch t-test, 2-sided, $t(27.7) = 1.1$, $p = 0.28$).

   2. *Exploratory analysis of infants' behavior*

Like in Experiment 1, we coded infants' reaction to the retrieved objects (83% of the trials for 20-month-olds and 100% of the trials for 16-month-olds). Below we report infants' production of object labels, object exploration patterns, and looking behavior. See summary in Table 2.

   1) *Verbal behavior (object label production)*

Coding infants' verbal behavior revealed that in the older group infants named the objects in hands on 28.6% of the coded trials, both on distractor and target trials. Like in Experiment 1, naming was less frequent in the younger group – 7.81% of the trials, both target and distractor. As in Experiment 1, infants occasionally rehearsed the label after the experimenter while searching in the box. This occurred only in the older group on 19.7% of the coded trials, both target and distractor. Younger infants in this experiment never repeated the experimenter's reference before seeing an object. In the older group, rehearsing the label after the experimenter sometimes led to infants mislabeling a distractor object after they had retrieved it already. This occurred on 5 out of 8 instances (62.5%) when infants named the objects on distractor trials. For example, one child was repeating after the experimenter: "Find shoe! Shoe!" She said "shoe" after having found a sock, then said "socky" several times, then said "shoe" again and reached

back into the box. In the younger group there was only 1 instance of mislabeling, and it occurred on a target trial: the child was told there was an apple inside, he retrieved an apple and said "nana" (banana).

2) Object exploration

Coding of infants' object exploration patters revealed that infants sometimes performed the following category-specific actions: trying to bite the apple and the banana, trying to drink from the cup and the bottle, trying to put the sock and the shoe on foot. Actions like putting the sock and the shoe in mouth or putting pants or the diaper on head were not considered in this analysis. Category-specific actions occurred on 26.8% of trials in the older group and on 31.2% trials in the younger group. These actions were equally often on target and distractor trials. Interestingly, in the younger groups category-specific actions occurred more often in Experiment 2 than in Experiment 1 (12.5%). This suggests that infants were not less engaged with the objects in this experiment compared to Experiment 1.

3) Looking behavior

Coding the duration of infants' initial look at the retrieved object on target vs. distractor trials showed that 20-month-old infants spent less time looking at distractor objects than on target objects before looking away (M(distractor) = 3.87 sec., SD = 3.29, M(target) = 5.71 sec., SD = 3.1, paired t-test, $t(27) = 2.35$, $p < 0.05$). This provides additional evidence that 20-month-old infants treated distractor objects differently than target objects. The difference between the duration of the initial look at the retrieved distractor vs. target objects did not emerge for 16-month-old infants (M(distractor) = 3.39 sec., SD = 2.68, M(target) = 3.58 sec., SD = 2.02, paired t-test, $t(31) = 0.37$, $p = 0.71$).

Further analysis of infants' looking behavior revealed that infants in both age groups often looked back at the experimenter to check on her reaction. This occurred on 81.2% of the trials in the younger group and on 41% of the trials in the older group, and both, on target and distractor trials.

Table 2. Exploratory analysis of infants' behavior.

	Naming object in hands	Mislabeling on the distractor trials	Rehearsing the label while reaching	Object exploration	Duration of 1st look	Looking back at the experimenter
20 months	28.6%, both T and D trials	62.5% of the D trials where the naming occurred (5 out of 8)	19.7%, both on T and D trials	26.8% of T and D trials	Mean T = 5.71(3.10) Mean D = 3.87(3.29)	41% of T and D trials
16 months	7.81%, mostly on T trials	1.6% (only 1 instance)	4.7%, both on T and D trials	31.2% of T and D trials	Mean T = 3.58(2.02) Mean D = 3.39(2.68)	81.2% of T and D trials

As shown above, younger infants in this experiment did not reach back on distractor trials more than on target trials. This suggests that they detected the similarity of the distractor objects to the category of objects denoted by the experimenter's reference, and this made it difficult for them to reject the distractors 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 distractor trials than on target 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's unlikely that 20-month-old infants reached back on distractor trials more than on target trials in this experiment because they did not detect that the distractors were categorically close to the targets. A more likely explanation is that they detected this, but were still able to reject categorically related objects as incorrect ones.

A potential alternative explanation for the finding that infants in the younger group did not reach back on distractor trials as often as in Experiment 1 is that they might not have been tested with labels they knew as well as those in Experiment 1. The comparison of the words used to refer to absent objects in Experiments 1 and 2 with the 16-month-old group showed that the

most frequent words in the first experiment were banana, shoe and dog, and in the second experiment they were shoe, banana and apple (see Appendix A). The fact that the word sets are highly comparable makes it less likely that infants did not reach back on distractor trials as often as in Experiment 1 due to their insufficient word knowledge. Additionally, if infants in Experiment 2 did not know the words they were tested with we would expect them to reach on target trials more often. This did not happen, and the rates of reaching back on target trials were the same in both Experiments – 25%. Therefore, 16-month-old infants in Experiment 2 did not reach back on distractor trials as often as in Experiment 1 likely because of their difficulty rejecting categorically related objects.

Altogether, Experiment 2 shows that 20-month-old infants' knowledge of category labels is robust enough for them to tell the difference between apples and bananas, shoes and socks, cups and bottles, and diapers and pants. At the same time, 16-month-olds appear to have fuzzy category boundaries as they have more difficulty rejecting related objects.

In the next experiment we investigate 20-month-old infants' ability to reject perceptually similar distractors. For this purpose we tested infants with distractor that matched typical referents of the mentioned categories on both, color and shape.

Experiment 3

Method

Participants

Sixteen 20-month-old infants participated (range 18 months 26 days – 20 months 25 days; mean 20 months), 8 girls). Participants were recruited as in Experiment 1.

Materials and design

In previous experiments stimuli were chosen such that both target and distractor objects were familiar to infants and infants knew their labels. Following this strategy, it was possible to find perceptual matches to only 2 objects in the previously used set – the red plastic apple and the banana. The match for the red apple was a red plastic ball (both red and round), and the match for the banana were two tall yellow blocks put together (both long and yellow) (see pictures in Appendix B). Parents were asked if their infants knew the words "apple", "banana", "ball" and "blocks". All but one child knew the first 3 words and not all knew the word "blocks".

Therefore, in the pair "banana – blocks" banana was always the target except for one child who did not know the word "banana", but knew the word "blocks."

Procedure, design and coding were the same as in Experiments 1 and 2.

Results and discussion

1. *Reaching back for another object*

The purpose of this experiment was to test infants' ability to reject perceptually similar distractors. We predicted that if infants know what typical tokens of a target category look like they may have difficulty rejecting distractor objects that match in color and shape. The results supported this prediction (see Figure 3). There were no significant differences in infants' rates of searching back on target and distractor trials. Infants in this experiment reached back on 37.5% of target trials, and on 31.25% of distractor trials (McNemar Change test, $\chi^2(1) = 0.07$, p = 0.79). There were no sex or order effects.
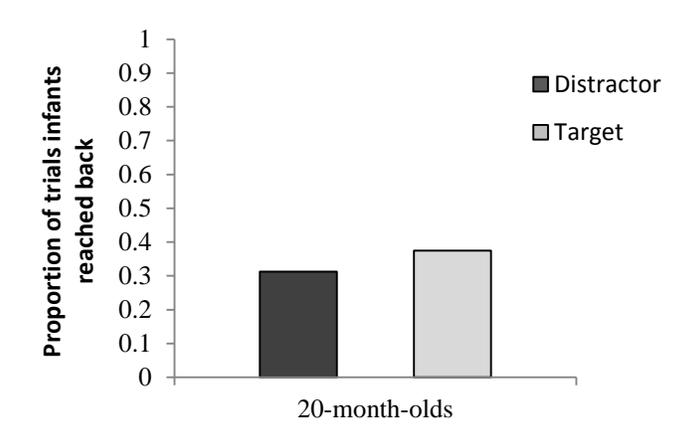
Figure 3. Proportion of trials infants reached back into the box to find another object.

These results may indicate that infants bring to mind some perceptual features associated with mentioned categories and thus perceptually similar distractors appear very misleading to them. One potential alternative explanation is that these results were observed because of the limits we had to place on the stimuli set and because we could not be sure that infants were tested with the words they knew best. To investigate this idea we analyzed whether infants' rates of searching back on target trials varied by experiment.

If infants reach back on *target* trials in Experiment 3 more than in 2 other experiments that would indicate that they might not be able to recognize typical referents of the mentioned category labels used in this experiment. A GEE analysis revealed that experiment was not a significant predictor of infants' reaching back into the box on target trials ($\chi^2(2) = 4.72$, $p = 0.094$). Infants did not reach back on target trials in Experiment 3 more than in Experiment 2 ($b_1 = 0.4$, $\chi^2(1) = 2.53$, $p = 0.61$). However, infants' rate of reaching back on target trials in Experiment 3 was marginally higher than in Experiment 1 ($b_2 = 1.4$, $\chi^2(1) = 3.63$, $p = 0.06$). This suggests that word knowledge could have potentially constrained performance in this experiment.

Additionally, we compared the most frequently used words in Experiments 1-3 (see Appendix A) and performed an item analysis in Experiment 3. The 3 words most often announced by the researcher in Experiment 1 with 20-month-olds were spoon, apple and shoe. In Experiment 2 they were shoe, apple and banana. In Experiment 3, the words announced by the researcher were banana, apple and ball. The word apple is used in all 3 experiments. If infants' word knowledge constrains their performance in Experiment 3 we should see that infants performed better on trials where the word "apple" was used as a reference, but not with other words. We found that infants in Experiment 3 reached back on distractor trials while not reaching back on the matched target trails 3 times with the word "banana", 3 times with the word "ball" and 1 time with the word "apple". This may indicate that infants' lack of label comprehension cannot completely explain experiment 3 findings. At the same time, it cannot be completely ruled out because parents were not given the complete questionnaire with 12 words like in experiment which would allow us to know if the words banana, apple and ball were among best known words for each participant. Therefore, although we favor the explanation that perceptual similarity of distractor objects made it difficult for infants to detect a mismatch and attempt to find another object on distractor trials, there is still a potential explanation that these results were obtained because we had to constrain the stimuli set and could not test each child with the best known words.

2. *Exploratory analysis of infants' behavior*

Like in the previous two experiments we coded infants object label production, object exploration patterns and looking behavior (94% of the trials). See summary in Table 3.

1) *Verbal behavior (object label production)*

As in previous 2 experiments, infants often named the objects while exploring them. This was observed on 31.7% of the trials, both target and distractor trials (compared to 45% in Experiment 1 and 28.6% in Experiment 2). On distractor trials infants sometimes mislabeled the objects, and it did not occur more often than in previous 2 Experiments: 37.5% (3 out of 8 instances) of distractor trials where naming occurred in this Experiment compared to 43.8% in Experiment 1 and to 65.7% in Experiment 2). Rehearsing the label while reaching did not occur very often in this experiment: there were only 3 instances of such behavior. The fact that infants' verbal behavior was very similar to that in Experiments 1 and 2 suggests that, as a group, infants were familiar with the words they were tested with.

2) Object exploration

Infants in this experiment often performed actions appropriate for the retrieved objects: taking the blocks apart, bouncing the ball against the table, trying to bite the apple and the banana. Such actions occurred on 58.3% of the trials, both, target and distractor trials (compared to 37% in Experiment 1 and to 26.8% in Experiment 2). Interestingly, there were 6 instances when the actions infants performed on the retrieved objects were inappropriate and reflected their confusion about what the object was: trying to bounce the apple on the table and trying to bite the ball or the blocks. Four of such instances occurred on distractor trials and 2 occurred on target trials that came after the distractor trials. Infants' production of category-specific actions suggests that they often, but not always, recognized the object's category membership. Several instances of producing "wrong" actions suggests that perceptual similarity of distractor objects may indeed be misleading and confusing for infants.

3) Looking behavior

The analysis of the duration of infants' initial look at the retrieved objects revealed no significant differences between target and distractor trials (M(target) = 4.14 sec., SD = 2.55, M(distractor) = 4.91 sec., SD = 3.64, paired t-test, $t(27) = 94$, $p = 0.35$). However, infants in this experiment, like in Experiments 1 and 2, often looked back at the experimenter right after looking at the object. This behavior was observed on 76.7% of the trials and it indicates that infants were sensitive to the social aspect of the interaction. Looking back at the experimenter was observed more often in Experiment 3 than in Experiment 1 (57%) and Experiment 2 (41%) most likely because in Experiments 1 and 2 infants reached back in the box more often than in Experiment 3. They often did it before checking on the experimenter's reaction.

Table 3. Exploratory analysis of infants' behavior.

	Naming object in hands	Mislabeling on the distractor trials	Rehearsing the label while reaching	Object exploration	Duration of 1st look	Looking back at the experimenter
20 months	31.7%, both T and D trials	37.5% of the D trials where the naming occurred (4 out of 8 instances)	4.7%, 2 instances on T trials	58.3% of T and D trials; +6 instances of wrong actions	Mean T = 4.14(2.55)	76.7% of T and D trials
					Mean D = 4.91(3.64)	

Altogether, the coding of infants' verbal behavior suggests that many of them were tested with the words that were familiar to them, and that infants were often able to recognize category-membership of the retrieved objects, but sometimes they may have been confused about it because of the object's appearance.

Duration of trials in Experiments 1, 2, and 3.

As shown above, in Experiment 1 in both age groups, and in Experiment 2 in the 20-month-old group infants searched again in the box after having found an object on distractor trials significantly more than on target trials. The analysis of the duration of trials revealed that distractor trials were longer than target trials in Experiment 1 in both age groups and in Experiment 2 in the 20-month-old group (see Table 4 for summary): Experiment 1, 20-month-olds, paired t-test, $t(30) = 2.28$, $p < 0.01$; 16-month-olds, paired t-test, $t(29) = 2.17$, $p < 0.05$; Experiment 2, 20-month-olds, paired t-test, $t(30) = 1.84$, $p = 0.08$. No significant differences were revealed in Experiment 2 for 16-month-olds (paired t-test, $t(31) = 0.55$, $p = 0.59$), and in Experiment 3 for 20-month-olds (paired t-test, $t(27) = 0.81$, $p = 0.42$).

Table 4. Duration of target and distractor trials by age group and Experiment.

		Experiment 1	Experiment 2	Experiment 3
20 months	Target	18.5(6.69)*	16.1 (7.96)*	18.9 (7.12)
	Distractor	24.4(9.53)*	18.9 (8.85)*	20.2 (9.15)
16 months	Target	20.4 (8.05)*	18.5 (8.55)	
	Distractor	23.2 (9.97)*	19.5 (8.38)	

To ensure that the difference in the durations of distractor and target trials in Experiments 1 and 2 (20-month-olds) was not because the experimenter waited longer on distractor trials for infants to reach back than on target trials, but because infants were reaching back on distractor trials and this took extra time we conducted the following coding. For the distractor trials on which infants reached back to find another object we measured the duration of time from the onset of the trial to the moment infants started reaching back. We compared this to the duration of the corresponding target trials in the same trial blocks. We found that the duration of target trials was significantly longer than the latency of reaching back on the distractor trials: Experiment 1, 20-month-olds, M(target) = 18.5 sec., SD = 6.69, M(reaching back) = 12.7 sec., SD = 6.29, paired t-test, $t(16) = 2.59$, $p < 0.05$; 16-month-olds, M(target) = 20.4 sec., SD = 8.05, M(reaching back) = 14.1, SD = 7.41, paired t-test, $t(15) = 2.26$, $p < 0.05$; Experiment 2, 20-month-olds, M(target) = 16.1 sec., SD = 7.96, M(reaching back) = 9.25 sec., SD = 4.13, paired t-test, $t(21) = 3.39$, $p < 0.01$). This demonstrates that infants had enough time on target trials to initiate reaching back.

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

General Discussion

The purpose of the current research was to investigate infants' use of category labels in understanding 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 target trials they retrieved an object that matched the experimenter's reference, and on distractor trials they retrieved a different object – not what was promised by the researcher. Infants' ability to recognize a mismatch on distractor trials and reach back to find another object, while accepting target objects as correct referents, demonstrates their comprehension of words as category labels. In Experiment 1, when distractor objects were both categorically and perceptually unrelated to targets 16- and 20-month-old infants reached back into the box on distractor trials more often than on target trials. In Experiment 2, when distractor objects were from the same superordinate category as the targets, but looked different, 20-month-olds, but not

16-month-old infants, searched again for another object on distractor trials more than on target trials. In Experiment 3, when the distractor objects were categorically unrelated, but were perceptually similar (matching the targets in shape and color) 20-month-old infants did not show a clear pattern of reaching back on distractor trials more often than on target trials.

The Experiment 1 findings suggest that infants at both ages were able to recognize novel tokens of familiar categories as the correct referents and to reject unrelated distractor objects. Thus, infants' absent reference comprehension does not seem to be solely based on their ability to recall a particular object in its specific location. If it were the case they should not have been able to accept target objects as correct referents. Infants also were not satisfied at finding wrong objects and searched again in the box. Thus, they 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 words 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 distractor objects were drawn from the same superordinate category as the target objects, but were perceptually dissimilar, 16-month-old infants had difficulty detecting a mismatch between the experimenter's reference 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 distractors. Most likely this happened because infants at 20 months have more precise word knowledge and more clear category boundaries than infants at 16-months, and thus they were able to understand that bananas are not apples, and socks are not shoes. Yet another possibility is that 20-month-old infants did not recognize that the distractor objects were close categorically to typical referents of the announced words and treated them as unrelated objects, like in Experiment 1. We do not favor this explanation because it presupposes that older infants have less knowledge about categories of objects than younger infants, which is unlikely.

In Experiment 3, 20-month-old infants had difficulty rejecting perceptually similar, but categorically unrelated distractors. This suggests that infants may also retrieve some perceptual information in response to hearing a word. They know what typical referents look like, and this interferes with their ability to recognize that distractor objects similar in shape and color are

incorrect. Such instances of infants' object exploration behavior as bouncing the apple on the table, or trying to bite the blocks provide additional evidence that infants may have been confusing the distractor objects with the correct referents because of their appearance.

The finding that categorically related distractors and perceptually similar distractors are more difficult for infants to reject than unrelated distractors is consistent with previous research on toddler's language comprehension. For example, in Arias-Trejo & Plunkett (2010) 21-24-month-old toddlers' ability to look at the picture of the mentioned object was impaired when the distractor was drawn from the same global category and when it was perceptually similar to the target. The authors conclude that "early representations of meaning are linked not only to their original referent, but also to related concepts sharing ontological status and/or perceptual properties" (Arias-Trejo & Plunkett, 2010, p.78). This conclusion was also reached in priming-interference studies. For example, in Styles & 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, McQueen & Huettig, 2011; Mani et al., in press). In the current research, these findings were extended to younger ages (16 and 20 months).

One question that remains unanswered and can be address in future research is when perceptual and conceptual activations take place 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 bring to mind 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 if 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. Again, infants' secondary search does not require them to represent anything specific.

This second possibility is in accord with previous research on adults' and toddlers' language comprehension. For example, in Huettig & Altmann (2010) adult participants were presented with a word and a picture that contained unrelated distractors and one color associated

distractor (a conceptually unrelated object in the color prototypical to the target concept: e.g., green blouse when hearing the word "frog"). Only when the pictures were presented in color were the participants more likely to fixate at the color associated distractor than at other distractors. When the stimuli were presented in black and white or in line participants were not more likely to fixate on color associated distractors (e.g., spinach as a distractor for the word "frog"). This suggests that visual effects found in the first case (green blouse) were driven by perceived color information (e.g., the perceived surface color of the visual object), not by stored *conceptual* information (e.g., the stored knowledge about the typical color of the target object).

Similar results were found for 3-year-old children in Johnson & Huettig (2011) and for 2-year-old children in Johnson, McQueen & Huettig (2011). Children fixate at color matched distractor (red plane) after hearing a word (strawberry) more than at unrelated distractors (yellow plane). This effect did not hold when the stimuli were presented in line drawings or in black and white. As concluded, color is not an intrinsic property of conceptual representations and is only retrieved at the stage of visual search. Likely, children know the prototypical color of the mentioned concept, but only bring this information to working memory when searching for the target among other objects presented in color.

Exploratory analysis of infants' behavior on experimental trials in the current research revealed several interesting patterns. First, infants often labeled the retrieved objects, 20-month-olds more often than 16-months-olds. This occurred on both, distractor and target trials, and in all 3 experiments. This suggests that infants were indeed familiar with the objects used in this study, and that their productive language is more robust at 20 months than at 16. Infants (mostly 20-month-olds) also occasionally rehearsed the labels provided by the experimenter when searching in the box. This cannot be taken as evidence that their search is guided by a specific mental representation because they might have been just repeating the words after the experimenter without representing anything. However, it does demonstrate that they might have a high enough level of phonological memory to hold in mind a previously announced word when processing later retrieved objects.

Rehearsing the words sometimes led infants to mislabel distractor objects. Some of the 20-month-old infants were able to produce correct labels after having detected a mismatch. This further demonstrates infants' productive vocabulary and word knowledge at this age. Additionally, this provides further evidence that their searching for another object on distractor

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trials was driven by detecting a mismatch between the experimenter's reference and the retrieved object.

Infants' detection of a mismatch between objects in hands and the experimenter's reference is also reflected in their looking behavior and mimics. As found in Experiment 1 and 2, 20-month-old infants' first look at distractor objects was quicker than their first look at target objects. On distractor trials they were able to quickly detect a mismatch, and then they either looked back at the experimenter or reached again to find another object. On target trials they concentrated on exploring the objects because there was no mismatch.

The coding of infants' looking behavior also showed that they were sensitive to the social component of the interaction. After having retrieved an object they often looked back at the experimenter to check on her reaction. This happened in both age groups and on both distractor and target trials.

Altogether, these findings suggest that infants as young as 16 months can 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. Infants' language comprehension is social in nature, and they are sensitive to the potential of words to refer to any object from a given category.

CHAPTER III

INFANTS' USE OF INTONATION TO INTERPRET AMBIGUOUS REFERENCE

Introduction

Language provides us with an important means of communicating information to each other. However, verbal messages are not a perfect and a direct way of meeting minds. Linguistic expressions do not perfectly reflect what the speaker has in mind, and in everyday life we deal with a number of ambiguous verbal messages. For example, there can be multiple potential objects that a pronoun can refer to or there can be several objects in view that can be named with the same noun (e.g., several different cups). Despite this ambiguity, people manage to understand each other by relying on different nonverbal information (e.g., linguistic context or their knowledge of the speaker) or (if they are able) by simply asking for clarification.

Previous research has shown that the ability to interpret ambiguous references is available to infants in their second year of life. Infants can rely on various types of information to infer what exactly the speaker refers to. For example, infants as young as 12 months are able to use the direction of the speaker's voice when the speaker is not visible to infer which of the 2 possible referents she is attending to (Rossano, Carpenter & Tomasello, 2012*).* In this study, 12- and 16-month-olds watched the experimenter go behind a barrier. While the experimenter was not visible to them they heard her verbally express excitement about a toy hidden in one of two boxes at either end of the barrier. When infants were allowed to find the toy at both ages they went to the box that the experimenter's voice was directed at.

Infants as young as 15 and 18 months have been shown to use previous shared linguistic context to infer the referent of an ambiguous pronoun "it" (Ganea & Saylor, 2007). In this study, infants saw the experimenter searching for an absent toy (puppy) while saying "I really want to find my puppy!" and "Is my puppy under here?" Then infants were shown two toys – the target (a puppy) and a distractor. When asked "Can you get it for me?" they were able to infer that experimenter meant the puppy based on what she had been previously talking about. This did not happen because the representation of a "puppy" was still active in infants' minds at the time of the request. When a different experimenter provided an ambiguous request infants selected the objects at chance.

Southgate, Chevallier & Csibra (2010) demonstrated that 17-month-old infants can also track the requester's epistemic state and use this to infer the referent of an ambiguous request. In this study, infants saw the experimenter put two novel objects each in its own box. After the experimenter left, an assistant appeared from behind curtains. She switched the objects in boxes in the "false belief" condition and did not switch them in the "true belief" condition. Then the experimenter came back and pointed at one of the boxes and said: "There's a sefo in here. There's a sefo in this box. Shall we play with the sefo?" Infants retrieved the object from the non-referred box when the experimenter had a false belief about the contents of the box she was pointing at. Infants approached the referred box in the true belief condition.

Finally, infants have been shown to keep track of other people's experiences with objects and use that information to interpret ambiguous verbal references (Liebal, Carpenter & Tomasello, 2010; Moll, Carpenter & Tomasello, 2007; Saylor & Ganea, 2007; Tomasello & Haberl, 2003). However, in some studies infants consistently select an object that is new to the experimenter, while in other studies infants infer that the experimenter wants an old, familiar object. For example, in Saylor and Ganea (2007), 14- to 20-month-old infants saw two experimenters play separately with a different ball. The balls were then put in opaque containers matching the colors of the balls. When one of the experimenters came back and asked for her ball using ambiguous request ("Give me the ball!") infants used to pick up the ball that she previously played with. Younger, 12-month-old infants can also select the old object for the experimenter if she uses possessive pronoun "my" instead of the definite article "the" when talking about her ball (Saylor, Ganea & Vazquez, 2011). In another study 18-month-old infants played with two experimenters sequentially using distinct objects (Liebal, Carpenter & Tomasello, 2010). Later they saw pictures of the objects in the company of either experimenter 1 or experimenter 2. They pointed to the pictures of those objects that they used in a shared game with the corresponding experimenter.

In contrast to this, in several other studies infants inferred that the experimenter was asking about a new object (e.g., Tomasello & Haberl, 2003; Moll, Carpenter & Tomasello, 2007). For example, in Tomasello and Haberl (2003) 12- and 18-month-old infants played with two experimenters with two toys. A third toy was introduced to them while one of the experimenters was absent. At test, while all three toys were on the tray, the experimenter who did not see the third toy showed great excitement ("Oh, wow! Look at that! Look at that!") and

asked the infants ambiguously "Give it to me, please!" Infants selected the toy that the experimenter had not seen before assuming she wanted the new object. Moll, Carpenter and Tomasello (2007) extended these findings showing that infants can make such inferences only when all objects are introduced in a joint attention episode and not after observing this from a third party perspective.

The purpose of the current research is to investigate this puzzling discrepancy between the studies demonstrating infants' ability to track peoples' experiences with objects to disambiguate reference. Why did infants select an old object in Saylor & Ganea (2007) and in Liebal, Carpenter & Tomasello (2010), and a new object in Tomasello and Haberl (2003) and Moll, Carpenter and Tomasello (2007)? One possibility is that infants can rely on the intonation of the request to infer whether a person is asking them about an old or a new object. In the current study we test if infants' choice of a new vs. a familiar object depends on the intonation of the experimenter's request (excited vs. neutral).

There is indication that infants are sensitive to the way adults talk to them and understand affective intonation from a very young age. Infants prefer to listen to infant directed speech (Fernald, 1989; Pegg et al., 1992). Five-month-old infants react more positively to affirmative than prohibitive vocalizations with no lexical content, but only do it when vocalization are delivered in infant-directed speech (Fernald, 1993). Brain activity as measured by event-related potentials shows enhanced sensory processing of emotional compared to neutral prosody at 7 months (Grossman, Striano & Friederici, 2005). There is evidence that infants not only recognize emotional valence in speech but also understand its meaning: infants as young as 5 to 7 months of age are able to match happy, sad, angry, neutral affective intonations with corresponding facial expressions (Walker, 1982; Walker-Andrews, 1988). Infants also attend to the visual modality of emotions. For example, they consult their mom's facial expression to decide whether to approach a strange toy (Klinnert, 1984) or whether to cross a visual cliff (Sorce et al., 1985).

Importantly, it has been demonstrated that infants understand excited intonation in a special way. Moll et al. (2006) has shown that infants interpret excitement as specifically directed at something new. In that study, when infants of 14, 18 and 24 months saw the experimenter being excited about an old, familiar object they interpreted this excitement as directed to either a part of that object or to something else in the lab, but not to the object itself. At the same time, excitement directed to a new object was interpreted as about the object as a

whole. According to this, it is possible that infants in Tomasello and Haberl (2003) and Moll, Carpenter and Tomasello (2007) selected the object that was new to the experimenter possibly because the request was delivered in a highly excited manner. In comparison, in Saylor & Ganea (2007) the request was made in an infant friendly, but neutral way, and infants selected the object that was familiar to the experimenter.

In the current study we investigate infants' ability to recognize and use emotional prosody in reference resolution. For this purpose, we adapt the ambiguous reference task used in Saylor and Ganea (2007) so that for one group of infants the request is made in a flat neutral way, and for another group it is made in a highly excited manner. As suggested by previous research, infants are able to keep track of others' experiences with objects and to understand excitement as directed at something new at about 14 months (Moll et al., 2006; Saylor & Ganea, 2007). Therefore, we predicted that infants should be able to pick the new ball in the *excited request* condition and pick the old ball in the *neutral request* condition. We expected 20-month-old infants to do it more robustly than 16-month-old infants because their working memory, language and intonation understanding is more robust than that of 16-month-olds.

Experiment 1

Method

Participants

Participants were 56 healthy full-term infants with normal hearing and from English-speaking families. Twenty-four were 16 months old (range 14 months 19 days – 17 months 20 days, mean 16 months 1 day; 14 girls) and 32 were 20 months old (range 19 months 1 day – 21 months 18 days; mean 20 months 4 days; 12 girls). Ten additional 20-month-old infants participated, but were omitted: 2 for being unresponsive (did not approach any ball), 5 for grabbing both balls at the same time, 3 for approaching the balls when they were not supposed to. One 16-month-old infant participated but was omitted due to experimenter error. Participants were primarily Caucasian and from middle class families. They were recruited from the Greater Nashville area by phone from a database of interested families.

Materials

During experimental sessions infants played with a red and a blue ball. Two sandbox buckets of matching colors were used to store the balls. Two cameras were used to videotape the

sessions: one camera recorded infants from the front to code their behavior and the other camera positioned at the corner of the room recorded the experimenter from the front and infants from the back side.

Design

Infants in each of the age groups were randomly assigned to one of two experimental conditions. In the *excited request* condition the request for the ball was made in a highly excited manner. In the *neutral request* condition the request was made in a neutral manner. To make the experimental manipulation stronger the difference between the excited and the neutral intonation was exaggerated: the neutral tone was more neutral than in Saylor and Ganea (2007), and the excited intonation was clearly very excited.

Procedure

Infants were tested in a rectangular room with two 1 m. high cabinets positioned along the short wall to the left of the entrance. The front camera was placed in between the cabinets. Parents were positioned at the center of the opposite wall facing the front camera. The rear camera was placed in the corner of the room to the right of participants. Infants were free to move around the room. Room set-up is schematically represented in Appendix C.

During the experimental sessions infants played with two experimenters that were physically distinct from each other. The requester role was randomly assigned to one of the two experimenters.

Experimental sessions consisted of two parts – ball introduction and test. The purpose of the ball introduction phase was to give infants experience with each of the two experimenters and their balls. The purpose of the test phase was to assess whether infants reverse their interpretation of the ambiguous reference based on the intonation with which the request is delivered.

Ball introduction

At the beginning of the ball introduction phase the buckets were placed on file cabinets, one on the right cabinet and one on the left. Infants will see each of the experimenters play with one of the balls and label the ball several times. The first experimenter took her ball out of its bucket (e.g., the blue ball from the blue bucket) and said: "Look! Here is the ball!" She played with the infant for one minute. During the play she could bounce the ball, roll it, throw it, hid it under the bucket or perform other actions according to infants' interests. She mentioned the ball

8-10 times (e.g., "We are playing with the ball!, "Can you give me the ball?"). She could also make general comments on the situation or infants' actions (e.g., "Are you having fun?", "Are you going back to mommy?"). During this phase the experimenter talked in an infant directed speech like she normally would talk to a child, and avoided being either too neutral or too excited. At the end of the ball introduction phase the experimenter put her ball in the bucket saying "My ball goes here" and put the bucket with the ball inside on the cabinet. She then walked out of the door while the second experimenter came in. They met at the door to ensure infants understood that there were 2 different people. The other experimenter repeated the entire sequence with the other ball and at the end of this phase put the ball with the bucket in their initial position on the cabinet.

Test phase

At the beginning of the test phase the experimenters came in one at a time, took the bucket with their ball and put it on the floor in front of the infant in the same spatial position as they had been on the cabinets. For example, if the blue bucket was on the left cabinet and the red bucket on the right one they remained on the floor in the same configuration – the blue bucket to the left of the red one. The buckets were initially put 1.22 m. apart. The parents were instructed to hold on to their infants to prevent them getting the balls at this time.

Following this, one of the experimenters came back, sat between the buckets, took them both at the same time and brought them close together without looking inside. Then she looked inside both buckets at the same time, raised her eyes on the infant again and said: "Look at that! Do you see it? I see it! Can you give it to me?" In the *excited request* condition the experimenter said these phrases in a very excited manner, stressing the words "look" and "that", using high pitch, loud voice, and making sharp pitch changes. She also brought her palms together at the beginning of the request to make sure infants notice her excitement. In the *neutral request* condition the experimenter used a neutral falling intonation saying "Look at that" and "I see it", and neutral interrogative intonation saying phrases "Do you see it?" and "Can you give it to me?" In both conditions, while saying "Can you give it to me?" the experimenter moved the buckets forward to the baby and slightly apart to make it easier to tell which bucket infants attend to. At this time the experimenter gave parents a hint to release the infant and continued looking straight until the infant made her choice to avoid biasing infants' responses with a head movement. Once infants made their selection, the experimenter clapped and said "thank you." If

a baby would not make the selection in 10 seconds after the request the experimenter repeated the request: "Do you see it? I see it! Can you give it to me?" – using the same intonation as before. Which ball served as the target, the side it appeared on and whether E1 or E2 is the requester were counterbalanced across participants.

Coding

Infants' responses were coded depending on whether they select the ball that the requester previously played with (old) or the other ball (new). If infants did not approach and take the ball out of the bucket their first look or point at one of the buckets were considered. If an infant first approached one ball, but did not pick, and then went and picked the other one, the ball that they picked was considered as their choice. Initial judgments were made during the session by the requesting experimenter. Videotapes (78.6%) were then coded by a naïve coder. Overall agreement between the experimenter and the coder was 95.5%. Disagreement occurred in two cases in the *neutral request* condition with 20-month-old infants who did not walk to pick a ball, but only looked at one or the other. Disagreements were resolved by discussion which resulted in the coding identical to the experimenter's initial one.

Results and Discussion

The purpose of the experiment was to test if infants at 16 and 20 months are able to take into account the speaker's intonation of the request when settling down on the right referent of an ambiguous request. We predicted that infants would reverse their selection of new vs. old referents depending on whether the request is made in the excited or a neutral way, and 20-month-old infants to so more consistently that 16-month-olds. The results supported our predictions (see Figure 4).

The analysis of infants' selection of the old vs. the new balls in the *excited* and the *neutral request* conditions indicated that for older infants the choice of the ball was overall influenced by the intonation of the request ($\chi^2(1) = 4.99$, $p < 0.05$). Fourteen out of 16 kids selected the ball that was new to the experimenter (one infant looked and all other approached and picked) and only 2 picked the old ball (Binomial test, $p < 0.01$). In contrast, in the in the *neutral request* condition infants did not select the old ball at above chance levels as predicted: 9 out 16 infants selected the old ball (Binomial test, $p = 0.8$). This means that infants successfully picked the right ball only in the *excited request* condition. Sixteen-month-olds did not reliably

use intonation to determine which ball to choose: in the *excited* and the *neutral request* conditions 6 infants selected the new ball and 6 selected the old ball, which is not different from chance level (Binomial tests, *p's* = 1).
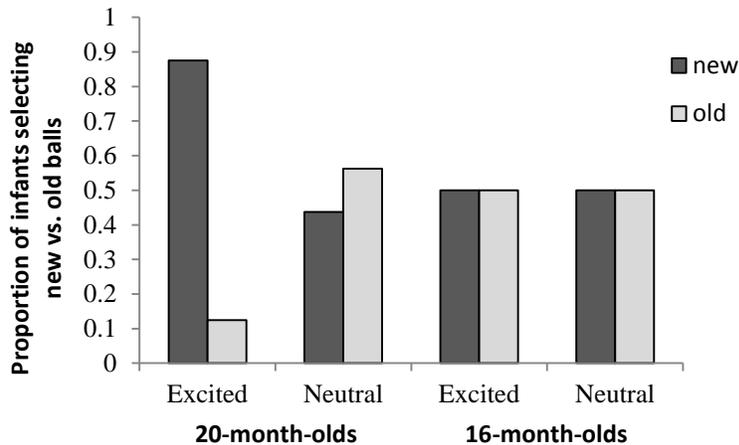

Figure 4. Proportion of infants selecting new vs. old balls.

To ensure that infants' behavior was not biased by the experimenters' behaviors we conducted several additional analyses. First, to check that the requesting and the non-requesting experimenter were playing with infants in a similar way an independent coder analyzed 68.8% of the rear camera recordings of the play phase (all from the older group of participants) and guessed which of the 2 experimenters was going to perform the request. She could correctly guess on 50% of the trials, which is not different from chance (Binomial test, p = 1). This suggests that there were no systematic differences in the experimenters' behavior. Additionally, we calculated the number of times the requesting and the non-requesting experimenters used the word "ball" in the play phase in both age groups (94% of the tapes coded for 20-month-olds in the excited condition, 87.5% for 20-month-olds in the neutral condition, 91.7% for 16-month-olds in the excited condition, and 67% for 16-month-olds in the neutral condition). There were no systematic differences in the older group of infants: *excited request,* M (requesting exp.) = 8.06, SD = 1.44; M (non-requesting) = 8.20, SD = 1.70, $t(27.26)$ = 0.23, p = 0.82; *neutral request,* M (requesting exp.) = 8.14, SD = 1.56; M (non-requesting) = 9.36, SD = 2.81, $t(20.3)$ = 1.41, p = 0.17. No systematic differences were found in the younger group *excited request* condition: M (requesting exp.) = 9.36, SD = 1.43; M (non-requesting) = 10.54, SD = 2.01,

t(18.04) = 1.58, p = 0.13. However, in the *neutral request* condition the non-requesting experimenter tended to use the word "ball" more often than the requesting experimenter: M (requesting exp.) = 10.36, SD = 1.19; M (non-requesting) = 14.63, SD = 5.29, *t*(7.7) = 2.22, p = 0.06. However, this did not affect infants' responses, as they chose the new and the old balls at chance levels. Finally, to test if cuing during the test phase occurred, the same coder analyzed 81% of rear camera recordings of the test phase (all from the older group of participants) and guessed which ball was the target. She could correctly identify the right ball on 42% of the trials which is not different from chance (Binomial test, p = 0.6). Thus, the requesting experimenter did not cue infants at the test phase.

Altogether, our results suggest that infants at 20 months, but not at 16 months, can rely on the intonation of the request to interpret ambiguous reference. Older infants were consistently selecting the new ball for the requester in the *excited request* condition, however, did not show this clear pattern in the neutral condition. This is consistent with the findings reported in previous research by Tomasello and his colleagues showing that infants understand excitement as directed at new objects (Tomasello & Haberl, 2003). Sixteen-month-old infants did not demonstrate such understanding most likely because of the cognitive load imposed by our procedure: there were 2 people coming in and out, and 2 very similar objects to choose from.

Additionally, we did not replicate the Saylor and Ganea (2007) results in the neutral condition where infants were expected to pick the old ball. This could be due to one of the two changes we've made to the Saylor and Ganea (2007) procedure. We changed the request from "Where is the ball? Can you give it to me?" which is more clearly about the old ball, to "Look at that! Can you give it to me?" which is much less clearly about the old ball even if pronounced without any excitement. Second, the buckets were brought together at the beginning of the test phase to allow the experimenter to look inside both of them simultaneously. This weakens the spatial cue that is reported to be highly important for infants in Saylor and Ganea (2007). They found that keeping the buckets in their original locations is crucial for infants' ability to identify the target ball. Despite infants' poor performance in our *neutral request* condition, the comparison between conditions suggests that infants at this age use intonation to disambiguate references.

In this experiment, both experimenters introduced their balls to infants in the play phase in an infant friendly, but neutral way. None of them was excited or showed any emotions to their

ball in the play phase. When infants saw one of the experimenters excited about something in the test phase they interpreted the request as about the new ball. In Experiment 2 we ask if infants can take into account a person's prior interaction with an object to interpret excitement as about something old. In Experiment 2 infants saw an experimenter being very excited about an object. At test, the experimenter saw a new object and another very similar to the familiar object she used to be excited about before and asked infants for one in an excited way. We were interested to see if infants could infer that the experimenter may have been asking for the familiar object again.

Experiment 2

Method

Participants

Twenty full-term, healthy 20-month-old infants with normal hearing and from English-speaking families participated (M = 20 months 8 days, range 19 months 8 days – 21 months 9 days, 12 girls).

Materials

Four objects were used for this experiment. Two were toy cars identical in shape, but of different colors (one yellow, one red), and 2 sets of toy keys that were of slightly different color and shape, but of a similar size (see pictures in Appendix B). The objects were selected such that they were equally interesting for infants and were familiar to them. Label knowledge for these objects was not required as the objects were never mentioned by names during the experiment.

A 25 X 50 cm tray was used to play with the objects during the *object introduction* phase and during the *test phase* to present the objects in front of the infant. The experiment was videotaped from the front and the back to enable coding the experimenter's behavior and the infant's behavior.

Procedure

During the experiment infants sat on the parent's lap across the table from the experimenter and the assistant. The experimenter and the assistant sat next to each other. The table was oriented such that the door was behind the experimenter. Parents were instructed not to name any objects and not to encourage infants in any way.

Object introduction phase

    1. *Experimenter's play*

        During the *object introduction* phase, once every one was seated the experimenter looked at the infant and said: "Let's see what <assistant's name"> has for us! Then the assistant took an object from under the table where neither the experimenter, nor the infant could have seen it and gave it to the experimenter. The object could be either one of the 2 cars or one of the 2 sets of keys. The experimenter took the object and exclaimed: "Wow! Look at that! What a great toy! I like it a lot!" The objects were referred to as either "a toy", "it", "this one" or "this thing". The experimenter first played with the object herself showing to the infant that she was excited about this toy. She performed a variety of actions like rolling or hiding the car under the tray, spinning the keys around the ring, sliding them down the tray of hiding them under it. The experimenter mentioned the actions she was performing: "We can roll it/hide it/spin it", etc., and said general phrases like: "Is this fun?" After having manipulated the object she gave it to the infant asking: "Do you want to play with it?" The infant and the experimenter then played with the object together for a minute. At the end of the *object introduction* phase the assistant took the object and put it away. The experimenter then said "OK, <the assistant's name> took it away! Nothing else to do… Boring…" Then she stood up and said "I need to go now! I will be back to play with you soon!" She went into the adjacent room and closed the door. She was able to watch what was going on in the experimental room through a semi-transparent window (the experimenter was not visible to the infant, but the experimenter saw the infant). Whether a car or a set of keys, and which of the two in each pair was used in this phase was counterbalanced across participants.

        The experimenter showed great excitement about the toy throughout the whole *experimenter's play* and demonstrated that she likes this object. The play phase was later coded by an independent coder who was asked to rate how excited the experimenter was during the play phase on a 4-point scale: 1 for neutral, 2 for cheerful, 3 for excited, 4 for really excited. The experimenter's excitement received the highest rating (4) 100% of the time.

    2. *Assistant's play*

        The purpose of the *assistant's play* was to introduce both test objects to the infant to keep infants from selecting the new object for the experimenter because of their own novelty reference. Once the experimenter was gone, the assistant took 2 more objects out and played

with the infant with these objects until the infant got familiar with both of them (about a minute). One of the objects was from a different category than the object used during the *experimenter's play*. The other object was similar to the one that the experimenter played with before leaving. For example, if the experimenter played with a toy car in the *experimenter's play*, in the *assistant's play* the assistant showed the infant the other car and a set of keys. The reason for using an object similar to the one used in the *experimenter's play* and not the same one was to keep the relative novelty of the 2 test objects comparable for the infants. The assistant played with the 2 objects in a neutral way and encouraged the infant to play with both objects rather than with only one of them. At the end of the *assistant's play* phase she took the objects from the infant and put them under the table on her lap. The tray stayed on the table.

Test phase

Once the objects were put away, the experimenter entered the room again and stopped behind her chair facing the infant. At this time the assistant put the 2 objects used in the *assistant's play* on the opposite sides of the tray. She kept the tray close to herself out of the infant's reach. The experimenter looked at the table in between the 2 objects (to avoid cueing infants) and exclaimed in an excited way: "<Infant' name>! Look at that! Do you see it? Can you give it to me?" While saying the last phrase she reached out with her hand for the infant to give her one object. If the infant did not pick any objects, she repeated the request. If the infant gave her both objects she asked: "Can you give me one?" The right/left position of the new and familiar objects on the tray was counterbalanced.

Coding

We coded if infants picked the new or the familiar object for the experimenter in the test phase. If they first touched one and then picked the other, their second choice was coded. If they just touched one object or looked at it, but did not pick any of the objects, we coded their first touch or look. Infants' responses were first recorded after the study by the experimenter. A coder naïve to the study hypothesis analyzed the test phase of the experiment and recorded which of the objects the infant picked. The coder and the experimenter agreed on the chosen object for 100% of the participants.

Results and Discussion

The purpose of this experiment was to test if infants can take into account the speaker's previous interactions with the object to interpret excitement as directed at something familiar. We expected that if infants watch the experimenter being excited about an object, when the experimenter sees a similar object and a new object, infants would be likely to pick an object similar to the one that she liked (we call it "familiar"), rather than a new object. The results did not confirm our predictions: 15 of them picked the new object, which is higher than chance (Binomial test, $p < 0.05$), and 5 infants picked the old object (see Figure 5). Most of the infants picked one of the objects. Three infants looked at one of the objects, but did not pick any, and 2 touched an object, but did not pick. There were no gender, object side or object type effects.
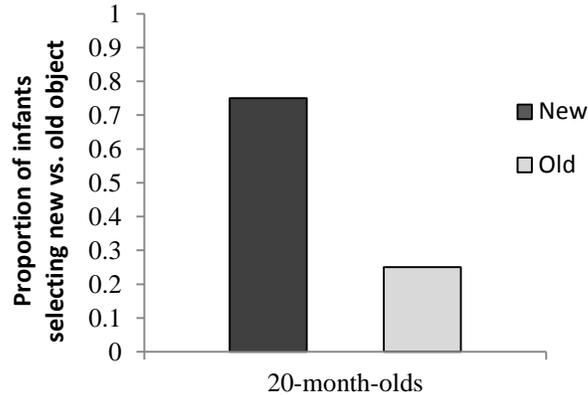

Figure 5. Proportion of infants selecting new vs. old object.

The findings from this experiment suggest that at 20 months, infants do not reliably take into consideration the nature of the speaker's previous interactions with an object to interpret excitement as referring to a familiar object. If a speaker displays excitement at an object, when a similar object and a different object are present in front of her, infants still pick the object that is new to the speaker.

General Discussion

The purpose of this study was to investigate infants' ability to use intonation of the request to interpret ambiguous reference. In Experiment 1, 20-month-old infants' selection of familiar vs. new objects was influenced by the intonation of the request. When asked ambiguously in an excited way "Look at that! Can you give it to me?" infants reliably chose the

object that was new to the experimenter. When asked in a neutral way infants were not sure which of the two possible referents the researcher meant. Younger, 16-month-old infants did not reliably use the speaker's intonation to guess which of the 2 objects she was asking about.

In Experiment 2, 20-month-old infants interpreted the speaker's excited request as about a new object and disregarded the fact that she previously used be very excited about the familiar object. Thus, at 20 months, infants very robustly interpret excitement as directed at something new, and this understanding does not change as a function of a person's previous interactions with a familiar object. This shows that infants' resolution of ambiguous references is quite limited by their own understanding of what's interesting and by some heuristics developed across observations of typical human behavior and preferences. Another possibility though is that exposure to only one object during the *experimenter's play* was not enough for infants to understand that the experimenter likes the whole category of such things. It could be that during the test phase it was too difficult for them to generalize the experimenter's preference to another token of the given category and infer that she was asking about that kind of stuff again rather than about a new object.

An important question frequently asked about the knowledge infants demonstrate is at what level they pass the experimental tasks. They can rely on low-level attentional and memory processes or on higher level social and conceptual knowledge. Infants' ability to track other' experiences and goals to interpret ambiguous requests for objects can be supported by two different processes. According to Tomasello and his colleagues, young infants are capable of understanding others as intentional agents and interpret others' behavior in terms of mental states and desires (Tomasello, 2000; Tomasello & Farrar, 1986). When interpreting ambiguous requests for object infants may reason about the speaker's communicative intent to refer to one of several objects, and engage in perspective-taking to decide which one she wants. However, it is also possible that infants interpret ambiguous requests based on low level attentional and associationistic processes. For example, they can choose the ball that the experimenter previously played with because the experimenter's presence activates the representation of one of the balls, and this representation is stronger at the time of the request than the representation of the other ball. At the same time, in Tomasello & Haberl, 2003; Moll, Carpenter & Tomasello, 2007) infants may have been choosing the object that was new to the requester because this object was treated differently comparing to other objects on the tray (Samuelson & Smith, 1998).

It was introduced in a special context: one of the experimenters left the room before it was shown to the infants.

Reasoning at a higher level of others' mental states and desires presupposes that infants consider all possible referents and think about the speaker's intention to refer to one of them. In the current study 20-month-old infants' selection of the new ball in the *excited request* condition is difficult to explain by low-level attentional and associationistic processes. If they acted based on the existing association between the requesting experimenter and one of the balls they would have selected the old ball in both conditions. Almost all infants selected the new ball in the *excited* condition which suggests that they must have considered both potential referents and took into account the speaker's desire to play with a particular one – the one that she had not yet explored. At the same time, younger infants' failure to reliably pick the new ball in the excited condition does not have to be due to their inability to consider all possible referents and rely on the speaker's communicative intent to pick one. It could be due to the overall cognitive load of the procedure which made it difficult for them to pass the task.

Overall, this research shows that between 16 and 20 months there is a significant improvement in infants' ability to interpret ambiguous reference. At 20 months, infants are able to consider multiple objects as potential referents and to rely on the intonation of the request to infer which one the speaker has in mind. By doing so, infants display their sensitivity to the social component of linguistic interaction, their ability to take the perspective of the speaker and to infer her intention behind the words.

CHAPTER IV

GENERAL CONCLUSION

The purpose of the current two studies was to investigate infants' access to and their use of two sources of information when establishing common ground with the speaker. In study 1, I investigated infants' access to shared linguistic evidence through understanding words as category labels. In study 2, I investigated infants' access to shared perceptual evidence and their ability to use speaker's intonation during a request to identify referents.

The findings from Study 1 suggest that infants as young as 16-months understand words as category labels. When presented with a reference to an absent object infants had an expectation to see one of many possible objects from the mentioned category rather than one particular object they initially learned the name for. On target trials, infants accepted objects as the correct referents although they had never seen those objects before, and such objects were not the ones that infants initially learned the names for. Such behavior must have been based on infants' long-term knowledge of how typical referents of the mentioned words look like and based on their understanding that object names most often function as category labels. This suggests that infants' understanding of absent reference does not require bringing to mind a particular recently seen object in its specific location. At 16-20 months infants' understanding is rather general and they can consider a group of similar objects belonging to the mentioned category as a set of potential referents.

At the same time, in this study infants did not accept unrelated objects as the correct referents on distractor trials. In both age groups infants assumed there must have been a different object inside and reached back into the box in an attempt to find one. Infants could have done this only if they recognized the mismatch between the object found in the box and what the experimenter asked them to find. This suggests that infants' memory for the label was strong enough for them to remember the experimenter's reference while reaching for an object in the box and still hold it in mind while exploring the retrieved object. Infants' inference that there must have been a different object in the box and their attempt to find one also suggests that they understand the intentional component of a linguistic reference. Likely, they interpreted the experimenter's reference as an invitation to join attention on an object from the specified

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category, and not on any kind of object. This also suggests that infants' knowledge of words is precise enough for them to recognize that distractor objects do not belong to the set of objects that are from the mentioned category.

Study 1 findings suggest that infants may also be able to recognize that some objects are categorically closer to each other than other objects. Younger, 16-month-old infants, had difficulty rejecting distractor objects that were from the same superordinate category as the mentioned targets. For example, when asked find a shoe (banana, bottle, etc.) they did not reach back for another object after having found a related object like a sock (apple, cup, etc.) Infants at this age may not have clear category boundaries and may overgeneralize certain common nouns to tokens of proximal categories. However, this effect may be limited to situations when referents are absent. Infants may be well able to tell the difference between categorically related objects like cups and bottles, shoes and socks, apples and bananas in referent-present situations, because in such situations working memory demands are smaller than in referent-absent situations. Older, 20-month-old infants were able to reject categorically related objects as incorrect ones and reached again into the box for another object. This suggests that at this age infants are more advanced in their object category knowledge and word comprehension than at 16 months. They no longer generalize common nouns to tokens of related categories.

Study 1 findings also suggest that at 20 months infants have difficulty rejecting distractor objects that look similar to the mentioned targets. Twenty-month-old infants did not consistently reach back on distractor trials after having found objects that matched typical tokens of the mentioned categories by color and shape. This could have happened for one of 2 reasons: infants did not realize that the distractor objects were actually wrong, or they realized they were not the correct referents, but accepted them as "pretend" referents. Exploratory analysis of infants' behavior may suggest that the first reason is more likely: the actions that infants sometimes produced on distractor objects (e.g., bouncing the apple, or biting the ball) revealed that they misinterpreted the objects' category membership. Additionally, they sometimes mislabeled distractor objects. No matter which explanation is right, infants must activate perceptual features associated with typical tokens of the mentioned categories for this effect to be observed.

A question that remains unanswered in Study 1 is whether infants' search for hidden objects was guided by a mental representation associated with the mentioned category of objects or infants' behavior was solely based on visual recognition of objects when they were present. It

is possible that infants initially reached into the box simply in response to the experimenter's request to find an object and because they were trained to do this during the familiarization phase. They did not have a specific idea about what to search for in order to reach in the box. After having retrieved an object they could have decided if it was the right or a wrong object just by matching the experimenter's label that was still in their memory with their recognition of that object. Additionally, on distractor trials infants' reaching back for another object could have been guided by detecting a mismatch, and not by activating a representation associated with the experimenter's label. Future research should address this question by using a different paradigm that would allow manipulating infants' lexically derived mental representations and their visual object recognition.

Study 2 findings suggest that infants starting at 20 months are able to keep track of people's experiences with objects, and also can take into account the intonation of an ambiguous request to infer if a new or a familiar object is the intended referent. When an experimenter asked them ambiguously in a very excited way about one of the two balls that were present at the moment "Can you give it to me?" infants were able to interpret this ambiguous request as about the ball that was new to the experimenter. Younger, 16-month-old infants were not able to make such inference. When the request was made in a neutral way, infants at both ages failed to reliably infer that an old ball was meant.

Older infants' reliable selection of the new ball in the *excited request* condition suggests that at this age they are able to remember which person was familiar with which object. This finding is consistent with other research showing that infants at this age have access to the information about shared perceptual evidence. However, in previous research infants responded to ambiguous requests by selecting the new object for the researcher in some studies (Tomasello & Haberl, 2003; Moll, Carpenter & Tomasello, 2007), and selecting the old one in other studies (Liebal, Carpenter & Tomasello, 2010; Saylor & Ganea, 2007). The current research suggests that this discrepancy is likely due to infants' ability to rely on the intonation of the person's ambiguous request during reference resolution. Infants understand the difference between neutral and excited intonation. They consistently interpret excitement as directed at new objects, while the absence of excitement, or neutral intonation, does not by itself serve as a good clue for them that an old object is desired. Study 2 findings also demonstrate that infants generalize their

understanding of excitement as linked to seeing new objects to situations where the experimenter previously showed that the old object was highly desirable.

Study 2 findings also add to the existing debate about the level of reasoning infants engage in when dealing with ambiguous reference. On one hand, young infants may understand others as intentional agents and interpret others' behavior in terms of mental states and desires (Tomasello, 2000; Tomasello & Farrar, 1986) and use this knowledge in reference resolution. On the other hand, infants may just rely on associationistic and attentional processes to interpret ambiguous requests. They may be simply picking the object that was previously brought out by being introduced in a special context (see Samuelson & Smith, 1998, a response to Akhtar, Carpenter & Tomasello, 1996), or they may be going with the object that is most strongly associated with the requesting experimenter (Saylor & Ganea, 2007). Low-level associationistic and attentional accounts presuppose that infants think about only one object that is most salient during the test situation, and not consider all potential referents. This helps them reduce the ambiguity of the situation and thus allows them to pass the task. In the current research, both balls were introduced under the same circumstances. Additionally, infants could not have relied on their existing memory association between the requesting experimenter and one of the balls to pick the right ball in the *excited request* condition. They had to consider both referents and make an inference about which of the two balls the researcher was asking them about. By picking the new ball, 20-month-old infants demonstrated their ability to take the perspective of the speaker and deal with an ambiguous reference by relying on their understanding of people, of their preferences and desires.

One question that remains unanswered in Study 2 is why 16-month-old infants failed to change their selection of the new or the familiar balls depending on the intonation of the request. Previous research has shown that infants are able to keep track of other's experiences with objects from 12 months (Saylor, Ganea & Vazquez, 2011), and that they understand excitement as about new things before 16 months (Tomasello & Haberl, 2003). Sixteen-month-olds' failure to infer which ball the experimenter meant in the current experiment could be explained by several possibilities. They may not be able to consider multiple referents at the same time and rely on their understanding of intonation as a cue to the requester's preference, while in previous reference resolution tasks infants might have used low-level strategies to identify the correct referent. It is also possible that the current task was not manageable for infants of this age

because of the required working memory load. They had to keep track of two people and two objects at the same time, while the spatial cue that was found to be very important in Saylor and Ganea (2007) was removed. Without this assistance infants might have simply lost track of which ball was familiar to the requester. Therefore, future research should investigate younger infants' use of intonation in reference resolution using more sensitive methods, or simpler procedures (for example, preferential looking or sequential touch procedures).

Overall, across the two studies presented here it appears that infants between 16 and 20 months of age move away from the simple associative nature of word comprehension to rely more on cognitively and socially sophisticated strategies in referential understanding. At 16 months and older, infants are able to understand absent reference in a general categorical way, and their understanding is not limited to a particular object in its specific location. Between 16 and 20 months are increasingly able to use their knowledge of objects and category labels to understand absent reference. By 20 months of age infants are also sensitive to the social component of linguistic interaction. When dealing with ambiguous reference situations they appear to be responsive to the speaker's intention to refer to a particular object out of several possible ones, and they rely on the speaker's intonation to read this intention. In general, infants' representation of meaning is based on their knowledge of object categories, and their ability to identify the right referent among several possibilities is based on their understanding of people and their intentions.

Chapter II: Frequencies of objects used as targets and distractors
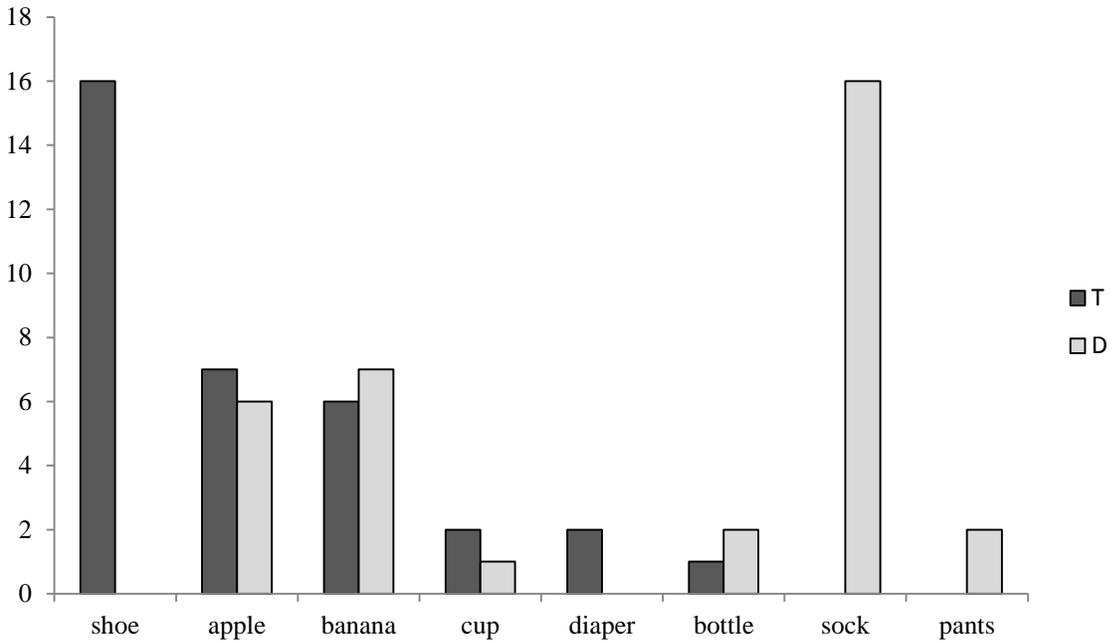by age group and Experiment

A1. Chapter II, Experiment 1: Frequency of items by trial type in the 20-month-old group (distractor objects were never mentioned by the experimenter).
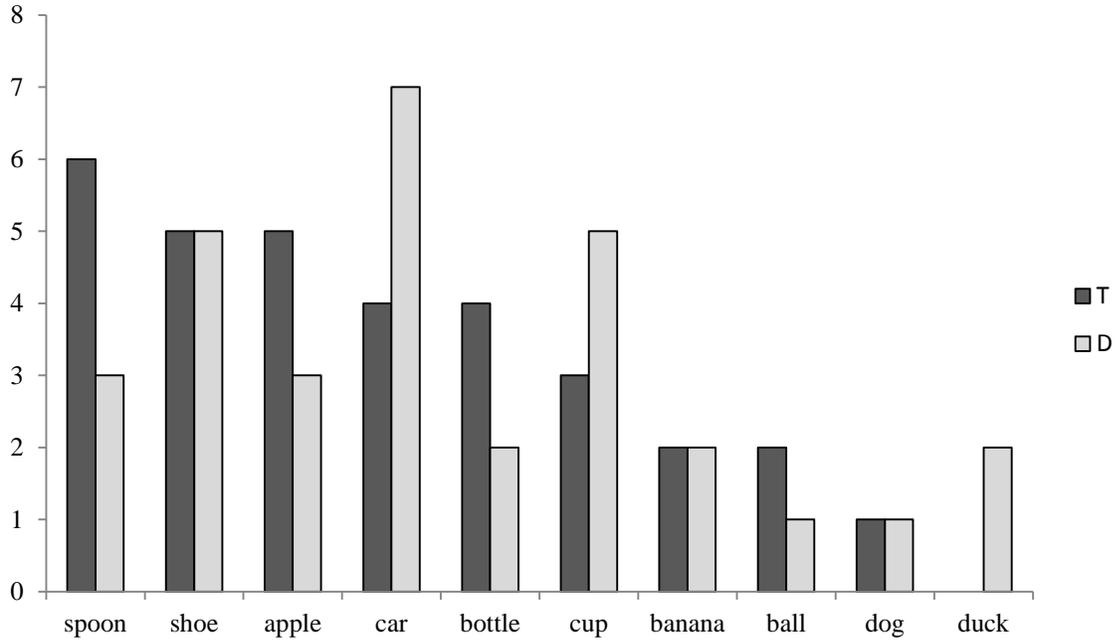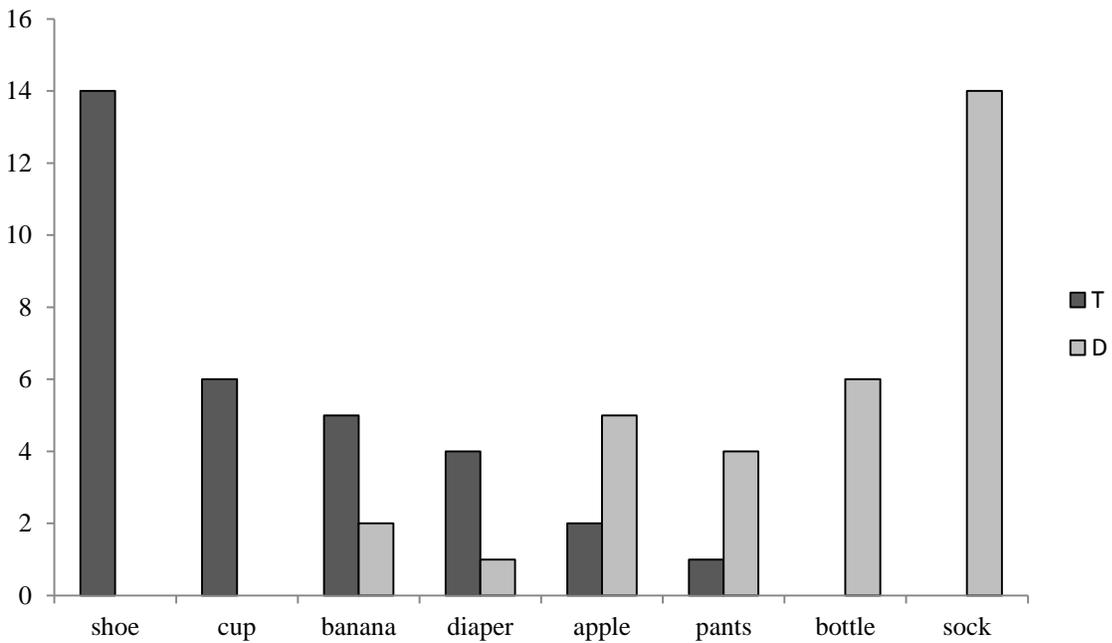

A2. Chapter II, Experiment 1: Frequency of items by trial type in the 16-month-old group (distractor objects were never mentioned by the experimenter)
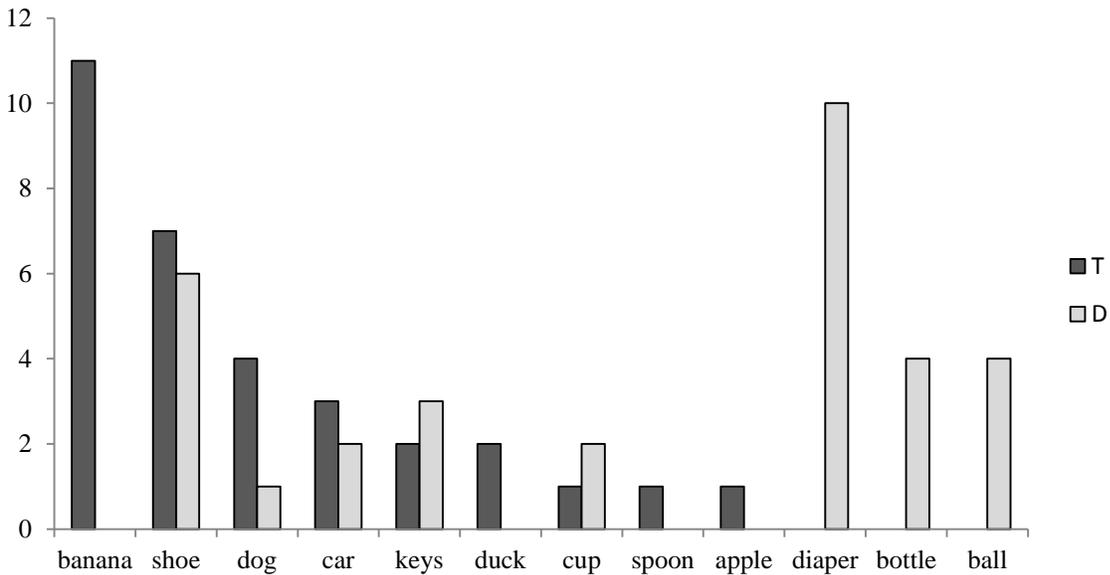
A3. Chapter II, Experiment 2: Frequency of items by trial type in the 20-month-old group (distractor objects were never mentioned by the experimenter).

A4. Chapter II, Experiment 2: Frequency of items by trial type in the 16-month-old group (distractor objects were never mentioned by the experimenter).

A5. Chapter II, Experiment 3: Frequency of items by trial type in the 20-month-old group (distractor objects were never mentioned by the experimenter).
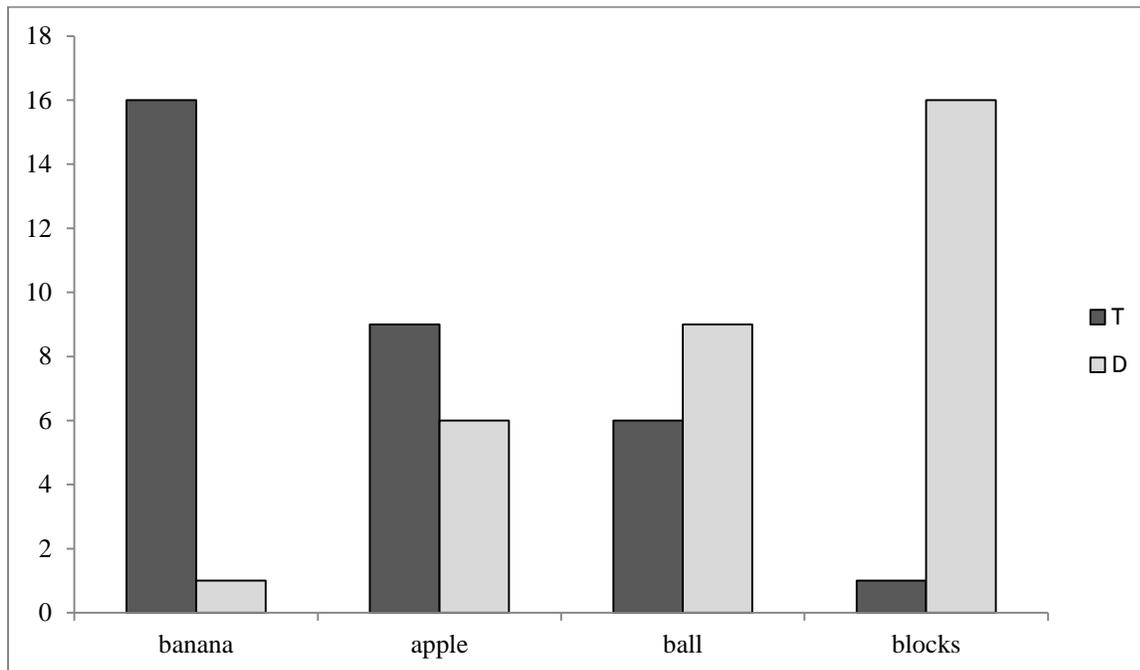
Chapter II, Experiments 2 and 3, Chapter III, Experiment 2: Pictures of stimuli

B1. Stimuli used in Chapter II, Experiment 2 "Categorically related distractors"

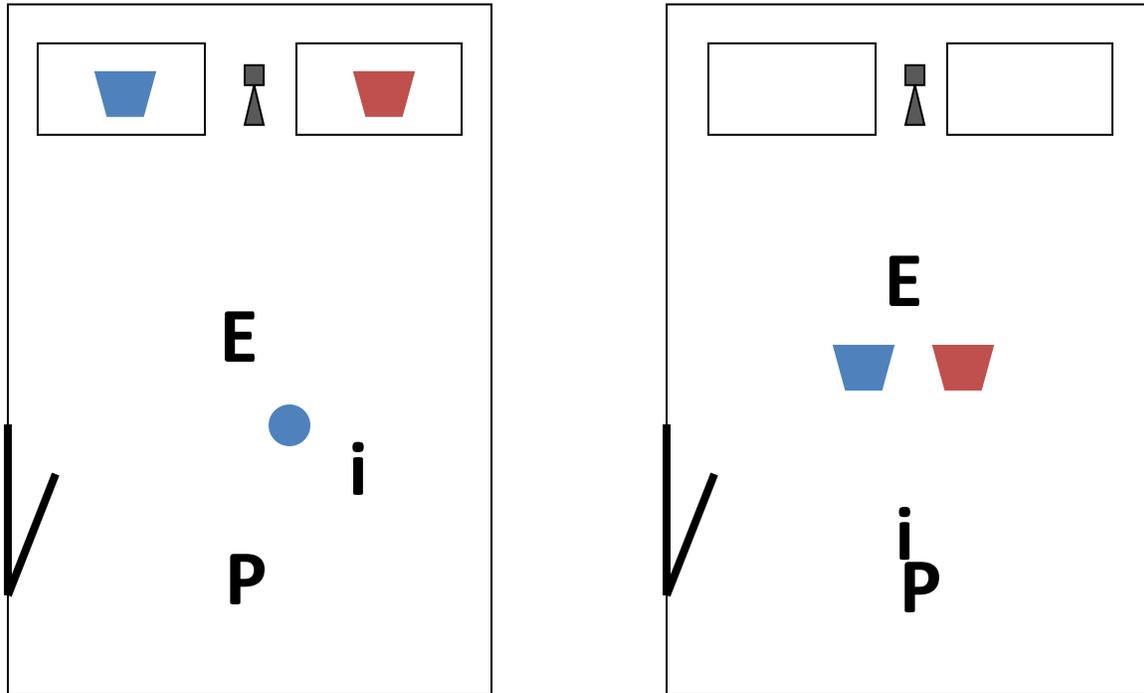**B2.** Stimuli used in Chapter II, Experiment 3 "Perceptually similar distractors"

B3. Stimuli used in Chapter III, Experiment 2

APPENDIX C

Chapter III, Experiment 1: Room setup

C1. Chapter III, Experiment 1: Room setup (ball introduction and test). E = experimenter, P = parent, i = infants.

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