# Infants' Ability to Use a Nonhuman Speaker's Gaze to Establish Word-Reference

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# ABSTRACT

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By 18 months of age, infants can link a novel word with the target of a speaker's gaze, suggesting that they are sensitive to the speakers' referential intentions. Adopting a procedure developed with human speakers, infants' ability to follow and use a nonhuman agent's gaze when learning new words was examined. A programmable robot acted as the speaker (Experiment 1). Infants followed its gaze toward the word referent whether or not it coincided with their own focus of attention but failed to learn a new word in either case. Infants correctly mapped words in both cases when the speaker was human (Experiment 2). While having eyes appears sufficient to elicit gaze-following in 18-month-olds, it does not suffice for the attribution of referential intentions.

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Infants' Ability to Use a Nonhuman Speaker's Gaze to Establish Word-Reference

Language acquisition comes both quickly and effortlessly to children. By only 10-12 months of age, infants reach a major milestone in language development, receptivity of language and word understanding (Golinkoff & Hirsh-Pasek, 2006). Infants begin to produce words soon after, compiling a vocabulary of near 10,000 words between the age of 18-months to five years, averaging at the amazing rate of seven to nine new words per day (Carey, 1978; Sabbagh, Henderson, & Baldwin, 2007). Despite this rapid rate of acquisition, the challenges of correctly mapping a novel label onto its referent are enormous. Firstly, there exists an abundance of objects and events in the world, many of which have multiple labels. Furthermore, infants must surmount the hurdle of determining what exactly a new label should be linked with. Quine (1960) was the first to depict this challenge as the basic problem of referential indeterminacy, bringing to light a question which elicited an eruption of empirical studies aiming to uncover its answer. How does a child decide upon attaching the word *car* to the vehicle parked in the driveway, as opposed to its vibrant red colour, its shape, or even the person sitting in the front seat?

Several major theories have been proposed to account for this conundrum, each suggesting different strategies by which infants approach the word learning challenge (Hirsh-Pasek, Golinkoff, Hennon, & Maguire, 2004). The constraints theory maintains that when confronted with new words, infants use a set of assumptions and principles to determine the appropriate referent, some of which are considered before others. For example, infants will often associate a novel word with a whole object, rather than its individual parts (Markman, 1989). Other researchers claim that rather than entertaining hypotheses, infants simply link frequently used labels with what is most salient in the environment, thus reducing word learning to word-object associations (Smith, 2000). Lastly, social theorists argue that contiguity alone is insufficient for the formation of new word mappings. Instead, they hold that infants seek out information indicating the object to which the speaker is referring. More specifically, infants are sensitive to a speaker's social cues, such as pointing and gaze direction and use this information in order to understand the speaker's intentions (Atkhar, Dunham, & Dunham, 1991; Baldwin, 1993; Graham, Nilsen, & Nayer, 2007; Tomasello, 2001). Whether infants understand the act of seeing when they follow adults' gaze toward an object in the environment, however, is hotly debated. Proponents of the rich interpretation suggest this to be the case (Baron-Cohen, 1995; Bretherton, 1991; Caron, Kiel, Dayton, & Butler, 2002; Carpenter, Nagell, & Tomasello, 1998). In contrast, supporters of a leaner account suggest that infant's attention is drawn to a location due to an automatic orienting response or as a result of conditioning (Langton, Watt, & Bruce, 2000; Moore, 1999; Moore & Corkum, 1994; Povinelli, 2001).

An ideal scenario for word learning involves an adult producing a new word at a time when the infant is currently attending to the desired referent. In fact, mothers in Western cultures will often follow the line of regard of their child or will point to an object so as to facilitate joint reference between themselves and their child (Baldwin, 1991). For instance, in a study conducted by Harris, Jones, and Grant (1983), 70% of mothers' utterances referred to those objects to which their 6- to 10-month-old child was already attending. However, labels are often produced when their specific referent is absent or when a child is focused on something other than the object an adult is referring to (Baldwin, 1991, 1993; Baldwin et al., 1996). For this reason, infants must attend to cues other than temporal contiguity alone; otherwise infants would often make mapping errors.

The extent to which infants adhere to only one of these theories when learning new words, has been addressed in the literature. The emergentist coalition model (ECM) proposes the fusion of the aforementioned theories, suggesting that infants differentially attend to perceptual (object salience, contiguity), social (eye-gaze, pointing, and handling of objects), and linguistic (grammar) cues over the course of their development. In fact, recent research undertaken by Hollich et al., (2000) and Pruden, Hirsh-Pasek, Golinkoff, and Hennon (2006) provide initial support for this perspective. At the early age of 10 months, infants were found to rely entirely on perceptual cues when making word mappings, associating new words with those objects they found most interesting (Pruden et al., 2006). However, only two months later, infants recruit social cues when learning new words, yet continue to rely on perceptual indicators as well (Pruden at al., 2006). In fact, by age 13 months, Woodward (2004) reported that infants searched for behavioral evidence from the experimenters as a means of informing them of the referent of a new word. The use of social cues becomes even stronger at 19 months of age, with infants' reliance on perceptual cues lessening gradually (Golinkoff & Hirsh-Pasek, 2006). Only at age 24 months do infants complete the shift from perceptually-dependent to socially-dependent word-learners (Hollich et al., 2000). By using social indicators, infants are less likely to erroneously associate new words with inappropriate objects, thus enabling them to become more sophisticated word learners.

Consistent with the notion that social cues are increasingly attended to over the second year of life, empirical evidence exists showing that infants actively consult a speakers' gaze direction to determine the correct referent of a new word. Baldwin (1993) presented 14- to 19-month-old infants with a novel word in two conditions. In the 'follow-in' condition, the novel label was produced while the speaker was looking at a novel toy on which the child was also focused. By contrast, in the 'discrepant' condition, the speaker uttered the novel label while looking at a toy just as the child was focused on a different toy. Infants aged 14 and 15 months failed to make word mappings in either condition, perhaps resulting from the demanding acoustic and memory components involved in the task. In contrast, the 16-month-olds made proper word mappings only in the follow-in, but not in the discrepant condition. Nonetheless, infants 16 months of age successfully avoided mapping errors in the latter condition, suggesting that they were aware of their discrepancy of gaze. However, at 18 months of age and older, infants consistently linked the novel word with the object that the experimenter was attending to when she uttered the label, in both conditions.

In a follow-up study, Baldwin and her colleagues (1996) examined infants' ability to make correct word mappings in a more stringent situation. That is, while 18- to 20-month-olds were focused on their own novel toy, they heard a novel label uttered by an experimenter seated next to the child, or seated behind a rice-paper screen. Although infants learned the words when they were spoken in the presence of the experimenter, they failed to do so when the experimenter was out of sight, providing further evidence for infants' sensitivity to gaze direction in word learning situations (Baldwin et al., 1996). Moreover, recent work undertaken by Akhtar, Jipson, and Callanan (2001) demonstrated that 2-year-old infants engage in such gaze-seeking behavior even in situations where the child is not the intended listener of a novel label. For instance, when overhearing an adult label a novel object to another adult, infants search for the speaker's direction of gaze to infer the speaker's intended referent.

However, gaze-following tendencies need not be indicative of children's understanding of mentalistic agent, or intentionality of the speaker. Interestingly, a dissociation between gaze-following and the attribution of referential intentions has been observed in autistic populations. Baron-Cohen, Baldwin, and Crowson (1997) applied the methodology of Baldwin's (1993) original word learning task, to a study involving 9-year-old children with autism. A key deficit found in autistic children is their lessened ability to formulate a theory of mind (ToM), the understanding that others have mental states different from one's own. Unlike normally developing children engaging in the word learning task, Baron-Cohen and colleagues (1997) reported that autistic children were unable to establish correct word mappings in either the follow-in or discrepant condition, which the authors attributed to the autistic children's failure to use the speaker's eye-gaze. As such, it may be that due to their difficulty in comprehending the mentality of others, these children lack the understanding of the mental significance of direction of gaze. An autistic child's failure to engage in joint attention with another seems to inhibit their ability to learn new words correctly. The research on normally developing as well as autistic children suggests that the formers' early word learning may be guided by their sensitivity to speakers' referential intentions. That is, infants understand that individuals have the intention to refer to particular objects when uttering words. As a means of determining the appropriate referent, infants pay particular attention to a cluster of social cues (head orientation, voice direction, body posture) collectively referred to as gaze direction (Sabbagh et al., 2007).

If eye-gaze is a critical cue used by infants to establish word reference, perhaps it is sufficient for infants to infer referential intentions to any speaking agent with eyes. Infants' attributions of intentions to a nonhuman agent has been widely examined using devices with human properties such as morphological features, self-propulsion, and the ability to engage contingently and reciprocally with another person (Johnson, 2000). For instance, Johnson, Slaughter, and Carey (1998) examined infants' gaze-following tendencies to a nonhuman agent by presenting 12- to 15-month-olds with a novel object with or without a face and that acted contingently (beeping and flashing lights) or non-contingently (silent and motionless) with an experimenter. Infants followed the gaze of the object when its actions were contingent with the experimenter or when it possessed a face. In a recent study, Arita, Hiraki, Kanda, and Ishiguro (2004) examined 10-month-olds' understanding of intentionality of nonhuman agents, and found that infants were less surprised to see a subsequent interaction between a human and a humanoid robot after having witnessed a contingent interaction between the two. The authors interpreted this finding to suggest that the infants attributed intentionality to the previously contingent robot. Self-propulsion and morphology alone were insufficient to elicit such attributions. Similarly, 12-month-old infants consider the behavior of a green ambiguous object as goal-directed after viewing it move independently and beep in response to an experimenter, but not when this previous interaction was absent (Shimizu & Johnson, 2004). Taken together, these researchers concluded that infants over attribute intentions to nonhuman agents, especially when such agents are found to interact with another human.

To date, research on infants' concept of mentalistic or intentional agent has focused on the attribution of object-directed behavior and gaze-following in very young infants. However, a few studies have also examined infants' concept of agent at a later age and on more advanced mind-reading skills, such as desire and intention. In one study, Meltzoff (1995) uncovered that at 18 months of age, infants who witness a human experimenter fail to complete a target action, will infer the intended goal of the experimenter and reenact the unseen target action. Infants at this age, however, fail to do so after viewing a self-propelled, mechanical pincer attempt these same actions. Nonetheless, under this same procedure involving an autonomous, contingent nonhuman agent possessing morphological features (a stuffed orangutan toy), 15-month-olds do, in fact, reproduce the agent's intended goal (Johnson, Booth, & O'Hearn, 2001). On the one hand, the presence of human-like features may have enhanced infants' tendency to attribute mental states to a nonhuman agent. On the other hand, it is also possible that, infants' concept of intentional agent might narrow and become more refined with age. That is, by 18 months of age, infants may have acquired a clear understanding that human, but not nonhuman, agents are capable of desires, intentions, goals, and so forth. Before these developmental questions can be clearly addressed, it is of interest to contrast infants' tendency to make attributions of intent on the basis of gaze-following behavior exhibited by different agents under controlled conditions.

The main goal of the current study was to investigate 18-month-olds' concept of mentalistic agent by addressing communicative intentions. Previous research reveals that

18-month-old infants actively seek a speaker's gaze to learn the association between a novel label and its referent (Baldwin, 1993) and at age 12 months will follow the gaze of a nonhuman agent (Johnson et al., 1998). In light of these findings, the current study examined, for the first time, young children's ability to learn a new word by following the gaze of a nonhuman agent (i.e., a robot).

Eighteen-month-old infants were exposed to both a coordinated (follow-in) and discrepant condition of a modified version of Baldwin's (1993) procedure. In Experiment 1, the speaker was a small robot which labeled novel objects, and infants' comprehension of the novel labels was tested with a human experimenter. In Experiment 2, using the same procedure, labels were uttered by a human speaker, while a second experimenter was present to test infants' comprehension of the novel words.

## Experiment 1

### *Method*

#### *Participants*

Twenty-nine infants aged 18 months participated in the current study. Three infants were excluded due to fussiness, resulting in a final sample of 26 participants (mean age=18.63 months, range=17.95 to 19.75 months, SD=0.46), males and females being equally represented. Infants' contact information was obtained through birth lists provided by a governmental health services office (see Appendix A for Recruitment Letter). All infants were born full term and had had no major health complications as reported by the parents. The children belonged to families speaking either French or English at home. Of the 26 infants included in the final sample, 9 were exposed to only French at home, 7 to English, and 10 belonged to a multilingual household (combination of English and/or French with Spanish, Italian, Chinese, or Arabic). The range of presenting languages was not expected to influence the results of the current study as all infants were tested in their dominant language.

*Materials*

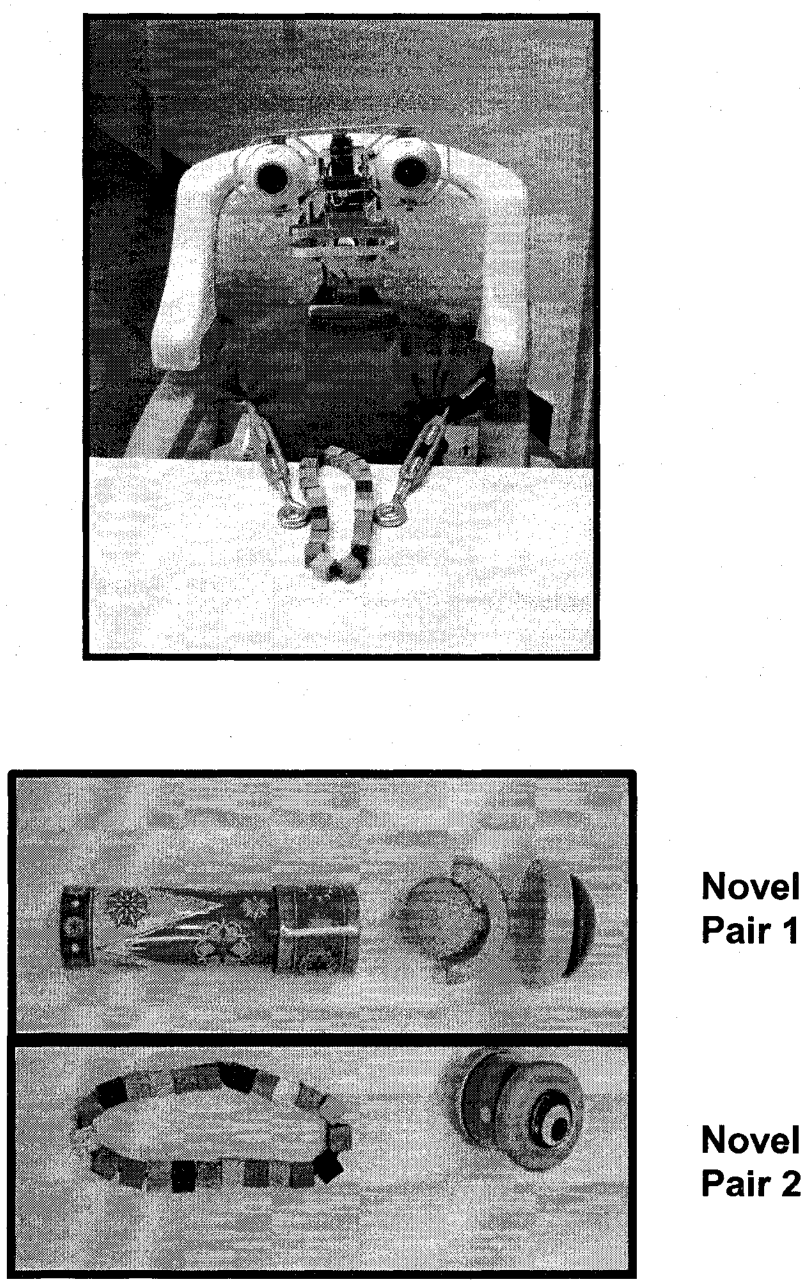
All infants saw three pairs of familiar objects. A list of 18 familiar items was presented to the parents prior to testing, consisting of: *airplane, rabbit, bird, cat, doll, ball, sock, duck, car, shoe, spoon, flower, bottle, dog, banana, boat, cup, and keys*. Parents indicated which words their child understood, six of which were selected by the experimenter to use for testing.

Infants were also presented with two pairs of novel objects during testing, as shown in Figure 1. The first novel toy pair was comprised of a colourful kaleidoscope and a wooden "nut-bolt" toy, while the second pair consisted of a blue cylindrical rattle and coloured wooden beads on a string. Novel toys were selected based on their novelty, attractiveness, manipulability, visual distinctiveness from one another, as well as equivalence in saliency.

Infants heard two novel labels during testing: *fep* and *dax.* These words adhere to the phonological rules of both French and English languages and were chosen based on their novelty and ease of pronunciation for infants, as well as their distinctiveness from one another and from the familiar word items. The assignment of the novel words to the four novel objects was counterbalanced across infants.

A programmable robot (Model DRK8000, Dr. Robot Inc.) was used as the nonhuman speaker (see Figure 1). The robot stood 46 cm tall and had two wheels on its base allowing it to move around. It wore a red shirt, had fixed arms, and spoke with a human voice. The experimenter controlled the head movements and speech of the robot using a laptop computer. Three video cameras and a Hi-8 video cassette recorder were used to record the testing sessions.

*Figure 1.* Picture of robot and novel toy pairs



*Procedure and Design*

Each infant participated in two conditions: *coordinated labeling (follow-in)* and *discrepant labeling*. Both conditions consisted of a *training phase* and a *testing phase.* During training, a novel label was repeated four times by the nonhuman speaker, at a time when the infant was attending to a novel toy previously given to him/her by the experimenter. In the coordinated labeling condition, the robot uttered the novel label when both child and robot were focused on the same novel toy (the child's toy). In contrast, during the discrepant labeling condition, the novel label was produced when the child and robot were each focused on a different toy.

In each condition, the training phase was immediately followed by a testing phase. To determine whether infants had correctly associated the novel word with its referent, a female experimenter presented infants with the novel toy pair and asked comprehension questions (i.e., "Where is the *dax*?") on four trials per word. Infants' understanding of familiar words was also examined to ensure their understanding of the experimental task and to serve as a motivator. The same familiar toy pair was presented to the infants four times in each condition. Questions regarding novel words alternated with familiar word questions, for a total of eight comprehension questions per condition.

The order of conditions, assignment of toy pairs, and labels for novel toys was counterbalanced across infants. More specifically, half of the infants were first exposed to the coordinated condition followed by the discrepant condition, while the other half was exposed to the conditions in reverse order. The order in which infants were presented with the novel toy pairs also alternated, such that half viewed the kaleidoscope and 'nut-bolt' toy in the first condition and then the rattle and cubes in the second condition. The other half of the infants were presented with the toys in the opposite order. The labels assigned to the target toy in each condition alternated as well. That is, half of the children heard the word *dax* and then *fep* in the first and second conditions, respectively. In contrast, the other half of the infants heard the word *fep* in the first condition and then *dax* in the second. Each novel toy was selected as the target toy equally often over the course of the experiment. Finally, during testing, the target toys (novel and familiar) were positioned equally often on the right and left sides during comprehension testing.

Families were greeted and shown to a reception room, where parents completed several forms: a consent form, a demographic form, and the familiar words checklist (see Appendix B, Appendix C, and Appendix D). During this time, the two experimenters played with the infant, allowing him/her to become comfortable with them. Next, infants were guided into the adjacent testing room where they were instructed to sit with their parent on a small stool positioned in front of the robot. While one of the experimenters surreptitiously controlled the robot's movements using a laptop computer hidden underneath the testing table at the opposite end of the room, the other experimenter sat on the floor near the robot and directed the child's attention to it. During this *familiarization phase*, the robot turned its head from side to side, moved back and forth, and said 'hello' and 'oooh'.

After the familiarization period with the robot, the first experimenter distracted the child with a toy, while the second experimenter moved the robot to the testing table. Careful measures were taken to ensure that infants did not see the robot being moved in order to avoid biasing infants' perceptions of the robot's animacy. During the testing phase, children either sat in a high chair attached to the testing table with their parent seated directly behind, or on their parent's lap. The first experimenter sat directly across the table from the child, while the robot was placed in another high chair to the left of the first experimenter.

Testing began with a *warm-up phase* whereby the experimenter produced a blue box holding two familiar items and shook it while placing it on the table in front of her. She then asked the child to identify one of the objects ("Where is the *car*? Can you find the *car*?") and pushed the box in front of the child. The experimenter applauded correct selections and corrected wrong choices. Infants who did not make any selection were prompted and ultimately shown the correct toy, by the experimenter, in the case that they continued not to respond.

*Coordinated condition.* The *training phase* began when the experimenter placed a box on the table, removed two novel toys from it, and placed them on the table out of the child's reach. She then demonstrated how to manipulate the toys, three times each, and gave them to the child to explore. Once the child had examined both toys and was focused on the novel toy pre-designated as his/her own, the experimenter removed the other novel toy, placing it on the table between the robot's hands. When the child was attending to his/her own toy, the experimenter initiated labeling by the robot using the laptop computer concealed under the table. The robot then turned its head to look at the child's toy while simultaneously uttering a novel label ("It's a *dax*!"). This was repeated four times, each time the experimenter initiated labeling while the child was attending to his/her own toy. At the time that the robot labeled the toy, the experimenter looked down so as to avoid eye contact with the child. The was done to avoid the possibility of the child mistakenly believing the experimenter to have produced the label, and in turn following the experimenter's, rather than the robot's, gaze. After the fourth label, the robot's toy was returned to the infant to allow him/her the opportunity to explore both toys again for a maximum of 60 seconds. Both novel toys were then taken away from the child.

The training phase was immediately followed by a *testing phase.* Using the same novel toy pair and one familiar toy pair, infants' comprehension of novel and familiar labels was tested. The experimenter placed two toys, either familiar or novel, on a tray and positioned them on the table in front of her. She then encouraged the child to select a predetermined target toy by asking, "Where is the ____? Can you find the ____?", then pushed the tray toward the child. The experimenter looked directly at the child to avoid biasing his/her selection. Regardless of the infant's choice, the experimenter asked, "Did you find it?" in a neutral tone. The toys were retrieved and the experimenter began the next trial. In alternating order, infants were asked four novel and four familiar toy questions, resulting in a total of eight trials. Infants who selected both toys simultaneously, or who did not respond at all, were prompted once on each trial ("Can you give me the ___? Give Mommy the ___?"). Testing was discontinued if the child failed to respond on four trials in succession. This occurred with only three infants, each of whom was excluded from the analyses.

*Discrepant condition.* The discrepant *training phase* proceeded in the same manner as the coordinated condition with the exception that during labeling the robot was programmed to look down at its own toy, rather than at the child's. Additionally, a different novel toy pair and another novel label were used. The *testing phase* mirrored that of the coordinated condition, involving the novel toy pair used during training and a different familiar toy pair.

Testing was conducted in either English or French, depending upon the child's mother-tongue or, in the case of bilingual children, the language that infants were most familiar with. At the end of each session, parents received a vocabulary checklist, the MacArthur Communicative Development Inventory (MDCI), to complete at home, along with a pre-stamped and pre-addressed envelope.

*Coding*

Infants' behavior was coded in terms of where they were looking during the training phase. More specifically, infants' looking direction was coded at the moment the novel label was uttered as well as the following two looks. Therefore, the first three looks upon hearing the novel label were recorded (see Appendix E). Of importance was where infants were looking as labeling was initiated, if this look was succeeded by a look to the robot, and whether they followed the robot's gaze. In particular, infants' looks were coded as directed at the speaker, the experimenter, the child's toy, the speaker's toy, and at their caregiver. Six infants (23%) were randomly selected to be coded twice, by two different researchers, who reached 100% agreement.

During the testing phase, of primary importance was infants' toy selection in response to each comprehension question. That is, infants were coded with regards to which toy they touched first following comprehension questions. When two toys were touched simultaneously, the toy infants responded with upon being prompted (e.g., "Can you give me the *dax*?") was considered (see Appendix F). Six infants (23%) were coded independently by two coders, who were in 100% agreement.

## *Results and Discussion*

### *Looks During Training*

Infants' attentiveness to the gaze direction of the nonhuman speaker during the training phase was first examined. Of interest was whether infants looked in the direction of the robot at the time the novel label was uttered. Analyses revealed that out of four labeling trials, infants attended to the robot equally often in both the coordinated (M=3.62, SD=0.57) and discrepant condition (M=3.54, SD=0.76), $t(25)=-0.40$, $p>.05$, suggesting that infants were attentive to the robot speaking in both conditions (see Table 1).

In Baldwin's (1993) study, 18-month-old infants followed the gaze of the human speaker, as evidenced by their tendency to look more often to their own toy in the coordinated compared to the discrepant condition and more frequently to the speaker's toy during the discrepant as compared to the coordinated condition. Analyses revealed a similar pattern of results in the current study. That is, after attending to the robot during labeling, infants looked to their own toy significantly more often during the coordinated condition (M=1.27, S.D=1.08) than during the discrepant condition (M=0.77, SD=0.95), $t(25)=-2.00$, $p=.05$. Likewise, infants' looks to the robot tended to be succeeded by a look to the robot's toy more often in the discrepant (M=1.50, SD=1.45) compared to the coordinated condition (M=1.04, SD=0.92), $t(25)=1.85$, p=.08 (see Table 1). As expected, these results indicate the presence of gaze-following in 18-month-olds, even in response to a nonhuman speaker. However, whether infants impute referential intentions and use the robot's gaze cues to correctly associate the novel label with its referent remains unanswered.

*Comprehension Results*

*Familiar labels.* In line with Baldwin's (1993) findings, infants performed at high levels in response to questions testing their comprehension of familiar items. More specifically, infants performed equally well in both conditions, such that they correctly selected the familiar target item 67% of the time (SD=28.43) and 66% of the time (SD=28.99) in the coordinated and discrepant conditions, respectively. In both conditions, these success rates exceeded chance levels (50%) (Coordinated, $t(25)=3.05$, $p<.01$; Discrepant, $t(25)=2.76$, $p<.01$).

*Novel labels.* If infants utilize the robot's social cues to correctly associate the novel label with the target of the speaker's gaze, one would expect them to select the robot's toy significantly more often in the discrepant as compared to the coordinated condition. Infants' success on novel label comprehension questions revealed a different pattern of responses across conditions, compared to familiar label trials. That is, infants selected the novel toy in the robot's possession during training at equal rates in both the coordinated (M=49.68%, SD=32.70) and discrepant (50.64%, SD=35.51) conditions, $t(25)=0.11$, $p>.05$ (see Figure 2). In other words, infants succeeded in selecting the correct novel item 50.32% and 50.64% of the time in the coordinated and discrepant conditions, respectively. Their success rates were not significantly greater than predicted by chance (50%) in either case (Coordinated, $t(25)=0.05$, $p>.05$; Discrepant, $t(25)=0.09$, $p>.05$). As such, the results of the current study indicate that 18-month-old infants failed to learn the novel word from a nonhuman speaker. The above findings contrast with those reported by Baldwin's (1993) involving a human speaker in which similarly aged infants selected the speaker's toy at rates that exceeded chance in the discrepant, but not coordinated, condition.

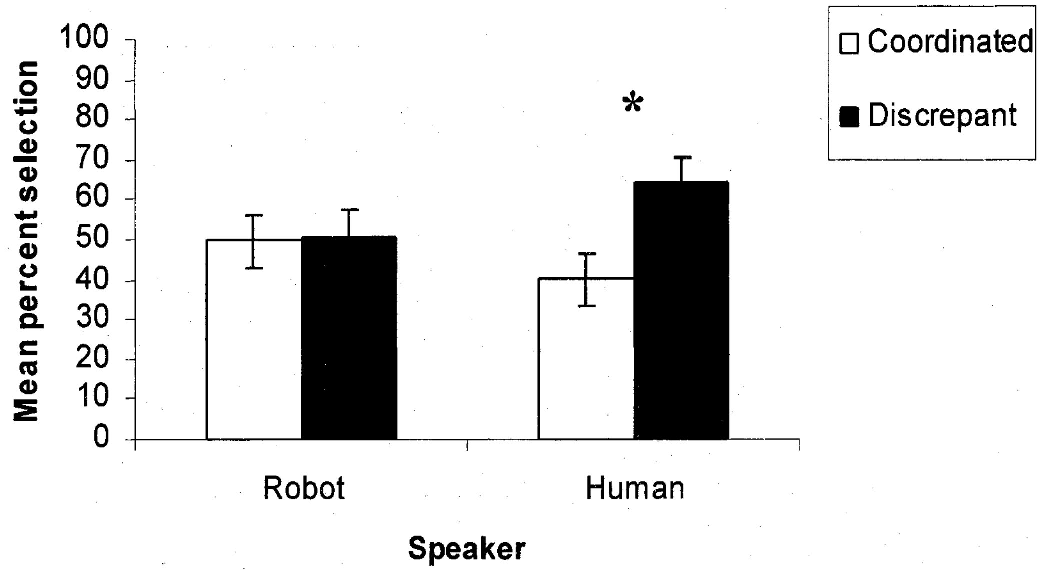



*Figure 2.* Mean percent selection of the speaker's toy in response to novel label comprehension questions in robot and human speaker conditions

The results of Experiment 1 indicate that at 18 months of age, infants will follow the gaze direction of a nonhuman speaker when hearing a novel label. However, infants' failure to associate the novel label with the object at which the nonhuman agent was gazing suggests that infants do not view such an agent as having the intention to name an object. That is, they fail to attribute referential intentions to the nonhuman speaker. When tested for their comprehension of familiar labels, infants selected the correct item at above chance levels, confirming that they understood the task at hand.

## Experiment 2

In Baldwin's original (1993) study, only one experimenter was present in the testing situation and was responsible for both training and testing of the child's word comprehension. However, in Experiment 1, two agents were present during testing: the experimenter and the robot, since the robot could not be programmed with the arm movements necessary to present the infants with toys. The presence of two agents during labeling may have confused the infants as they may not have known which agent's gaze to follow. Likewise, the infants may have consulted both the robot and the experimenter's gaze, each of which were looking in a different direction. That is, the robot looked to the appropriate object, while the experimenter looked down to her lap. To enable a direct comparison of infants' ability to follow a human and a nonhuman's gaze during word learning, a second experiment was conducted involving two human experimenters (speaker and tester). This additional investigation sought to determine whether the differences in results between human and robot conditions could be attributed to these methodological changes.

### *Method*

#### *Participants*

Twenty-eight 18-month-old infants participated in the current experiment. The final sample consisted of 25 after excluding three infants due to fussiness (mean age=18.65 months; range=17.79 to 19.56 months, SD=0.45). There were 14 males and 11 females in the final sample. Participants were recruited in the same way as described in Experiment 1. All participants were full term at birth and were normally developing. Four children belonged to households speaking only French, 9 to English households, and 12 belonged to families speaking multiple languages at home (combination of English and/or French with Italian, Portuguese, Uzbec, Arabic, or Albanian). To ensure that age differences between infants in the experiments involving the robot and the human speaker would not account for any variations in performance, the mean age of both groups was compared. Infants in both studies did not differ in age, $t(50)=0.00$, $p>.05$.

*Materials*

All stimuli and novel toy labels were identical to those used in Experiment 1. Two video cameras and a Hi-8 video cassette recorder were used to record the testing sessions.

*Procedure and Design*

The design and procedure were identical to Experiment 1, except that a second experimenter was present during testing and acted as the speaker during training. That is, two female experimenters were involved, one being responsible for labeling and the other responsible for comprehension testing. The same two individuals took part in all of the sessions, alternating roles depending upon the language of testing. Both experimenters played with the infant prior to testing, while his/her parent completed the required forms. This served to allow the child to become familiar with each. As in Experiment 1, the first experimenter (tester) sat directly in front of the infant, with the second experimenter (speaker) to her left. The second experimenter placed her palms flat on the table and looked directly ahead at all times except during labeling. With the exception of each labeling of the novel toy, she remained completely silent and motionless. During training, novel labels were uttered four times in each condition. Infants' comprehension of novel and familiar words were then tested in alternating order, four times each, resulting in a total of eight questions per condition.

*Coding*

Infants' behavior during the training and testing phase was coded in an identical manner to Experiment 1. All variables of six randomly selected infants were coded independently by two coders, who reached 100% agreement.

## *Results and Discussion*

*Looks During Training*

Consistent with Experiment 1, infants oriented to the human speaker upon hearing the novel label in both conditions. More specifically, out of four trials infants looked to the human speaker a mean of 3.72 times (SD=0.54) during the coordinated condition and a mean of 3.48 times (SD=0.65) in the discrepant condition, $t(24)=-1.81$), $p>.05$.

When examining infants' looking behavior following a look to the speaker during labeling, the same pattern of results emerged as in the previous experiment. After looking to the speaker, infants' mean number of looks to their own toy was significantly greater in the coordinated condition (M=1.68, SD=1.22) as compared to the discrepant condition (M=0.60, SD=0.70), $t(24)=-4.42$, $p<.0001$. In other words, infants attended to their own toy more often when the speaker had just labeled it, compared to when the speaker labeled its own toy. However, the reverse held true for infants' looks to the speaker's toy. That is, following a look to the speaker, infants looked to the speaker's toy significantly more often in the discrepant condition (M=2.40, SD=1.12) than in the coordinated condition (M=0.84, SD=1.03), $t(24)=4.70$, $p<.001$. Infants' looking behavior during training is presented in Table 2. The findings suggest that infants were aware of the speaker's gaze direction, demonstrated by the fact that they oriented more often toward the toy that the speaker was looking at when uttering a novel label, compared to the object that was not the target of the speaker's gaze.

*Comprehension Results*

*Familiar labels.* As expected, infants performed at high levels on familiar label comprehension questions. They performed equally well in both conditions, such that infants selected the correct familiar item an average of 67% (SD=31.59) of the time in the coordinated condition and 67% (SD=29.46) of the time in the discrepant condition. In both cases, these rates exceeded chance levels (50%) (Coordinated, $t(24)=2.69$, $p<.05$; Discrepant, $t(24)=2.83$, $p<.05$).

*Novel labels.* An important difference between the previous and current experiment was uncovered upon analyzing infants' performance on novel label comprehension questions. That is, whereas infants failed to correctly associate the novel word with its referent when labeling was performed by a robot, infants succeeded in this task when the speaker was human. Infants selected the speaker's novel toy during training significantly more often in the discrepant condition (M=64.33%, SD=31.04) than in the coordinated condition (M=41.00%, SD=33.84), $t(24)=2.72$, $p<.05$ (see Figure 2). Infants selected the correct novel item at above chance levels (50%) in the discrepant condition (64.33%), $t(24)=2.31$, $p<.05$ and almost exceeded chance in the coordinated condition (59.00%), $t(24)=1.33$, $p=.09$.

*MacArthur Communicative Development Inventory (MCDI)*

Because infants' performance in the word learning task could be affected by their verbal skills, an independent samples t-test was conducted to determine whether the vocabulary of infants in the robot and person conditions differed. Upon analysis, a significant difference was obtained (Experiment 1, mean number of words=78.05, SD=85.41; Experiment 2, mean number of words=169.37, SD=168.22), $t(36)=-2.11$, $p<.05$, such that, infants in Experiment 2 had a larger vocabulary score than infants in Experiment 1. This finding raised the possibility that infants in Experiment 2 succeeded in the word learning task as a result of more advanced verbal skills. To directly examine this question, two sub-samples were created by excluding the 4 infants with the lowest vocabulary scores in Experiment 1 and the 4 infants with the highest vocabulary scores in Experiment 2. After eliminating these outliers, no significant difference in vocabulary size was found (Experiment 1, M=96.00, SD=87.93; Experiment 2, M=93.80, SD=82.42), $t(28)=0.71$, $p>.05$). Using these new samples, infants' performance on the novel label comprehension trials in both experiments was compared. Consistent with the previous analyses, infants in Experiment 1 selected the robot's toy equally as often in the discrepant condition (M=53%, SD=33.68) compared to the coordinated condition (M=43.94, SD=32.04), $t(21)=1.06$, $p>.05$. Also consistent with previous analyses, infants in Experiment 2 selected the speaker's toy significantly more often in the discrepant condition (M=65.87, SD=30.49) than in the coordinated condition (M=45.24, SD=34.21), $t(20)=2.22$, $p<.05$. In other words, after accounting for vocabulary size, infants who were trained by a nonhuman speaker failed to learn the new word, whereas those trained by a human speaker successfully learned a novel word. These findings confirm that the discrepancy between infants' word learning abilities in the robot task as compared to the person task was not a result of differences in verbal skills between the two groups.

*Gaze-Following*

Regardless of the animacy of the speaker, in response to hearing a new label, infants in both experiments shifted their gaze to locate the focus of speaker's gaze. Nonetheless, a notable difference across the conditions was observed regarding the extent to which infants engaged in this gaze-following behavior. Specifically, the infants in Experiment 1 looked to the robot's toy a mean number of 1.50 trials (SD=1.45) in the discrepant condition, a value significantly smaller than its equivalent in Experiment 2, whereby infants looked to the speaker's toy a mean number of 2.40 trials (SD=1.16), $t(49)=-2.45$, $p<.05$. The extent to which infants followed the speaker's (robot or human) gaze during the coordinated condition did not differ across experiments (Experiment 1, Mean number of trials=1.27, SD=1.08; Experiment 2, Mean number of trials=1.68, SD=1.22; $t(49)=-1.28$, $p>.05$).

In order to account for the relatively lower level of gaze-following in the case of a nonhuman agent, further analyses were conducted to determine where infants were looking instead. Infants' looking behavior was combined across conditions (a total of 8 trials). The extent to which infants looked to the experimenter during labeling trials did not differ between the robot and human groups (Experiment 1, Mean number of trials=3.81, SD=2.26; Experiment 2, Mean number of trials=2.88, SD=1.86; $t(49)1.60$, $p>.05$). Interestingly, infants in Experiment 1 looked to their caregiver more often than did infants in Experiment 2 (M= 2.73, SD=1.66 and M=1.44, SD=1.26), respectively $t(49)=3.11$, $p<.01$. These findings suggest that upon hearing the robot's utterance, infants in Experiment 1 tended to orient to their caregiver for social referencing. Thus, the lower number of trials in which infants in Experiment 1 looked to the robot's toy during training can be explained by their increased tendency to engage in social referencing behavior upon hearing the speaker talk.

In sum, infants in Experiment 2 performed differently on the word learning task in comparison to infants of the same age who were presented novel words by a nonhuman speaker in Experiment 1. Since the only methodological difference between the two experiments was the animacy of the speaker, it can be concluded that infants' failure to map words to objects in Experiment 1 can not be accounted for solely by the modifications to the original procedure, notably, the presence of two experimenters instead of one. This replication of previous findings of word mapping using the gaze of a human speaker as a cue confirms that by 18 months of age, infants learn words by taking into account the referential intentions of the speaker.

## General Discussion

It has been argued that gaze-following may be an important component of language acquisition (Baldwin, 1995; Bruner, 1983; Graham et al., 2007; Moore, Angenopulos & Bennett, 1999; Tomasello, 1995). This theoretical proposal is supported by two lines of research. First, a number of longitudinal studies have shown that infant gaze-following predicts language development (Carpenter et al., 1998; Markus, Mundy, Morales, Delgado, & Yale, 2000; Morales, Mundy, & Rojas, 1998; Morales, Mundy, Delgado et al., 2000; Brooks & Meltzoff, 2005). Second, a large body of empirical evidence has demonstrated that children acquire words more easily in joint attention contexts (Aktar et al., 1991; Aktar & Tomasello, 1996; Baldwin, 1991, 1993; Tomasello & Barton, 1994; Tomasello & Farrar, 1986). Two alternative interpretations have been offered to account for infants' ability to use gaze to identify the referent of a novel word.

According to a rich interpretation, infants use gaze direction to map a novel word to a novel object (or event) because they appreciate that eye-gaze direction is an indication of the adult's intention to refer to that particular object. An alternative, leaner account of infants' reliance on gaze direction cues to learn novel words focuses on the salience-enhancing or the attention-getting nature of eye-gaze. Support for the rich interpretation has come from a series of studies showing that by age 12 months, infants will engage in gaze-following behavior when an adult's eyes are open, but not when they are shut or blindfolded (Meltzoff & Brooks, 2007). Additional support arises from research on autistic children who seem to be able to orient their attention reflexively to shifts in eye-gaze direction, but do not understand their predictive value or social meaning (Chawarska, Klin, & Volkmar, 2003; Kylliäinen & Hietanen, 2004).

The purpose of the current study was twofold: Firstly, to examine whether infants would follow the gaze of a nonhuman agent while labeling a novel object, and secondly, to determine whether in doing so they were able to properly link a novel word with its referent. Based on previous findings that 12-month-old infants consistently follow the gaze of an ambiguous object that possesses facial features (Johnson et al., 1998), it was expected that infants would demonstrate gaze-following behavior in the presence of a humanoid, self-propelled robot. However, it was predicted that by the age of 18 months, this attentional orienting would not be sufficient for infants to attribute referential intentions to the "speaker", causing them to fail to map words onto the correct referent. The present series of two studies produced two main findings. First, infants follow the gaze of an inanimate object that possesses human properties, such as morphological features and agency. This result is consistent with Johnson et al.'s (1998) work. It also extends this previous work by demonstrating that even infants as old as 18 months follow the gaze of a self-propelled, human-looking inanimate object. Secondly, and more importantly, the present findings showed that infant's attention was focused on the appropriate object through the robot's gaze direction, but they failed to associate the word with the object. That is, when tested for their comprehension of novel words, they did not select the appropriate toy at above chance levels in either the discrepant or coordinated condition. It appears that the 18-month-olds in the robot condition behaved like the 14-month-old infants in Baldwin's (1993) original experiment, who also monitored the gaze successfully but could not use it to establish the referent of the word, even in the coordinated condition. These results cannot be attributed to the demands of the testing procedure, as infants' performance exceeded chance levels in both coordinated and discrepant conditions when their comprehension of familiar words was tested. A strikingly different pattern of results emerged when infants underwent the same word training procedure with a human speaker. More specifically, in accord with previous studies, when the human speaker engaged in labeling, infants followed her gaze, orienting toward the target novel toy. In contrast to Experiment 1, and consistent with Baldwin's original (1993) study with a human speaker, infants in Experiment 2 learned the new words in both conditions, as demonstrated by their tendency to correctly select the novel items more often than would be predicted by chance during comprehension testing. As expected, these infants also selected the correct familiar item at above chance levels. These findings safely rule out the possibility that infants' inability to succeed in the word learning task in the nonhuman agent study was due to the fact that the speaker was not the person who tested infants' comprehension of novel and familiar words in the first experiment. Although the experimenter was very careful to look down and avoid making eye contact during labeling in the robot condition, infants may have felt confused since there were two gazes to monitor. However, 18-month-olds in the human speaker experiment were also faced with this potential confusion, yet were, nonetheless, able to make the proper word-object associations. Not surprisingly, social referencing behavior was more apparent when the speaker was nonhuman, accounting for the lower levels of gaze-following in Experiment 1 compared to Experiment 2. Differences in word learning skills were also ruled out to explain the differential performance across the two experiments.

Given that self-propulsion and morphological features were considered insufficient for infants' perceptions of referential intentions, one might argue that other animate cues might have elicited such attributions. Research recently undertaken by Arita and colleagues (2004) found that 10-month-old infants were less surprised to witness an interaction between an experimenter and a humanoid robot if they had previously viewed a video recording of the humanoid robot engaging contingently with a human. Similarly, Shimizu and Johnson (2004) concluded that two months later in their development, infants viewed the behavior of an ambiguous green object as goal-directed after viewing this object interacting with a human in a contingent manner, but not when this previous interaction was absent. These data indicate that at this young age, infants' understanding of an inanimate being as acting intentionally might be derived in part from contingent interaction. To our knowledge, few studies have examined the role of contingency in older infants' reactions to nonhuman agents. Dunham, Dunham, Tran, and Akhtar (1991) examined the role of a reciprocating social partner in facilitating conversation with 2-

year-olds. They found that a robot whose verbalizations corresponded to the children's actions and speech stimulated social conversation in the young children to a greater extent than a robot who engaged in the same script, but without reciprocating the children's comments. In light of these findings, one might expect that 18-month-old infants' word learning may be facilitated if infants viewed a previous contingent interaction between the robot and a human, prior to engaging in the testing procedure. Nonetheless, evidence would suggest otherwise. That is, in a very recent study, when a contingent agent was introduced into the word learning task used in the current research, 18-month-olds continued to fail to learn a novel word (Guay, Poulin-Dubois, & Sorokin, 2007). Thus, at 18 months, infants do not appear to interpret gaze direction of a contingent agent as a marker of intentionality in a word learning context.

No doubt, alternative interpretations exist for the absence of word mapping in the case of a nonhuman speaker. One interpretation is that infants may have correctly associated the word and its referent but were unable to generalize this association from the robot to the experimenter. A possible explanation for this is that infants did not consider the robot a reliable speaker. Recent research has demonstrated that when presented with one informant who consistently provides accurate names for familiar objects and a second who consistently provides inaccurate names, preschoolers reliably identify the unreliable informant and learn novel words from the reliable informant (Clément, Koenig & Harris, 2004; Koenig & Harris, 2005; Sabbagh & Baldwin, 2001). Similar word learning research has not yet been conducted with toddlers. However, in recent work 14-month-olds were found less likely to follow the gaze of a person behind a barrier when her gaze was unreliable in another context (Chow & Poulin-Dubois, 2007).

Thus, if infants perceived the robot as an unreliable speaker, it remains possible that prior exposure to the robot correctly labeling familiar objects might alter infants' perspective on this agent. Another interpretation concerns the perception of the robot as an unconventional speaker, that is, that the labels he uses are unique to him and are not generalizable to human speakers. Preschoolers and even toddlers presume that individuals share the knowledge of the meaning of novel labels, even in the absence of explicit evidence that this is the case (Diesendruck & Markson, 2001; Graham, Stock, & Henderson, 2006). This interpretation would be supported if, in future studies, infants learn the novel words when the robot is both the speaker and the tester. Because our robot did not have mobile arms, word comprehension trials were conducted by a human tester, a factor that we tried to control for by having the same procedure in the person condition. Nonetheless, determining an innovative way for the robot to test infants' comprehension of novel words is a matter for future research.

It has been proposed that infants' attributions of intentional behavior are activated whenever infants recognize an object as a psychological agent, based on an evolutionary designed system (Baron-Cohen, 1995; Johnson, 2000; Leslie, 1995). Although there is some evidence that infants do construe nonhuman agents as intentional beings, to date this research has been limited to infants aged 5 to 15 months and to goal detection and gaze-following abilities (Johnson, et al., 2001; Johnson et al., 1998; Luo & Baillargeon, 2005). Tracing developmental changes in the breadth of infants' agent category beyond this age range and on tasks that require that infants use the agent's actions to guide their own behavior was the main goal of the current study. The present findings extend prior research by showing that, like younger infants, 18-month-old infants follow the gaze of both human and nonhuman agents. However, children at this age use the speaker's direction of gaze strategy to correctly map a novel label only in the case of a human speaker. These results suggest a narrowing of the scope of intention attributions by 18 months of age, a finding that is in accord with previous research showing that infants do not attribute goals to nonhuman, unfamiliar objects (Meltzoff, 1995). The fact that the nonhuman agent has many obvious similarities to humans (e.g., body, face, voice) provides a more stringent test than previous studies. Because the present word mapping task could not be administered to younger infants (they failed in the original study), the developmental period during which this change in the concept of intentional agent develops remains to be documented with other tasks. However, other recent work on precursors of theory of mind skills in infancy suggests that the period between 12 and 18 months corresponds with significant changes in how infants interpret the actions of human and nonhuman agents (Bellagamba & Tomasello, 1999; Olineck & Poulin-Dubois, 2005; Poulin-Dubois, 1999; Repacholi & Gopnik, 1997).

References

Akhtar, N., Dunham, F., & Dunham, P. (1991). Directive interactions and early vocabulary development: The role of joint attentional focus. *Journal of Child Language, 18*, 41-49.

Akhtar, N., Jipson, J., & Callanan, M.A. (2001). Learning words through overhearing. *Child Development, 72*, 875-890.

Akhtar, N., & Tomasello, M. (1996). Two-year-olds learn words for absent objects and actions. *British Journal of Developmental Psychology, 14*, 79-93.

Arita, A., Hiraki, K., Kanda, T., & Ishiguro, H. (2004). Can we talk to robots? Ten-month-old infants expected interactive humanoid robots to be talked to by persons. *Cognition, 95*, B49-B57.

Baldwin, D.A. (1991). Infants' contribution to the achievement of joint reference. *Child Development, 62*, 875-890.

Baldwin, D. A. (1993). Infants' ability to consult the speaker for clues to word reference. *Journal of Child Language, 20*, 395-418.

Baldwin, D. (1995). Understanding the link between joint attention and language. In C. Moore & P.J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp.131-158). Hillsdale, NJ: Lawrence Erlbaum Associates.

Baldwin, D. A., Markman, E.M., Bill, B., Desjardins, R.N., Irwin, J.M, & Tidball, G. (1996). Infants' reliance on social criterion for establishing word-object relations. *Child Development, 67*, 3135-3153.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind.* Cambridge: The MIT Press.

Baron-Cohen, S., Baldwin, D.A., & Crownson, M. (1997). Do children with autism use the Speaker's Direction of Gaze (SDG) strategy to crack the code of language? *Child Development, 68*, 48-57.

Bellagamba, F., & Tomasello, M. (1999). Re-enacting intended acts: Comparing 12- and 18-month-olds. *Infant Behavior and Development, 22*, 277-282.

Bretherton, I. (1991). Intentional communication and the development of mind. In D. Frye & C. Moore (Eds.), *Children's theories of mind, mental states and social understanding* (pp. 49-76). Hillsdale, NJ: Lawrence Erlbaum Associates.

Brooks, R., & Meltzoff, A.N. (2005). The development of gaze-following and its relation to language. *Developmental Science, 8*, 535-543.

Bruner, J. (1983). *Child's talk: Learning to use language*. San Diego, CA: Academic Press.

Carey, S. (1978). The child as word-learner. In M. Halle, J. Bresnan & G.A. Miller (Eds.), *Linguistic Theory and Psychological Reality*. Cambridge, MA: MIT Press.

Caron, A. J., Kiel., E. J., Dayton, M., & Butler, S. C. (2002). Comprehension of the referential intent of looking and pointing between 12 and 15 months. *Journal of Cognition and Development, 3,* 445-464.

Carpenter, M., Nagell, K., & Tomasello, M. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development, 63*(4, Serial No. 255).

Chawarska, K., Klin, A., & Volkmar, F. (2003). Automatic attention cueing through eye movement in 2-year-old children with autism. *Child Development, 74*, 1108-1122.

Chow, V., & Poulin-Dubois, D., & Lewis, J. (in press). To see or not to see: Infants prefer to follow the gaze of a reliable looker. *Developmental Science.*

Clément, F., Koenig, M., & Harris, P. (2004). The ontogenesis of trust. *Mind and Language, 19*, 360-379.

Diesendruck, G., & Markson, L. (2001). Children's avoidance of lexical overlap: A pragmatic account. *Developmental Psychology, 37*, 630-641.

Dunham, P., Dunham, F., Tran, S., & Akhtar, N. (1991). The nonreciprocating robot: Effects on verbal discourse, social play, and social referencing at two years of age. *Child Development, 62*, 1489-1502.

Graham, S., Nelson, E.S., & Nayer, S.L. (2007). Following the intentional eye: The role of gaze cues in early word learning. In R. Flom, K. Lee, & D. Muir (Eds.), *Gaze-following: Its developmental significance*, (pp.193-216). Mahwah, NJ: Lawrence Erlbaum Associates.

Graham, S.A., Stock, H., Henderson, A. (2006). Nineteen-month-olds' understanding of the conventionality of object labels versus desires. *Infancy, 9*, 341-350.

Golinkoff, R. M. & Hirsh-Pasek, K. (2006). Baby wordsmith. *Current Directions in Psychological Science, 15*(1), 30-33.

Guay, A., Poulin-Dubois, D., & Sorokin, A. (2007). Can infants learn new words from a contingent non-human speaker? Poster presented at the Canadian Language and Literacy Research Network 6th Annual Conference (CLLRNT), Calgary, Alberta.

Harris, M., Jones, D., & Grant, J. (1983). The non-verbal context of mothers' speech to infants. *First Language, 4*, 21-31.

Hirsh-Pasek, K., Golinkoff, R.M., Hennon, E.A., & Maguire, M.J. (2004). Hybrid theories at the frontier of developmental psychology: The emergentist coalition model of word leaning as a case in point. In D.G. Hall & S.R. Waxman (Eds). *Weaving a lexicon.* (pp.173-204). Cambridge, MA: MIT Press.

Hollich, G. J., Hirsh-Pasek, K., Golinkoff, R. M., Brand, R. J., Brown, E., Chung, H. L., Hennon, E., & Rocroi, C. (2000). Breaking the language barrier: An emergentist coalition model for the origins of word learning. *Monographs of the Society for Research in Child Development, 65* (3, Serial No. 262).

Johnson, S. (2000). The recognition of mentalistic agents in infancy. *Trends in Cognitive Sciences, 4*(1), 22-28.

Johnson, S., Booth, A., & O'Hearn, K. (2001). Inferring the goals of a nonhuman agent. *Cognitive Development, 16*, 637-656.

Johnson, S., Slaughter, V., & Carey, S. (1998). Whose gaze will infants follow? The elicitation of gaze-following in 12-month-olds. *Developmental Science, 1*(2), 233-238.

Kliniäinen, A., & Hietanen, J. (2004). Attentional orienting by another's gaze direction in children with autism. *Journal of Child Psychology and Psychiatry, 45*, 435-444.

Koenig, M., & Harris, P. (2005). Preschoolers mistrust ignorant and inaccurate speakers. *Child Development, 76*(6), 1261-1277.

Langton, S. R. H., Watt, R. J., & Bruce, V. (2000). Do the eyes have it? Cues to the direction of social attention. *Trends in Cognitive Sciences, 4,* 50-59.

Leslie, A.M. (1995). A theory of agency. In D. Sperber, D. Premack, & A.J. Premack (Eds.), *Causal cognition: A multidisciplinary debate* (pp.121-149). Oxford, England: Clarendon Press.

Luo, Y., & Baillargeon, R. (2005). Can a self-propelled box have a goal?: Psychological Reasoning in 5-month-old infants. *Psychological Science, 16*(8), 601-608.

Markman, E.M. (1989). *Categorization and naming in children: Problems of induction.* Cambridge, MA: MIT Press.

Markus, J., Mundy, P., Morales, M., Delgado, C.E.F., & Yale, M. (2000). Individual differences in infant skills as predictors of child-caregiver joint attention and language. *Social Development, 9*, 302-315.

Meltzoff, A., (1995). Understanding the intention of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology, 31*, 838-850.

Meltzoff, A., & Brooks, R. (2007). Eyes wide shut: The importance of eyes in infant gaze-following and understanding other minds. In R. Flom, K. Lee, & D. Muir (Eds.), *Gaze-following: Its developmental significance*, (pp. 217-241). Mahwah, NJ: Lawrence Erlbaum Associates.

Moore, C. (1999). Gaze-following and the control of attention. In P. Rochat (Ed.), *Early social cognition: understanding others in the first months of life* (pp. 241-256). Mahwah, NJ: Lawrence Erlbaum Associates.

Moore, C., Angelopoulos, M., & Bennet, P. (1999). Word learning in the context of referential and salience cues. *Developmental Psychology, 35*, 60-68.

Moore, C., & Corkum, V. (1994). Social understanding at the end of the first year of life. *Developmental Review, 14,* 349-372.

Morales, M., Mundy, P., Delgado, C.E.F., Yale, M., Messinger, D.S., Neal, R., & Schwartz, H. (2000). Responding to joint attention across the 6- through 24-month age period and early language acquisition. *Journal of Applied Developmental Psychology, 21*, 283-298.

Morales, M., Mundy, P., & Rojas, J. (1998). Following the direction of gaze and language development in 6-month-olds. *Infant Behavior & Development, 21*, 373-377.

Olineck, K., & Poulin-Dubois, D. (2005). Infants' ability to distinguish between intentional and accidental actions and its relation to internal state language. *Infancy, 8*(1), 91-100.

Poulin-Dubois, D. (1999). Infants' Distinction between animate and inanimate objects: The origins of naive psychology. In P. Rochat (Ed), *Early Social Cognition*, (pp. 257-280). Hillsdale, N.J.: Erlbaum.

Povinelli, D. J. (2001). On the possibilities of detecting intentions prior to understanding them. In B. F. Malle, L. J. Moses, & D. A. Baldwin (Eds.), *Intentions and intentionality: Foundations of social cognition* (pp.225-248). Cambridge, MA: MIT Press.

Pruden, S. M., Hirsh-Pasek, K., Golinkoff, R. M., & Hennon, E. (2006). The birth of words: Ten-month-olds learn words through perceptual salience. *Child Development, 77*(2), 266-280.

Repacholi, B.M., & Gopnik, A. (1997). Early reasoning of desires: Evidence from 14- to 18-month-olds. *Developmental Psychology, 33*, 12-21.

Sabbagh, M.A., & Baldwin, D.A. (2001). Learning words from knowledgeable versus ignorant speakers: Link between preschoolers' theory of mind and semantic development. *Child Development, 72*, 1054-1070.

Sabbagh, M. A., Henderson, A. M., & Baldwin, D. A. (2007). What infants' understanding of referential intentions tells us about the neuro-cognitive bases of early word learning. In R. Flom, K. Lee, & D. Muir (Eds.), *Gaze-following: Its developmental significance*, (pp. 171-191). Mahwah, NJ: Lawrence Erlbaum Associates.

Shimizu, A., & Johnson, S. (2004). Infants' attribution of a goal to a morphologically unfamiliar agent. *Developmental Science, 7*(4), 425-430.

Smith, L.B. (2000). Learning how to learn words: An associative crane. In R.M. Golinkoff, K. Hirsh-Pasek, L. Bloom, L., L. Smith, A. Woodward, N. Akhtar, M. Tomasello, and G. Hollich (Eds)., *Becoming a word learner: A debate on lexical acquisition* (pp. 51-80). New York: Oxford University Press.

Tomasello, M. (1995). Joint attention as social cognition. In C. Moore & P.J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 103-130). Hillsdale, NJ: Lawrence Erlbaum Associates.

Tomasello, M. (2001). Perceiving intentions and learning words in the second year of life. In M. Bowerman & S.C. Levinson (Eds.), *Language acquisition and conceptual development* (pp. 132-158). Cambridge, England: Cambridge University Press.

Tomasello, M., & Barton, M. (1994). Learning words in non-ostensive contexts. *Developmental Psychology, 30*, 639-650.

Tomasello, M., & Farrar, J. (1986). Joint attention and early language. *Child Development, 57*, 1454-1463.

Quine, W. V. Q. (1960). *Word and object.* Cambridge, England: Cambridge University Press.

Woodward, A. (2004). Infants' use of action knowledge to get a grasp on words. In D.G. Hall & S.R. Waxman (Eds.) *Weaving a lexicon* (pp.149-171). Cambridge, MA: MIT Press.

# Appendix A

**Recruitment Letter**

Dear parents,

The Child Development Laboratory at Concordia University is involved in a series of studies looking at infants' understanding of human eyes and how they play an important role in informing us about another person's mental states. This research is funded by the Social Sciences and Humanities Research Council of Canada. The Commission d'Accès à l'Information du Québec has kindly given us permission to consult birthlists provided by the Régie Régionale de la Santé et des Services Sociaux de la Région de Montréal-Centre. Your name appears on the birthlist of ____________ which indicates that you have a child of an age appropriate for our study.

The present investigation involves examining how infants interpret a speaker's actions when they are learning a new word. Your child will hear a new word as he or she is looking at unfamiliar objects. The speaker will either look directly at the object your child is looking at, or will look at a different object when she utters a new word. Later, your child will be asked to find one of the objects. Furthermore, to provide us with information about how infants understand the unique nature of human eyes, we are also completing this task with a computerized robot. We are interested in whether infants will treat the human and the robot differently across this task.

Participation involves one visit of approximately 45 minutes to our research centre on the Loyola Campus of Concordia University, located at 7141 Sherbrooke Street West. Appointments can be scheduled at a time convenient to you, including weekends. Free parking is available on the campus for our participants, and we will gladly reimburse any transportation expenses at the time of your appointment. Upon completion of the study, a Certificate of Merit will be given to your child, and a report of the results of the study will be mailed to you as soon as it is completed.

For the purposes of this study, we are looking for infants who are 18 months of age, and who do not have any visual or hearing difficulties. If you are interested in having your child participate in this study, or would like any further information, please contact Laura O'Connell at 848-2424, ext. 2279 or Dr. Diane Poulin-Dubois at 848-2424, ext. 2219. We will try to contact you by telephone within a few days of your receipt of this letter.

Thank you for your interest and collaboration.

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# Appendix B

## Parental Consent Form

This is to state that I agree to allow my child to participate in a research project being conducted by Dr. Diane Poulin-Dubois and Laura O'Connell of Concordia University.

**A. PURPOSE**
I have been informed that the purpose of the research is to examine how infants understand human actions and mental states.

**B. PROCEDURES**
The present investigation involves examining how infants interpret a speaker's actions when they are learning a new word. Your child will hear a new word as he or she is looking at unfamiliar objects. The speaker will either look directly at the object your child is looking at, or will look at a different object when she utters a new word. Later, your child will be asked to find one of the objects. Furthermore, to provide us with information about how infants understand the unique nature of human eyes, we are also completing this task with a computerized robot. We are interested in whether infants will treat the human and the robot differently across this task. During these tasks, your child will be sitting in a child seat and you will be seated directly behind. We will videotape your child's responses and all tapes will be treated in the strictest of confidentiality. That means that the researcher will not reveal your child's identity in any written or oral reports about this study. Your child will be assigned a coded number, and that number will be used on all data collected in this study. The entire session is expected to last approximately one hour.

**C. RISKS AND BENEFITS**
Your child will be given a certificate of merit at the end of the session as a thank-you for his/her participation.

There is one condition which may result in the researchers being required to break the confidentiality of your child's participation. There are no procedures in this investigation that inquire about child maltreatment directly. However, by the laws of Québec and Canada, if the researchers discover information that indicates the possibility of child maltreatment, or that your child is at risk for imminent harm, they are required to disclose this information to the appropriate agencies. If this concern emerges, the lead researcher, Dr. Diane Poulin-Dubois, will discuss the reasons for this concern with you and will advise you of what steps will have to be taken.

**D. CONDITIONS OF PARTICIPATION**
- I understand that I am free to withdraw my consent and discontinue my participation at any time without negative consequences, and that the experimenter will gladly answer any questions that might arise during the course of the research.

- I understand that my participation in this study is confidential (i.e. the researchers will know, but will not disclose my identity).
- I understand that the data from this study may be published, though no individual scores will be reported.

I HAVE CAREFULLY STUDIED THE ABOVE AND UNDERSTAND THIS AGREEMENT. I FREELY CONSENT AND VOUNTARILY AGREE TO HAVE MY CHILD PARTICIPATE IN THIS STUDY.

MY CHILD'S NAME (please print) ______________________________

MY NAME (please print) ____________________________________

SIGNATURE ______________________ DATE _______________

WITNESSED BY ____________________ DATE _______________

If at any time you have questions about your rights as a research participant, you are free to contact Adela Reid, Research Ethics and Compliance Officer, Concordia University, at (514) 848-2424 ext 7481 or by email at areid@alcor.concordia.ca

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Participant # __________

Researcher: __________________

# Appendix C

**Participant Information**

Infant's name:______________________ Date of Birth: ____________________

Gender:_______ Language(s) spoken at home:_____________________________

Mother's name: ____________________ Father's name: ____________________

Address: ________________________________ Telephone #:________________home

________________________________ ________________work

Postal Code:______________________________ ________________work

Mother's occupation:________________ Father's occupation:________________

Mother's education (highest level attained):_______________________________

Father's education (highest level attained):_______________________________

Mother's marital status:_______________ Father's marital status:_______________

Please answer the following general information questions about your child:

Birth weight:________________ Length of pregnancy:__________weeks

Birth order:_________________(e.g., 1 = 1st child)

Number of siblings:________________

Were there any complications during the pregnancy?__________________________

Has your child had any major medical problems?____________________________

Does your child have any hearing or vision problems?________________________

Please answer the following general information questions about your family:

Does your family have a pet (or pets)? (yes/no) ______

If you answered yes, please list your pet(s) indicating the kind of pet(s) (e.g., dog, cat, fish) and the number of pets: ______________________________________________________________

Participant#:__________ Researcher:________________________

Appendix D

Participant #______

Please check the box to indicate whether your child knows the name for the following objects:

☐ Car
☐ Bird
☐ Ball
☐ Dog
☐ Cat
☐ Banana
☐ Duck
☐ Boat
☐ Rabbit
☐ Airplane
☐ Cup
☐ Spoon
☐ Doll
☐ Shoe
☐ Flower
☐ Bottle
☐ Keys
☐ Sock

Appendix E

**Word Learning Task – CODING SHEET – Gaze during training**

| | |
|---|---|
| **Participant #** | |
| **Order** | |

| | |
|---|---|
| **Date Coded** | |
| **Coded by** | |

**Training Phase:**
**Coordinated or Discrepant**

*First look at time of utterance*

| | Robot | experimenter | own toy | elsewhere | Robot's toy |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| Total: | ______ | ______ | ______ | ______ | ______ |

**Training Phase:**
**Coordinated or Discrepant**

*First look at time of utterance*

| | Robot | experimenter | own toy | elsewhere | Robot's toy |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| Total: | ______ | ______ | ______ | ______ | ______ |

# Appendix F

## Word Learning Task – CODING SHEET – Touch

| | | | | |
|---|---|---|---|---|
| **Participant #** | | | **Date Coded** | |
| **Order** | | | **Coded by** | |

***Test: Coordinated 1st or 2nd***

| Trial | | Response | Correct (Y/N) | Trial |
|---|---|---|---|---|
| 1 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F C** |
| 2 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F C** |
| 3 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F C** |
| 4 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F C** |
| 5 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F C** |
| 6 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F C** |
| 7 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F C** |
| 8 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F C** |

| **Condition** | **Correct Object** |
|---|---|
| Coordinated | |
| Familiar | |

| **Totals** | **Correct** | **Incorrect** | **Score** |
|---|---|---|---|
| Familiar | | | |
| Coordinated | | | |

## Word Learning Task – CODING SHEET - Touch

| **Participant #** | |
|---|---|
| **Order** | |

| **Date Coded** | |
|---|---|
| **Coded by** | |

***Test: Discrepant 1st or 2nd***

| **Trial** | | **Response** | **Correct (Y/N)** | **Trial** |
|---|---|---|---|---|
| 1 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F D** |
| 2 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F D** |
| 3 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F D** |
| 4 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F D** |
| 5 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F D** |
| 6 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F D** |
| 7 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F D** |
| 8 | 1st Toy Touched<br>Toy Shown to Parent/Experimenter<br>(only code if both toys were touched simultaneously) | ______ | ______ | **F D** |

| **Condition** | **Correct Object** |
|---|---|
| Discrepant | |
| Familiar | |

| **Totals** | **Correct** | **Incorrect** | **Score** |
|---|---|---|---|
| Familiar | | | |
| Discrepant | | | |

Table 1

*Mean Number of Looks to the Robot, Infants' Toy, and Robot's Toy During Training in Experiment 1*

| | Condition | |
|---|---|---|
| | Coordinated | Discrepant |
| Looks to robot | 3.62 (0.57)[a] | 3.54 (0.76) |
| Looks to infant's own toy | 1.27 (1.08) | 0.77 (0.95) |
| Looks to robot's toy | 1.04 (0.92) | 1.50 (1.45) |

[a] Standard deviation in parentheses

Table 2

*Mean Number of Looks to the Speaker, Infants' Toy, and Speaker's Toy During Training in Experiment 2*

| | Condition | |
|---|---|---|
| | Coordinated | Discrepant |
| Looks to speaker | 3.72 (0.54)[a] | 3.48 (0.65) |
| Looks to infant's own toy | 1.68 (1.22) | 0.60 (0.71) |
| Looks to speaker's toy | 0.84 (1.03) | 2.40 (1.16) |

[a] Standard deviation in parentheses