The object of my desire: Infants' ability to infer desire from object-directed behaviors exhibited by a human and a non-human agent

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Abstract

The object of my desire: Infants' ability to infer desire from object-directed behaviors exhibited by a human and a non-human agent

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The purpose of the present four experiments was to examine the proposal that joint attention behaviors reflect an understanding of people as intentional agents. An object-request interactive paradigm was designed to document infant's understanding of the referential cues and of the agent (i.e., a person or a humanoid robot). The two-phase paradigm examined infant's ability to follow and to infer desires from three different referential cues: (1) gaze direction (i.e., head and eyes), (2) gesture (i.e., a grasping towards the target toy); and (3) positive vocal affect. After infants' attention was directed towards the adult, the agent focused her (its) attention towards one of two objects by displaying one of the following: a one-cue combination (gaze or gesture), a two-cue combination (i.e., gaze and gesture, gaze and positive vocal affect, gesture and positive vocal affect) or a three-cue combination (gaze, gesture, and positive vocal affect). Following cue presentation, a female experimenter requested that the infant give a toy. The first experiment examined 14-, 18-, and 24-month-olds' ability to infer desires from a human agent's prior display of object-directed behaviors. Although all infants could follow the cues to the target toy, only the 18- and 24-month-old were able to use these cues to infer a person's desire. In Experiment 2, the position of the two toys was switched

following cue presentation for 18- and 24-month-olds. This switch resulted in infants' poorer performance. The findings from Experiment 3 indicated that while 14, 18-, and 24-month-olds could follow the cues of a humanoid robot they did not attribute desires to this agent at any age. Moreover, Experiment 4 demonstrated that these latter findings were not due to the robot's inability to request the target toy on its own behalf.

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Chapter 1. General Introduction

Children's understanding of the mind is perhaps the most lively research area in developmental psychology, a topic that is today referred to as children's "theory of mind". The phrase 'theory of mind' refers to the ability to explain and to predict human actions by appealing to unobservable mental states (e.g., beliefs, desires, intentions). It is often described as our common sense or folk psychology. The considerable mass of research, particularly on preschool-aged children, has addressed two main questions: (1). What do children understand about the mind at various ages? (2). What are the mechanisms that account for the origins of, and the rapid transformations, in children's theory of mind understanding? The present thesis is primarily concerned with the origins of a theory of mind in infancy thus the principal theoretical explanations that account for the earliest abilities will be reviewed.

A long-standing tradition is to differentiate between two separate aspects of the mind when examining what children understand about the mind. The first aspect is children's understanding of the nature of entities. That is, mental entities (e.g., thoughts, dreams), unlike real objects, are nonmaterial and fleeting and cannot be seen and touched. Over 70 years ago, Piaget examined children's responses to open-ended questions (e.g., "What are dreams?") and he concluded that before the age of 7 young children could not differentiate between unobservable entities such as dreams and real objects. Additionally, it appeared to Piaget that an understanding emerged gradually over a sequence of stages. For instance, he described that young children initially perceive dreams as real (e.g., "the giant…was really there but it left when I woke up. I saw its footprints on the floor" Kohlberg, 1996, p. 6) then they understand that dreams are unreal, which is subsequently followed by understanding that dreams are invisible and originate from an internal location. Contrary to the interpretations made by Piaget, more recent research has demonstrated that children quickly develop adult-like understandings of this aspect of the mind. For instance, when 3-, 4-, and 5-year-olds are asked which dog (i.e., imagined or real) can be seen, petted, and touched even the youngest children understand that only the real dog can be (Wellman & Estes, 1986)

The other aspect, which is the focus of this thesis, is the causal aspect of the mind. It is the understanding that people's actions are caused by their beliefs, desires, perceptions, intentions, thoughts, and hopes. Additionally, it is the understanding that the content of these mental entities may originate, for example, from the person's knowledge of the world and physiological states (e.g., desires). Piaget believed that young children often confused psychological and physical causality and would assign either to physical objects or to human actions. However, more recent findings have lead to a different understanding about developmental changes in the causal aspect of the mind, particularly in the preschool years (e.g., Flavell, 1999).

From a young age, children predominately ascribe psychological explanations to human actions (Wellman, 1990). For example, children have formed the ability to represent others' beliefs by their fourth birthday (e.g., Wimmer & Perner, 1983). At about the same age that children pass false belief tasks they also show related conceptual understanding. For example, young children are not fooled by deceptive appearances (e.g., a rock that looks like a sponge) that make an object look one way when actually it is something entirely different "in reality" (Flavell, 1986). Along the same lines, preschoolers understand that two people who view an object from different positions can have different views on its' visual appearance, which is referred to as Level 2 perspective-taking (Flavell, 1992); they can deceive others to obtain a reward (e.g., Sodian, Taylor, Harris, & Perner, 1991; Peskin, 1992; Ruffman, Olson, Ash, & Keenan, 1993; Russell, Jarrold, & Potel, 1994); they have the ability to infer that characters who have visual access to target objects will have specific kinds of knowledge about these objects (e.g., colour, location, texture; Pillow, 1989; Wimmer, Hogrefe, & Perner, 1988; Pratt & Bryant, 1990; O'Neill, Astington, & Flavell, 1992); and they recognize that a character will be surprised when he/she finds something different from what was expected (e.g., Ruffman & Keenan, 1996).

However, there are earlier achievements. Simple desire reasoning dominates 2- and 3-year-olds' explanations of human actions (Wellman & Banerjee, 1991; Wellman & Wooley, 1990). Young children seem to understand that wanting something causes people to engage in goal-directed actions and to experience either sadness or happiness depending on whether their desire was fulfilled or not (Wellman & Wooley, 1990; Yuill, 1984). Additionally, in their third year, children begin to understand that a character's desire could be different from his/her intention (Feinfield, Lee, Flavell, Green, & Flavell, 1999; Shultz & Wells, 1985; Joseph & Tager-Flusberg, 1999). Also young children can consider that others can see things that they cannot but only if the object is in the person's straight line of vision, which is referred to as Level 1 perspective-taking (Flavell, 1992).

A striking finding from the body of work on preschoolers is that an understanding of desires precedes that of beliefs. In the theory of mind literature, a pervasive argument for this developmental trend is often based upon Searle's (1983) conceptions of causal relations: <u>mind-world</u> and <u>mind-mind</u> (see e.g., Gopnik & Wellman, 1994; Joseph &

Tager-Flusberg, 1999). Imagine that my son runs to the closet to get his coat. I might explain my son's willingness to put on his coat by attributing to him the desire to go to the park and the belief that there will be dogs and children there. On the one hand, this example illustrates that a belief-desire psychology seems to inevitably frame our understanding of a person's actions. On the other hand, it also demonstrates that desires and beliefs relate in different ways to the world. Beliefs generally refer to expectations, knowledge, and convictions and have a *mind-to-world direction of fit.* This is because beliefs are related to perceptual reality. If there is a mismatch between the two, beliefs then undergo revisions to match what reality is. In contrast, desires are typically hopes, wants, wishes, and preferences and have a *world-to-mind direction of fit.* That is, aspects of the world are made to fit our desires and moreover, revisions to our desires are not called for when they are unrealized.

In their productive vocabulary, children typically use desire terms such as *want* and *wish* before belief terms such as *know* and *thin*k (Bartsch & Wellman, 1995). Children's vocabulary thus supports empirical findings, which show that desires are easier to represent than beliefs. The direction of fit between mind and world suggests that this is because children may simply use a goal-matching strategy to determine whether a person's desire is satisfied or not. This interpretation is further supported by studies that demonstrated that when explicit goal information was provided 3-year-olds were good at understanding intentionality (i.e., choosing a picture that matched the character's goal). However, when children were asked to represent the means to the goal (i.e., choose a picture that depicted the character's prior intention) an understanding of intentional causation emerged at a later age (Astington, 1991). In this way, an understanding of beliefs (or intentional causation) is more sophisticated because it involves conceptual abilities, in particular, metarepresentation. For example, imagine that you arrived at the park prior to my son and you see that there are no dogs. Since you can metarepresent beliefs, in your mind, will be representations of my son and his desired objects as well as representations of the actual world (i.e., a park with no dogs). Finally, a *mind-mind relation* refers to a consideration of the relationships, for example, between desires, beliefs, and intended actions. People's intentions are typically born out of their desires and feelings of happiness or sadness are often linked to things such as wants and expectations.

Social Understanding in Infancy

There are few empirical studies that have explored an understanding of the causal aspect of the mind in infancy, otherwise known as the "dark ages" (see Flavell, 1999; Meltzoff, Gopnik, & Repacholi, 1999 for recent reviews). However, there is widespread agreement that young infants display a great deal of social sensitivity. From the first moments of life, it certainly seems that infants find people's faces, voices, and movements highly intriguing. Moreover, even newborns with their reflexive cries have some clever tools at their disposal to keep people close and to interact with them thus providing learning opportunities about humans. Indeed, many researchers suggest that infants must be born with certain social dispositions that will help them learn about people (see e.g., Poulin-Dubois, 1999 for a review). There are three influential views about the development of the causal aspect of the mind in infancy: *primary intersubjectivity, starting-state nativism, and core knowledge.*

The first view is that infants are born with the ability to engage in early dyadic interactions that are characterized by sensitive mutual understanding that is evidenced in coordinated activities between the baby and her caregiver; this is named *primary intersubjectivity* (Trevarthen & Hubley, 1978). Indeed, in the first months of life, infants begin to show interest in face-to-face interactions (Trevarthen, 1979) whereby they respond with smiles to adult's expressions and gestures and they produce more positive vocalizations when making eye contact with their parents who respond, in turn, with more vocal reactions (Trevarthen, 1979; Murray & Trevarthen, 1986). These interactions seem to indicate a general tendency to engage in active turn-taking episodes on the part of infants and caregivers. Moreover, uncoordinated activities produce distress in young infants (Murray & Trevarthen, 1986).

Along the same lines, the second view describes infants' ability to identify with people from birth as evidenced by coordinated activities but instead the emphasis is placed upon imitative acts. This is named a "*starting-state nativism*" (Meltzoff & Gopnik, 1993). Young infants seem to have a general tendency to imitate people's facial gestures and expressions as well as object-directed actions at a later age. These imitative activities promote a matching process whereby infants perceive equivalences between what the person is doing and their bodily experiences from own actions. In other words, infants learn that others are "like me". Importantly, learning about equivalences between self-other provides the groundwork for the later understanding that people's actions are goal-directed. A matching process may also enable older infants to gain further knowledge about emotions when they coordinate their emotional responses to that of the adult in novel and ambiguous situations (Astington & Gopnik, 1991).

A third view is that infants are born with a rudimentary knowledge of the world (e.g., Carey & Spelke, 1994). Experiences with the world eventually enlarge and revise what infants initially know. There is core knowledge about several distinct domains including physics, biology, and psychology. An understanding of naïve physics (i.e., the understanding of objects and their properties) seems to emerge in young infancy. For example, young infants understand that objects cannot move 'through' other objects and that objects move along connected, continuous paths (Spelke, 1994). Also, there is the understanding that an object needs to be firmly supported by another object in order not to fall down (Baillargeon, 1998). In other words, infants look longer at events that violate these core principles. There is even some understanding of naïve biology (i.e., the distinction between living and nonliving things) in infancy. This understanding is restricted to motion cues. Around 12 months of age, infants expect people's movements to be independent, self-propelled, and to move in irregular paths (see Poulin-Dubois, 1999, Rakison & Poulin-Dubois, 2001, for reviews). There are more advanced understanding in children's naïve theories of biology that emerges in the preschool years including: (1) animate beings grow and get bigger (e.g., Rosengren et al., 1991); (2) internal parts in animate objects are blood and bones whereas metal is more likely in an inanimate object (Gelman & Koenig, 2001); and (3) when injured, only animate beings can be healed whereas inanimate objects must be fixed (Backscheilder, Shatz, & Gelman, 1993). While more controversial than the other two, it is also proposed that infants have a naïve theory of psychology. For example, older infants' lay knowledge about people seems to include goal-directed principles such as "people act on things they see" and "people approach things they want" (Spelke, Phillips, & Woodward, 1995). Whether infants are born with certain social dispositions as suggested by the three views or quickly develop social skills through dense and rich experiences remains unclear. However, it seems most likely that young infants' early social abilities set the stage for theory of mind understandings later on.

Late in the first year, infants begin to engage with people in interactions that involve a third object. These 'triadic' (also named secondary intersubjectivity or shared reference) interactions allow infants to learn that people's behaviors are 'about' objects. People's psychological relations to objects can occur in various ways such as looking at it, fearing it, wanting it, and so on (Flavell, 1999). Recently, Carpenter, Nagell, and Tomasello (1998) proposed that there is evidence for an understanding of 'aboutness' even in 9-months-olds. They documented a three-step developmental sequence whereby infants progress from sharing attention to objects, to following other's attention to objects, and to directing other's attention to objects. First, around 9 months, infants engage in episodes of joint engagement (i.e., where an infant looks to the adult's face and then back to the object) and show objects. This seems to mean that infant's understanding of psychological relations is one that is restricted to the understanding that people can attend to objects, what they named '*understanding that*'. However, it is sometimes the case that an adult's attention is directed elsewhere when, for example, an infant wants to show an object. These sorts of instances enable infants to further determine what the adult is attending to in order to get her/him to attend to his desired goal; this they named '*understanding what*'. They documented that following an adult's gaze and pointing to objects (e.g., 11 ½ months) preceded infants' ability to use their own points (imperative or declaratives) to direct adult's attention to objects (e.g., 12 to 13 months).

Carpenter, Nagell, et al. (1998) suggested that this set of new social skills indicate that infants must understand something about the intentions of others. In their view, there are two precursors to this new understanding of people. The first precursor is along the lines of Meltzoff and Gopnik's (1993) account whereby infants show an early identification with people, that is, they perceive others "like me". The second precursor is the infant's first awareness that his own actions are intentional, which provides the starting-point to understanding other's actions as intentional (see also Barresi & Moore, 1996). In their view, the starting-point is means-end behaviors emerging around 8 to 9 months whereby infants seem to understand that their own instrumental acts (i.e., removing an obstacle to obtain an attractive toy) will achieve a desired goal. The authors assert that young infants, prior to removing the obstacle, first 'formulate independent goals' and thus recognize that their own actions are intentional. In this way, infant's newfound understanding of the 'relativity of means and end' provides the impetus for changing their understanding of others as well as themselves. However, other nonmentalistic interpretations are as equally popular such as object affordances, associative processes, emotional contagion, and attachment processes (see e.g., Baldwin & Moses, 1996, for a review). In other words, there is currently no consensus which interpretation (mentalistic or nonmentalistic) best explains the joint attention data.

To address these interpretive problems, recently researchers have designed new procedures that examine infant's understanding that human actions are goal-directed, and that people's actions are connected to their perceptions and emotions. Precursors to an understanding of people's actions as intentional and goal-directed have even been shown to emerge in young infancy (Woodward, 1998). There are various studies that have demonstrated that older infants have an understanding of people's referential intention in various contexts including imitation and language. For example, Meltzoff (1995) demonstrated that 18-month-olds infer the intended outcome of a failed intended act. In Carpenter, Akhtar, and Tomasello (1998)'s study, an adult modeled either an intentional or an accidental action, on novel objects, to a group of 14- to 18-month-old infants. The results indicated that the adult's attentional and vocal cues as well as the physical manipulation of the objects guided infants to reproduce the intentional actions significantly more often than the accidental actions. However, using a larger sample of infants from 14- to 18-months-old and a similar design, Olineck and Poulin-Dubois (in press) found that the 18-month-olds differentiated between intentional and accidental actions significantly more often than the 14-month-olds. That is, the 18-month-olds were found to have a more advanced understanding of people's intentional acts.

In language learning studies, older infants have also demonstrated intentional understandings. By 18-20 months, infants can appropriately map a novel word to only one of two novel toys indicating their appreciation of the adults' referential cues (Baldwin, Markman, Bill, Desjardins, Irwin, Tidball, 1996; Baldwin, 1993; Baldwin & Moses; 1994; Dunham, Dunham, & Curwin, 1993; see also Tomasello, 1995, for a review). By 24-months-old, infants understand that a person's referential cues can be directed to even an absent object (Akhtar & Tomasello, 1996). There are also a few studies that demonstrate that infants in the second year of life connect people's perceptions and emotions to their previously stated desire (e.g., Poulin-Dubois, 1999; Phillips, Wellman, & Spelke, 2002). While these studies clearly illustrate that 18-month-olds possess a nascent theory of mind understanding, researchers have not resolved the issue of how to interpret those social skills that emerge late in the first year.

In summary, these findings support the view that infants understand that the actions of humans are goal-directed, which develops from earlier social interactions with people such as turn-taking episodes and imitative acts (e.g., Woodward, 1998; Meltzoff, 1995; Poulin-Dubois, 1999). However, an alternative view is that infants selectively focus upon certain features of objects that are indicative of goal-directedness thus resulting in broad attributions of mentalism to entities. This has been named the *cue-based account*. There are several findings that suggest that sometimes infants respond to actions by inanimate objects as goal-directed or as rational (see e.g., Johnson, Slaugher & Carey, 1998; Johnson, Booth, & O'Hearn, 2001; Biro & Leslie, 2004; Gergely, Nadasdy, Csibra, & Biro, 1995). For example, an inanimate object's shift in gaze elicits gaze following in 12-month-olds (Johnson, Slaughter, & Carey, 1998).

By the end of infancy, there are also other important achievements that indicate infants have a nascent folk psychology. One example is the first indication of self-awareness. On the self-recognition task, older infants will typically touch the red dot on their nose rather than the one they see in the mirror (Lewis & Brooke-Gunn, 1979). It is not unusual for infants to refer to themselves with a personal pronoun such as "me" or to prefer looking at photographs of themselves rather than other infants (Lewis, 1987). Also, Levine (1983) suggested that 20- to 28-month-olds who are more self-aware are much more likely to say "mine" when playing with their toys than toddlers who are not so self-aware. In his view, the toddler's display of possessiveness is not indicative of aggressive behaviors but rather it demonstrates how the child defines himself/herself. For instance, a toddler perceives playing with dinosaurs and toy cars as part of who he/she is. This may be accurate but there are surely instances where the child utters "Mine" as a defensive tactic (e.g., to stop another child from getting the toy). However, Levine's interpretation is in line with older preschoolers who identify themselves with concrete and observable characteristics, for example, "I have brown eyes" and "I love pasta" (Damon & Hart, 1988). Additionally, infants display empathy by comforting others in distress. In their symbolic play, infants assign human activities and experiences to inanimate objects. For example, toy characters are given food and take a bath. Potential experiences can also be played out, for example, the toy finds the food too hot and it must first cool it off with its breath.

Theoretical Explanations of Infants' Understanding of the Mind

With regard to the second main issue in theory of mind development, that is, the mechanisms of changes, there are several principal theoretical explanations that consider the origins of our theory of mind understandings including "Theory" and Modular Theory.

Theory theory

In the "Theory theory" approach similarities between scientific theories and the child's folk psychology are notably emphasized. However, infants are not seen as scientists in the broadest sense (e.g., using reasoning skills). Rather, they are seen to construct intuitive naïve theories that gradually and successively approximate our lay knowledge about the mind. Intuitive theories possess many properties of scientific theories: there is an abstractness as mental entities are intangible; there is coherence as the mental entities form a system in which there are clear interrelationships; and there is explanatory and predictive power. Children's conceptual changes of the mind are also linked to theory changes, similar to historical scientific paradigm shifts (Kuhn, 1962). Theory change occurs because eventually children confront counter-evidence from new data or from a wealth of information they acquired over numerous experiences that disconfirms their existing theory. Transitions from the old theory to the new one then take place. Initially, the old theory is left as is because the counter-evidence is ignored. This denial ultimately gives way to the formation of ad hoc auxiliary hypotheses that will account for some of the counterevidence and leave the old theory's ability to generalize intact. Novel theoretical ideas are initially under the shadow of the old theory but later they assist in reorganizing children's knowledge and ultimately become the central theories shaping their understandings (Gopnik & Wellman, 1994).

Wellman (1990) proposes that theory changes account for three major developmental shifts in children's conception of the mind over the first four years of life, with each shift corresponding to the understanding of new mental states. One shift occurs around 2 years of age when infants are described as *simple desire psychologists*. That is, 2-year-olds are seen to simply perceive intentional actions in terms of underlying desires, perceptions, and emotions (Wellman, 1993). There is the understanding, for example, that others can have "internal longings" that are directed towards or are about actual objects and events in the world. In other words, there is no adult-like understanding that desires could be directed towards representations of objects. A second shift occurs around 3-year-olds to a more advanced *desire-belief psychology*. At this age, children seem to still understand desires as primary in underlying human actions. However, there is an emerging understanding of beliefs when they are clearly stated and when they are directly connected to the person's desire (e.g., Wellman & Bartsch, 1988). This understanding has received different terms including the 'copy theory' and the 'situation theory' (Wellman, 1990; Perner & Davies, 1991). The third shift occurs during the fourth year of life when infants develop a *belief-desire psychology* that corresponds to their emerging ability to represent reality rather than just exactly mirroring what is. In particular, there is a nascent understanding that someone can believe something to be true even when it is not the case – that is, have a false belief (e.g., Wimmer & Perner, 1983). Similar to adults, albeit much less sophisticated, infants regularly use beliefs in their explanations of human actions.

Modular Theories

Fodor (1983) first wrote about innate psychological structures that he named modules. In his view, perceptual systems are modular as they are domain-specific, encapsulated, mandatory, fast, and hard-wired in the person. Systems involve three things: input, operations, and output (Baron-Cohen, 2002). The operation is applied to the input to produce the output. Input is provided by sensory information and output information is derived from conceptual processes, that is, representing what is seen. For example, seeing a dog and thinking "there is a dog" is a perceptual process. In contrast, thinking "the dog is going to bite me" reflects a separate conceptual process. Finally, Fodor (1992) describes operations as innate computational resources (i.e., the ability to make inferences from analyses of perceptual information) that automatically organize an understanding of people's actions in terms of abstract mental representations such as desires and beliefs. Young children's failure to understand other's beliefs reflects a performance constraint; with increasing age computational resources are made more accessible (Fodor, 1992). Leslie (1994) and Baron-Cohen (1994, 1995) expanded Fodor's work on modules to the area of theory of mind development.

Modular theorists argue that evolution through the process of natural selection shaped the cognitive architecture of the human brain. That is, modules/mechanisms evolved specifically to enable 'mind-reading' in our species; one of the many adaptive problems that our ancestors faced in their environments (Cosmides & Tooby, 1994). Baron-Cohen suggests that evidence for the evolutionary hypothesis is threefold; social sensitivity does not seem to exist in other species, emotional and social functioning is severely limited in certain people (i.e., those with autism), and there is no apparent explicit teaching of mind-reading to infants and children. Another key feature of modular theories is that learning experiences (e.g., observational, reinforcement) in the child's environment (e.g., seeing people respond with fear to dogs, simply moving around freely, listening to people talk about desires) along with maturation, trigger modules to come on-line but do not change the nature of the modules.

Leslie's theory

Leslie (1994) proposed that conceptual changes in folk psychology originated from innate mental modules that form a core cognitive architecture. Each of the three mental modules provides specific information, in turn, about an Agent. First, at 3- to 4-months a theory of physical objects (ToBy) comes on-line informing infants about the mechanical properties of Agents. Infants recognize specific patterns of motion (e.g., source is self-propulsion, changes in movement) to come from an internal source of energy that Leslie names "Force" and is associated with certain entities. Second, a theory of mind mechanism ($ToMM_1$) matures around 6 to 8 months allowing infants to understand the actional Agent. Infants represent an internal source of energy (e.g., a striving) flowing outward from the Agent that causes people to act to achieve outcomes (e.g., turn their head to look at something). Finally, between 18 and 24 months of age, $ToMM_2$ comes on-line providing infants with information about the metarepresentational cognitive properties of Agents. Thus, Agents are understood to have attitudes about objects and events that are real or possible. The earliest signs of cognitive understandings are pretense, desires, and perceptions.

Baron-Cohen's theory

In his work, Baron-Cohen (1994, 1995) emphasizes eyes as a 'window into other minds'. Two modules/mechanisms come on-line during the first year of life, which provide perceptual information and build dyadic communications. The first is the Intentionality Detector (ID) that allows infants to perceive behavior as volitional (i.e., having goals). The second is the Eye Direction Detector (EDD) that is sensitive to eye-like stimuli and to shifts in eye gaze to allow the inference of "seeing". The ID and EDD provide perceptual information to a later developing module around 12 months, the Shared Attention Mechanism (SAM) that builds triadic representations. In this way, infants can participate in joint attention episodes and also infer that the person's eye gaze indicates her/his desire. Baron-Cohen further claims that eye gaze is the most important cue used to infer a person's mental state.

Baron-Cohen, in particular, has argued most fervently that the findings on autistic infants support his account. Briefly, autism is a pervasive developmental disorder that has its onset in the first 36 months, is more prevalent in boys than girls, has a high likelihood of mental retardation (75%), and is characterized by severe impairments in emotional, social, and communicative functioning (American Psychiatric Association, Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, 1994). Baron-Cohen and his colleagues have provided considerable evidence showing that infants with autism exhibit social deficits in the precursors to theory of mind as well as on theory of mind tasks. For example, even as infants, children with autism show little interest in participating in joint attention acts such as showing objects to others, looking to see what someone else is looking at, and directing adult's attention to objects with their own points (Charman, Swettenham, Baron-Cohen, Cox, Baird, & Drew, 1998). Also, infants with autism are poor at deceiving others; have difficulties making mental-physical (i.e., real) distinctions, lack interest in pretend play, and fail false-belief tasks (Baron-Cohen, Leslie, & Frith, 1985; Sodian & Frith, 1993; Baron-Cohen, 2001). Conversely, several abilities have been found to be unimpaired including imperative looks (i.e., a request for a mechanical toy); the understanding of folk physics, perception, and "noncognitive" emotions (Baron-Cohen, 2001; Tager-Flusberg, 1992; Charman et al., 1998; Leslie & Frith, 1998). Baron-Cohen (2002) suggests that these findings support the "extreme male brain theory of autism" – an explanation of how people with autism understand people's behaviors. In his view, the ability to empathize is impaired (i.e., imputing mental states to others and responding appropriately to people's expressed feelings) whereas the ability to systematize is exaggerated, that is, autistics can be superior on rule-based areas such as math and chess.

Theory theories versus Modular Theories

Theory theorists and Modular theorists provide equally compelling explanations of children's conceptual changes. Moreover, the evidence does not always discriminate

Theory theories from Modular ones. That is, either camp can assert that the data reflects their position of how theory of mind understanding comes about. For example, equally appealing are innate modules or an innate starting-state as explanations for infant's early social sensitivities. As well, these two different theories could both account for evidence that the understanding of desires and beliefs are universal at least in those countries studied including the U.S.A., Austria, Germany, Canada, UK, Australia, Turkey, Japan, China (Hong Kong) (see e.g., Avis & Harris, 1991; Vinden, 1996, 2002; Tardiff & Wellman, 2000; Wellman, 2002). In other words, children universally develop mentalistic understandings because specified innate modules come on-line or the essential evidence about people's desires and beliefs are the same everywhere (Wellman, 2002).

Although, recent investigations of theory of mind abilities in various populations that either exhibit deficits or exhibit even greater mentalistic understandings may distinguish the two theoretical positions. For example, in the case of autism, modular theorists argue that the absence of mentalizing abilities provides strong evidence that there is an innate neurological insult to the theory of mind module. In their view, theory of mind deficits cause impairments in social, emotional, and communicative domains. On the other hand, Theory theorists can also easily explain the findings from studies conducted with autistic children. For instance, an initial inability to recognize and to 'read' people may lead to impoverished social interactions within the first year, which in turn, causes disruptions in theory of mind developments (Astington & Gopnik, 1991). One way to distinguish these two positions is to examine nonautistic populations whose impairments are limited to perceptual systems. This body of work has clearly documented that visually impaired or hearing-impaired children perform significantly poorer on false-belief tasks than same-aged unimpaired infants (e.g., Russell, Hosie, Gray, Scott, Hunter, Banks, Macaulay, 1998; McAlpine & Moore, 1995). These findings are attributed to few earlier experiences of participating in joint visual attention episodes (e.g., following a person's point, head turn or exposure to conversations about mental states). There is also further evidence that certain familial environments can promote a greater understanding of theory of mind. For example, infants with siblings pass false-belief tasks earlier than singletons (Perner, Ruffman, & Leekam, 1994; Jenkins & Astington, 1996) and infants who grow up in families that spend a great deal of time talking about feelings are described as sophisticated in their abilities to talk about their emotions and in particular consider why they feel as they do (Dunn, 1991). The findings from these various studies indicate that the frequency and quality of social interactions are necessary for normal theory of mind development. Moreover, it is possible to interpret the findings to also indicate that social experiences could change the nature of mind-reading modules if they exist. Such an interpretation undermines one of the basic claims made by Modular theorists. Conversely, the pattern of results on children with autism or with populations who are visually- or hearing-impaired support those theoretical speculations about the underlying causes of autism that are made by Theory theorists. More research is required to provide a stronger differentiation of these two theoretical accounts.

An 'Adequate' Theory

Seemingly in the same breath that Theory theorists contend that their account is the most plausible one they also assert that their theories lack comprehensiveness. Many researchers now sensibly argue that an adequate theory should include elements from a variety of theories to reflect the biopsychosocial forces that shape infants' understanding of the mind (see e.g., Astington & Gopnik, 1991; Flavell, 1999; Wellman, 2002). Even certain elements from modular theories would play a key role in an adequate theory. For example, it seems that normal brain maturation is critical to rapid and successive understandings of theory of mind and that this does not occur in the case of autism, whose cause may be linked to as yet unspecified damaged regions of the brain that enable the ability to 'read' people (e.g., Baron-Cohen, 2002). In addition, it is possible that innate psychological structures impose performance limitations on theory formations or perhaps provide the "starting-point" for the special recognition of people, that social experiences then further elaborate and revise (Astington & Gopnik, 1991). There are also alternative accounts that provide additional key elements in an adequate theory. A brief review will be provided, however, an evaluation of the merits of these accounts is beyond the scope of this thesis.

For example, *Simulation Theory* holds that we first become aware of our own wants, feelings, and beliefs through an introspection process, which provides the impetus to understanding others (Harris, 1990). Somewhat similar to placing themselves in another's shoes or role taking, people first imagine the other also having desires and beliefs and then they simulate how they would feel, think, and do in the particular situation. In other words, first gaining knowledge of one's own first person psychological experiences provides the force for simulating how another thinks or feels.

Another is a *Cultural Learning* account that emphasizes the role of evolutionary forces in human culture. Vygotsky (see e.g., Tomasello, 1998) first introduced the notion that human cognitions are the way they are because infants grow up in social or cultural contexts. Tomasello (1998) recently proposed how human infants, unlike the young of other primate species, are able to engage in cultural learning. That is, it is the understanding that people's behaviors are intentional, emerging around one year of age, which provides the impetus for infants to learn about human artifacts and symbolic tools (i.e., language). However, understandings gleaned about people's goal-directed actions in structured social interactions (e.g., peek-a-boo games), as well as an intrinsic motivation to attend to what people are doing with artifacts and to engage in face-to-face interactions, also enhance the process of cultural learning.

Finally, Nelson (1996) has extensively studied 'simple' *scripts*, what she defines as internalized cognitive models of familiar and repeated social situations (e.g., birthday parties, Christmas, weddings) that organize children's psychological knowledge. Scripts allow for shared meaning between members of a culture, and they provide simple predictions, but lack explanatory power.

In summary, there is widespread consensus that a theory formation process provides the most plausible interpretations of the existing data (e.g., Astington & Gopnik, 1991; Flavell, 1999; Wellman, 2002). Moreover, it seems likely that various important processes, besides theory formation, contribute to infants' developing conceptions of the mind. However, the present four experiments do not directly examine whether infant's natural 'scientific devices' (e.g., theory formation and testing) instigate changes in conceptual understandings. Instead, the experiments endeavor to examine when infants develop a causal understanding of the mind.

Five goals were investigated in the four experiments. An overall goal was to design a more naturalistic procedure since habituation or familarization ones have often been used to test infants' understanding of desire. In contrast to habituation procedures, the present object-request procedure required infants to give toys to the agent. In this way, the present procedure provided a more stringent test of infants' understanding of desire than a habituation one because their looking time at the toys was not the only measure considered.

The first experiment was designed with two goals in mind. One goal was to examine whether there was a developmental progression of desire understanding during the second year. It was predicted that infants as young as 14 months would shift their attention to follow the gaze and gesture of a person. However, it was expected that only the 18- and 24-month-olds would infer another person's desire from cues, and that the 14-month-olds would show no such understanding. In other words, it was expected that a dissociation between gaze following and desire attribution would emerge during the second year of life. A second goal was to determine the relative weight of different referential cues for infants to infer peoples' desires. It was predicted that infants would require more than one referential cue to determine a person's desire based on object-directed actions.

A fourth goal was designed for the second experiment. The position of the two toys was switched following cue presentation in order to provide a more stringent task for 18- and 24-month-olds. That is, it was predicted that infants would relate the person's cues to the desired toy and not to the other toy in the same location when requested to give the appropriate toy to the person.

The fifth goal, examined in Experiments 3 and 4, was to clarify the current debate about infants' concept of agent. One camp asserts that infants attribute desires solely to humans. Conversely, the cue-based approach camp claims that infants possess a broad concept of agent that includes all objects that possess human properties (e.g., self-propelled motion; Premack, 1990). A humanoid inanimate object (i.e., a robot) was created to determine which camp's interpretations were more plausible. It was expected that infants would shift their gaze to follow a nonhuman agent's cues to toys in the same way as they would for a human, but that they would not attribute desires to a nonhuman. As mentioned earlier, the tasks in the four experiments were not designed to test major predictions of Theory theory. Nevertheless, the four experiments have one common thread, namely, the goal to highlight weaknesses in predictions made by Modular theorists. That is, Experiment 1 was designed to clarify the importance of eye gaze for infants in the second year of life whereas one of the important goals of Experiment 3 was to show that infants do not attribute desire to any agent that is self-propelled.

Chapter 2.

The object of my desire: Infants' ability to infer desire from object-directed behaviors exhibited by a human and a non-human agent

Paula Bennett, Diane Poulin-Dubois, and Samantha Nayer

Contributions of Authors

This section will document the contributions of the first author in the article titled, "The object of my desire: Infants' ability to infer desire from object-directed behaviors exhibited by a human and a non-human agent". In the article, results are reported on 205 participants who were tested in Dr. Diane Poulin-Dubois' laboratory.

In the first series of studies (i.e., the person agent condition) the first author tested 120 participants divided into five separate groups by age and by condition: 1) NonSwitch Condition: 14-, 18-, and 24-month); 2) Switch Condition: 18- and 24-month-olds. As well, the first author coded looking time and object choice, entered the data into an SPSS spreadsheet, and conducted the analyses. Independent research assistants conducted inter-rater reliability tests on the coding as well as ensured that data entry was accurate.

In the second series of experiments, 72 infants divided into three age groups (i.e., 14-, 18-, and 24-month-olds) were tested in a robot agent condition. The first author along with Samantha Nayer tested the participants in two of the three age groups: 14- and 18-month-olds. The first author coded object choice and conducted all the analyses for the participants in the three age groups.

Dr. Diane Poulin-Dubois supervised the testing of the control group of thirteen 18-month-old participants as well as the testing of the 24-month-old participants in the Robot Agent condition. Honors students conducted the testing, coding, and data entry for these two age groups. As well, independent research assistants ensured that data entry was correct and conducted inter-rater reliability tests on looking time and toy choice. The first author trained and supervised research assistants on looking time and toy choice coding and as well conducted the analyses for these two age groups.

Abstract

The proposal that joint attention behaviors reflect an understanding of people as intentional agents was examined in four experiments. A person or a humanoid robot displayed object-directed behaviors towards one of two toys in an object-request interactive paradigm. The agent (or a female experimenter) then verbally requested that infants give their desired toy. Infants' abilities to gaze follow to the desired toy and to infer desires were examined. In Experiment 1, the effect of different object-directed behaviors displayed by a person upon infants' ability to infer desires was examined in 14- 18-, and 24-month-olds. Although all infants could follow the cues to the target toy, only 18- and 24-month-old were able to use these cues to infer a person's desire. Switching the position of the target toys in Experiment 2 resulted in 18- and 24-month-olds' poorer performance. In Experiments 3 and 4, the proposal that infants attribute intentionality broadly to entities was investigated in 14-, 18-, and 24-month-olds. All infants could follow the cues of a humanoid robot but did not attribute desires to this agent. These findings indicate developmental changes in infants' concept of mentalistic agents during the second year.

By preschool age, children have a well-developed theory of mind (e.g., Flavell, 1999). For example, children have formed the ability to represent others' beliefs by their fourth birthday (e.g., Wimmer & Perner, 1983). Simple desire reasoning dominates two and three-year-olds' explanations of human actions (Wellman & Banerjee, 1991; Wellman & Wooley, 1990). Young children seem to understand that wanting something causes people to engage in goal-directed actions and to experience either sadness or happiness depending on whether their desire was fulfilled or not (Wellman & Wooley, 1990; Yuill, 1984). Additionally, in their third year, children begin to understand that a character's desire could be different from his/her intention (Feinfield, Lee, Flavell, Green, & Flavell, 1999; Shultz & Wells, 1985; Joseph & Tager-Flusberg, 1999). More recently, innovative nonverbal procedures have been designed to explore the origins of theory of mind understanding in infants (e.g., Repacholi & Gopnik, 1997; Poulin-Dubois, Demke, & Olineck, in press). In particular, this area of research has focused upon infants' ability to react to peoples' nonverbal behaviors including eye gaze, gestures, and emotional displays. There is a consensus that infants are sensitive to people's attentional and emotional cues by their first birthday (e.g., see Carpenter, Nagell, & Tomasello, 1998). Nevertheless, there is controversy regarding the interpretation that infants make on the basis of these behaviors, with regard to people's mental world.

Gaze direction is one of the first social cues infants initially follow. Even 2-month-olds will occasionally follow an adult's head and eye turn to an object (Scaife & Bruner, 1975). More reliable gaze following appears at 6 months. However, young infants will scan only to the first visible target even though a more distant target was the object of the adult's gaze (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; cf. D'Entremont, Hains, & Muir, 1997). Gaze following continues to develop until the middle of the second year (Carpenter, Nagell, & Tomasello, 1998; Corkum & Moore, 1995; Moore & Corkum, 1994; Morissette, Ricard, & Gouin-Décarie, 1995; Moll & Tomasello, 2004).

There have been several studies that demonstrate that following of head orientation emerges earlier than eye orientation (Butterworth & Jarrett, 1991; Moore & Corkum, 1998; Moore, Angepoulos, & Bennett, 1999). For example, one-year-old infants will follow an adult's head turn even when her eyes are looking directly ahead, at the infant (Moore & Corkum, 1998). Around the age of 18 months, infants consistently follow an adults' eye turn (Moore & Corkum, 1998; cf. Caron, Butler & Brooks, 2002). While not significantly different at this age, head and eye movement combined provides a stronger cue than the eye movement cue alone (Butterworth & Jarrett, 1991).

Gestures are also important social cues that infants show sensitivity to from an early age. Around 10 months, infants begin to use their own pointing or reaching gestures to show objects (i.e., declaratives) and, a few months later, to direct adults' attention to objects (i.e., imperatives; Bates, Camaioni, & Volterra, 1975; Carpenter, Nagell, & Tomasello, 1998). By their first birthday, infants consistently follow others' points to objects (Butterworth & Grover, 1988, 1989). In her work, Woodward (1998) used a habituation paradigm to examine whether young infants understand an actor's hand reaching and grasping an object as goal-directed behaviors. She found that even 6-month-olds perceived human actions as goal-directed. Additionally, young infants did not perceive either an inanimate claw touching an object (Woodward, 1998) or an unintentional human action (i.e., hand falling onto an object) as goal-directed behaviors (Woodward, 1999). In another experiment, Woodward (2001) found that 12-month-olds, but not 7- and 9-month-olds perceived a person's looking behavior (i.e., eye and head turn) toward an object as goal-directed. The younger infants in this experiment were successful when gaze was combined with a grasping action. More recently, Sodian and Thoermer (2004) attempted to test the generalizability of Woodward's (1998, 2001) findings. In their experiments, three separate groups of 12-month-olds were habituated to an actor displaying facial and verbal enjoyment while she either: (1) gazed at the object; (2) gazed and grasped the object; and (3) gazed and pointed to the object. Contrary to Woodward (2001) the gaze cue alone was not seen as goal-directed by 12-month-olds. However, the 12-month-olds did form the relation between looker and object when gaze was paired with either a grasping or a pointing cue.

A third social cue that might provide infants with information about people's minds is emotional displays. From a young age, infants discriminate happy from sad, angry, and fearful facial expressions (Soken & Pick, 1999; Ludemann & Nelson, 1988). By their first birthday, infants respond to adult's facial expressions as if they are meaningful reactions to novel objects by either approaching or avoiding an object; this is known as social referencing (e.g., Campos, 1983; Feinman, 1982). However, while findings illustrate that12-month-olds respond differentially to positive and negative vocal intonations alone (Mumme, Fernald, & Herrera, 1996) and in combination with facial expressions (Baldwin & Moses, 1994; Walden & Ogan, 1988; Hornik, Risenhoover, & Gunnar, 1987), there is inconsistent evidence for facial expressions alone (see Mumme, Fernald, & Herrera, 1996, for a review). Nevertheless, the results from these social referencing studies highlight that vocal affect provide infants with a powerful cue to peoples' emotions (Baldwin & Moses, 1994).

Although researchers agree that joint attention skills are well developed by the end of the first year, there is no consensus regarding the level of infants' understanding of peoples' social signals. That is, do infants understand a person's gaze, gesture or expression of vocal affect as connecting him or her mentally to the world? Several researchers contend that joint attention behaviors (e.g., gaze, gesture) themselves are evidence for infants' understanding of people as intentional agents (Tomasello, 1995; Carpenter, Nagell, & Tomasello, 1998). Other theorists assert that one-year-olds understand intentional actions simply in terms of learned patterns of behaviors (Corkum & Moore, 1995). Other alternative explanations to intentionality include mood contagion and associative processes such as temporal contiguity and stimulus saliency (Moses, Baldwin, Rosicky, & Tidball, 2001; Moore & Corkum, 1994; Baldwin & Moses, 1994; Moore et al., 1999).

Recently, a new line of research has aimed to clarify what infants understand about a person's attentional and emotional cues. The most compelling evidence thus far has emerged from research conducted in the emotion domain. In one study, Repacholi (1998) compared 14-month-olds' behaviors upon seeing an adult express pleasure (facial and vocal) towards the invisible contents of one box and disgust towards the contents of another box. While infants subsequently touched both boxes they were more likely to search within the box that contained the "positive" object rather than the box that contained the "negative" object. In another study, 12- and 18-month-olds observed an adult direct different facial and vocal emotional expressions (i.e., pleasant or disgusting) to two toys; one toy was labeled in a joint-attention condition whereas the other toy was labeled in a discrepant-attention condition (Moses et al., 2001). The authors found that, regardless of condition, infants played more with the pleasant object than with the disgust object. Further, they attended to the adults' focus of attention and shifted their gaze toward the other toy when it was discrepant with their own. These findings were interpreted as demonstrating infants' ability to monitor the attentional focus of people when interpreting the referent of emotional displays (see also Mumme & Fernald, 2003).

An interactive object-request task has also been used to examine infants' understanding of desires on the basis of facial and vocal expressions (Repacholi & Gopnik, 1997). A female adult requested 14- and 18-month-olds to give her food once she displayed either pleasure or disgust upon tasting the cracker and the raw broccoli. In other words, the adult sometimes expressed disgust upon tasting the cracker. The 18-month-olds consistently gave the adult the desired food, even when it did not match with their own preference (i.e., the cracker). In contrast, the 14-month-olds were poor food givers (i.e., 35% response rate) and they did not give the desired food more often than chance. These results imply that during the second year there is a developmental progression in infants' understanding of desires based on emotional cues.

In order to assess whether infants make predictions about a person's emotional state from observing object-directed actions (e.g., she will be happy when she gets the object that she attended to), Poulin-Dubois (1999) compared 18-month-olds' looking time responses to two screens following a televised movie depicting an actor's desire towards one of two objects. In the movie, the actor stated, "I want that one" when she looked at and pointed to one of the two objects. A second actor gave her either the desired object in one condition or the undesired object in another condition. In the test phase, infants tended to look longer at the screen where the actor displayed a sad facial expression (unfulfilled desire) and there was a reverse looking pattern in the fulfilled desire screen condition. Thus, the 18-month-olds could successfully connect the adult's prior expression of desire to subsequent emotional displays. In the same way, preschoolers do with stories (e.g., Wellman & Wooley, 1990). Using a habituation paradigm, Phillips, Wellman, and Spelke (2002) tested a similar hypothesis in even younger infants. In one experiment, 8- and 12-month-olds saw an actor gaze toward one of two familiar toys (i.e., a kitty) with a joyful facial expression, and heard her say a positive vocalization. Subsequently, in an outcome scene, infants saw the actor holding the desired toy. Infant's looking time was then compared on two test events: consistent (i.e., actor holding desired toy) and inconsistent (i.e., actor holding undesired toy). Only the 12-month-olds looked significantly longer to the inconsistent event. In follow-up experiments, the authors removed the outcome scene. That is, no physical link was made between the actor's facial and vocal expressions and the toy. The 14-month-olds, but not 12-month-olds, succeeded at making a perceptual-emotional and object link. The authors proposed that their findings support a lean interpretation whereby infants responded to adults' intentional actions as familiar behavioral sequences (Phillips et al., 2002).

The research reviewed thus indicates that infants possess an early competency to decode people's emotional signals as object-directed actions. This competency initially allows infants to act towards their environment in accordance with people's affect and then soon afterwards allows infants to make inferences about the ways people ought to respond emotionally to outcomes. However, few studies have explored infants' understanding of the information provided by gaze direction. In their series of studies using verbal interviews, Lee, Eskritt, Symons and Muir (1998) presented infants with either a static facial display or a televised actor, both of which provided directional cues (such as eye gaze, head orientation, and pointing) to one of many objects. Then infants were asked two questions: "where is Larry [Giggles] looking?" and "what does Larry [Giggles] want?" The first question assessed an understanding of eye gaze direction whereas the second determined their understanding of desire. By 3-years of age, infants could judge where a person's eyes were oriented in the static face pictures (see also Doherty & Anderson, 2000). The 3-year-olds also successfully used pointing direction and head orientation in the static face conditions to determine the focus of attention as well as to make inferences of desires. However, only the 4-year-olds, in the static face conditions, understood that eye gaze direction indicated a person's desire (see also Baron-Cohen & Cross, 1992; Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995; Pellicano & Rhodes, 2003). The authors found evidence for an understanding of desire with the eye gaze direction cue in 3-year-olds only when they viewed televised dynamic scenes. However, when a pointing cue conflicted with the eye gaze cue, 3-year-olds favored the former, even when it was incorrect. Preliminarily results were also found for 2-year-olds using televised dynamic scenes. The 2-year-olds successfully made inferences of desires when provided with eye gaze in combination with head orientation and pointing, or with head orientation alone.

A nonverbal seeing=knowing task was recently designed to test a more advanced understanding of how gaze direction affects future actions. Poulin-Dubois, Sodian, Metz, Tilden and Schoeppner (2004) tested the understanding that a person will correctly search for an object based upon whether they had prior visual access to the hidden location in 14- to 24-month-olds using a violation of expectancy paradigm. Infants watched movies in which an actor hid a toy under one of two buckets when a second actor was either blindfolded (no visual access condition) nonblindfolded (visual access condition). In each condition, infants' looking time was compared to two screens: one depicted the second actor looking at the target bucket and the other depicted the second actor looking at the nontarget bucket. Looking time results indicated that by 18 months, infants expected the actor to search for a toy under the target bucket when she had prior visual access and did not expect her to do so when she was blindfolded. While these results indicate that 18-month-olds have an understanding of eyes, the authors acknowledge that infants' success on their task may simply reflect an understanding of behavioral regularities (see Poulin-Dubois et al., in press).

Taken together, it appears that infants understand certain features (e.g., gaze direction) of people's actions as goal-directed. An important issue to determine is whether these inferences are specific to humans. That is, whether infants have a broad concept of intentional or mentalistic agent. According to one view, infants only understand the actions of humans as goal-directed (e.g., Woodward, 1998). This understanding may have its roots in earlier dyadic and triadic experiences with people including turn taking and imitation (e.g., Woodward, 1998; Meltzoff, 1995). It does seem that from an early age, infants provide differential responses to human and nonhuman communicative actions. Infants imitate facial expressions and hand gestures that people model but do not do so when inanimate objects 'model' acts (Legerstee, 1991). By 2 to 3 months of age, social behaviors such as smiling and vocalizing occur in the company of people, but not inanimate objects (see Legerstee, 1992, for a review). From 6 months to 1 year, when inanimate objects either appear to be part of a conversation with a person, or perform self-propelled motions, infants respond with signs of trepidation (e.g. surprise, crying) (Legerstee, Barna, & DiAdamo, 2000; cf. Molina, Spelke, & King, 1996; Poulin-Dubois, LePage, & Fernald, 1996).

Recent empirical findings from different contexts also provide evidence that infants possess specific reasoning skills about the actions of people. Meltzoff (1995) designed a behavioral re-enactment procedure that examined 18-month-olds responses to a human and to a non-human agent. In one study, some 18-month-olds observed an actor (person or a machine) demonstrate a target action (e.g., insert a peg into the hole of a box) whereas others observed the actor fail in the intended action. Thus, infants who observed the failed attempt did not see the outcome. The findings indicated that 18-month-olds reproduced both the person's target actions and the outcome of the failed intended action. In other words, they were able to infer the person's intention from the failed action. However, when the machine modeled both of these actions, the 18-month-olds did not imitate any acts.

In her work, Woodward (1998) used a habituation paradigm to examine younger infants' understanding of goal-directed actions. In one experiment, a group of 9-month-olds was habituated to a human actor reaching towards and grasping one of two toys that sat side-by-side. A second group of 9-month-olds was habituated to an inanimate object (i.e., a rod whose metal exterior was covered by paper and topped with a soft sponge) performing an identical action. Both groups of 9-month-olds were then given two test events after the positions of the two toys were switched: (1) a reach to the opposite side but to the same toy (old goal), and (2) reach to the same side and different toy (new goal). She found that 9-month-olds in the human actor condition looked longer at the new goal whereas 9-month-olds who observed the rod showed no preference for either old or new goals. In follow-up experiments, even 5- and 6-month-olds did not perceive the inanimate objects' (i.e., rod or a claw) actions as goal-directed. Woodward (1998) interpreted these findings to indicate that young infants attend to the connection between a human who reaches and the object of her/his grasp in ways that they do not with inanimate agents.

Another study used the standard gaze following paradigm with one modification (Legerstee & Berillas, 2003). A series of training trials were used prior to the test trials to condition 12-month-olds to follow either the person's gaze or the inanimate object's gaze (i.e., the doll) when they turned to look at one of two interesting sights (i.e., stuffed toy animals). They found that infants equally followed the person and the doll to the target toys. However, 12-month-olds significantly directed social behaviors (i.e., pointing, vocalizations, and looking) to the person than to the doll. The authors interpreted their findings to indicate that infants distinguish between people and nonhuman objects and that they understand that communication is only directed towards the former. As such, infants appear to understand people's gaze direction as providing information about an underlying mental state (e.g., attention), which is unique to humans.

According to another view, infants possess a broad concept of intentional agent, and attribute goals to any object that possess certain critical human features (e.g., Johnson, 2000). For some, self-propelled motion is a feature that automatically triggers the infants' sense that a mentalistic agent is present (Baron-Cohen, 1995; Premark, 1990). For others, motion is considered along with other cues such as physical features and contingent behaviors (Johnson, Booth & O'Hearn, 2001; see Johnson, 2000 for a review). In support of this cue-based approach, Johnson, Slaughter, and Carey (1998) used a gaze following paradigm to determine whether 12-month-olds understand that facial features and contingent behaviors are indicative of mentalistic agents. Infants were first familiarized to a person and to an inanimate object. The latter object was a small, fuzzy, round shaped object that either possessed or did not possess facial features (i.e., eyes, ears, mouth) and that either responded contingently (i.e., flashed and beeped) to the infants' behaviors (e.g., babbling) or remained still. After the familiarization phase, the object beeped and then turned towards an interesting sight. Infants followed the inanimate object when it included one of the two above cues (i.e., facial features or contingent behaviors) and when the two cues were combined. Also, infants followed the person's head turn to the correct side. The authors argued their findings indicate that infants perceive certain characteristics such as contingent behaviors and facial features as markers for intentionality rather than a specific understanding of person.

In another study that used Meltzoff's (1995) procedure, Johnson, Booth, and O'Hearn (2001) examined 15-month-olds' ability to imitate an orangutan toy animal that modeled completed actions and failed intended actions on novel objects. The results indicated that the infants re-enacted the orangutan's completed action as well as the outcome from the failed intended act. The authors also found that infants directed significantly more social behaviors (i.e., waves, giving and requesting objects) to the orangutan than to a table lamp that was covered in soft material. As such, since infants significantly directed more social behaviors towards the orangutan than to the lamp they concluded that the former was perceived as a mentalistic being.

In a recent study, Biro and Leslie (2004) used Woodward's (1998) paradigm with one modification. Infants aged 9- and 12-month-olds were first given three training trials in which they observed a rod touching and then lifting up one of the two toys. In the test trials, the older infants looked longer at the new goal, indicating that they interpreted the rods' actions as goal-directed. Recently, Shimizu and Johnson (2004) also used Woodward's paradigm to examine whether 12-month-olds would attribute goals to a nonhuman object (i.e., a green oval-shaped object) that either beeped or did not beep when a person spoke to it. Once infants were introduced to the nonhuman objects, they were then habituated to the interactive or to the noninteractive green object approaching one of two toys. In the test trials, infants looked longer at the new goal only when the green object initially behaved 'intentionally' (i.e., beeped in response to the person talking) because they interpreted the nonhuman agent's approach behaviors as goal-directed.

Two additional studies also provide support for the finding that infants attribute goals to inanimate objects (Gergely, Nadasdy, Csibra, & Biro, 1995; Kiraly, Jovanovic, Prinz, Aschersleben, & Gergely, 2003; Csibra, Gergely, Biro, Koos, & Brockbank, 1999). For example, Gergely et al. (1995) habituated 9- and 12-month-olds to a small computer-animated circle that jumped over an obstacle to reach a large circle. In the two subsequent test trials, the obstacle was removed. Infants saw the small circle jumping as it approached the large circle, and the small circle moving in a straight line towards the large circle. Infants at both ages looked longer at the event featuring the small circle jumping indicating a surprised reaction. In other words, infants seemed to expect the small circle to choose the most rational means to reach its goal. That is, infants may have a principle of rational reasoning. Recently, Kuhlmeier, Wynn, and Bloom (in press) habituated 12-month-olds to a triangle 'helping' a circle up a hill and to a square that appeared to obstruct the circle from going up the hill. Test trials depicted the circle moving towards the triangle, and the circle moving towards the square. They found that infants looked longer at the triangle, and interpreted this as indicating that the 12-month-olds inferred that the circle desired to reach its goal. In other words, infants attributed mentalistic abilities to the inanimate object. However, they also acknowledged that the principal of rational action could explain their results as well (as suggested by Gergely et al., 1995).

In summary, the research to-date provides evidence that infants are sensitive to attentional and emotional cues by the end of the first year of life. However, it remains to be determined what characteristics infants attribute to agents who display referential cues. The present studies were designed with four goals in mind. A first goal was to determine infants' sensitivity to different attentional and emotional cues in a naturalistic setting, that is, with no habituation or familiarization. It was expected that an interactive object-request paradigm would provide a more stringent test of infant's understanding of referential cues and agents than, for example, habituation. This is because the paradigm was not only designed to elicit gaze following, but also to examine infant's ability to give desired toys on the basis of an agent's prior display of object-directed behaviors. A second goal was to assess infants' ability to attribute desires based on a person's attentional and emotional cues. It was expected that infants as young as 14 months would shift their attention to follow the gaze and gesture of a person. In contrast, it was expected that although 18- and 24-month-olds would infer another person's desire from these cues, 14-month-olds would show no such understanding. In this way, it was hypothesized that a dissociation between gaze following and desire attribution would emerge during the second year of life. A third goal was to determine the relative weight of different referential cues for infants to infer peoples' desires. It seems most likely that infants require various cues to make desire inferences (see e.g., Lee et al., 1998). As such, it was predicted that infants would be more successful at giving the appropriate toy when prior object-directed actions include two or more cues. Conversely, infants would find it more difficult to determine a person's desire from the display of one object-directed action. A fourth goal was to examine whether infants possess a narrow concept of mentalistic agent that is restricted to humans, or a broad concept that encompasses all objects that possess human properties. It was expected that infants would shift their gaze to follow a nonhuman agent's cues to toys in the same way as they would for a human, but that they would not attribute desires to a nonhuman.

Experiment 1

The first experiment was designed to explore infant's understanding of people's object-directed actions in the second year of life. In particular, infant's ability to attribute desires based on a person's attentional and emotional cues and the relative weight of different referential cues on infant's ability to infer desires were examined. Firstly, although there is an abundant literature on gaze direction, gestures, and emotional displays demonstrating that infants are sensitive to people's object-directed behaviors by the end of the first year, the interpretation of infant's understanding of, for example, gaze following is a topic of debate (see e.g., Carpenter, Nagell, & Tomasello, 1998). One view is that infant's ability to follow gaze cues means that one-year-olds have an intentional understanding of people (e.g., Tomasello, 1995). The other view, however, asserts that these findings merely indicate that infants have learned to make an association between, for example, a person's head turn and an interesting sight (e.g., Corkum & Moore, 1995). To differentiate between these two interpretations, an object-request interactive paradigm was designed to provide a stringent test that required infants to give a toy to the experimenter following the display of object-directed actions. It was predicted that it would not be until the middle half of the second year of life that infants perceive object-directed actions as predictive of desires. Secondly, the experiment was designed to examine the relative weight infants place on the different combination of cues for inference of desires. For example, one view is that infants' ability to follow eye gaze reflects their understanding of people as intentional beings (Tomasello, 1995). This would suggest that infants would be successful on the eye gaze cue alone. However, empirical evidence seems to suggest that infants require more than one cue to successfully attribute desires (see e.g., Lee et al., 1998).

An interactive object-request paradigm was designed to document infant's understanding of referential cues. After the person directed the infant's attention to her, the person focused her attention on one of two objects by displaying different cue combinations: a one-cue combination (gaze or gesture), a two-cue combination (gaze and gesture, gaze and affect, gesture and affect) or a three-cue combination (gaze, gesture, and affect). A total of six trials were administered. Following cue presentation, infants were asked to give the target toy to the experimenter. If infants understood that these behavioral cues were indicative of people's desires, they would give the person the object toward which the behaviors were directed.

Method

Participants. The final sample consisted of 72 participants, who were divided into three equal age groups: 14-months-olds (*M* age = 14.09, range = 13.39 to 15.52) including 13 girls and 11 boys, 18-month-olds (*M* age = 18.14, range = 17.07 to 18.89) including 14 girls and 10 boys, and 24-month-olds (*M* age = 23.96, range = 23.39 to 24.88) including 13 girls and 11 boys. Of the original sample, four 14-month-olds were excluded due to fussiness (*n* = 3) and parental interference (*n* = 1); seven 18-month-olds were excluded due experimenter error (*n* = 1) and fussiness (*n* = 6); and six 24-month-olds were excluded due to parental interference (*n* = 1) and fussiness (*n* = 5). Participants were recruited from birth lists provided by a governmental health center in the Montreal area and came predominantly from white middle-class homes.

Materials. A red three-sided puppet theatre, with a window cut in the middle of the front panel (62 cm wide, 40 cm long) was used for testing. A clear thick plastic covered the window. Below the window was a white ledge onto which two toys were placed, one at each end of the ledge. Velcro was used to attach the toys to the ledge so that infants were able to easily pull toys off. A red curtain was used to hide the placement of the toys from the infant's view. Six pairs of attractive small toys were used, approximately 8 cm and 4 cm wide. These toys included characters from Barney, Winnie the Pooh characters, Teletubbies, and Sesame Street. A small fishnet was used so that infants could place a toy inside it.

Procedure and Design. The testing session took place in a large playroom. Infants were seated at a table directly across from a female experimenter. Parents sat directly behind their infants. Two cameras were used to record the session, one to record infant's behavioral responses and the other to record the experimenter's display of behavioral cues. Three types of behavioral cues were presented to infants: gaze (eye and head turn towards the target toy); gesture (reaching for a target toy behind the plastic); and affect (a positive vocalization: "Aaah"). Six different combinations of behavioral cues were used: one 3-cue presentation: gaze + gesture + vocal positive affect; three 2-cue presentations: gaze + gesture; gesture + positive vocal affect; gaze + positive vocal affect; and two 1-cue presentations: gesture alone; and gaze alone. The order of the six trials was counterbalanced so that one-third of the sample received the 3-cue presentation first; one-third of the sample received a 2-cue presentation first; and one-third of the sample received a 1-cue presentation first. Within each of these orders, the side of the ledge (left or right) on which the first cue was presented was counterbalanced.

Infants and their parents were first brought to a small waiting room. Parents were asked to complete a consent form for the study and infants were familiarized with a female experimenter. When the testing session began, infants were initially allowed to play with three pairs of toys that were used in the first three trials of the session. The toys were then taken away and a covered puppet theatre was immediately placed on the table out of the infant's reach. The experimenter sat directly across from the infant. Two warm-up trials were first administered to train infants how to play the game. The curtain was removed from the theatre and infants saw two novel toys velcroed on the ledge, one at either end. A fishnet was placed in the center of the window facing toward the child. The infant was asked to pull off each toy, one at a time, and to place each in the fishnet. Upon each successful completion, the experimenter clapped and said, "Bravo".

The experimenter then put away the warm-up toys, placed the curtain over the puppet theatre, moved it out of the infant's arm reach, and commenced the experimental trials. The first pair of toys was attached to the ledge, underneath the curtain and out of the infant's view. Then the curtain was removed and the experimenter called the infant's name to get her/his attention. Next, the experimenter displayed the appropriate cue(s), a total of three times. Each time, she attracted the infant's attention before presenting the cue. The duration of each trial was approximately ten seconds. Once the cue(s) was resented, the experimenter placed the curtain back over the puppet theatre, lightly scratched the plastic covering, and then removed the curtain again. This was done in order to compare the performance of these infants to those in Experiment 3. The experimenter handed the fishnet through the window and said, "I want a toy. Give me the toy I want". After the infant chose a toy, the experimenter proceeded to the next trial. After three trials, three new pairs of toys were presented for the infant to play with briefly, and were then used in the last three trials.

Coding. Each participant was videotaped, and the first author coded all the tapes using an event recording program. A second independent scorer randomly coded 25% of the participants from each of the age groups for the following dependent variables: infants' looking time at the toys during cue presentation; toy choice including touching the toy and putting the toy in the fish-net; and latency to touch a toy.

Coding infants' looking time included looking to the left side of the ledge, to the right side of the ledge, and at the experimenter; inter-rater reliability was $r = .90$, $r = .91$, and $r = .90$, respectively. The mean percentage of looking time to the target toy was calculated by summing the percentages for infants' looking times at the target toy, and then dividing that sum by the total looking time (to both the target and nontarget toys) and then multiplying the result by 100. Toy choice was coded for the first toy that was touched and the first toy that was given to the experimenter. A score of 1 was given to a correct response and a score of 0 was given for an incorrect response (e.g., the infant first touched the nontarget toy or the infant first put the nontarget toy, both toys, or no toy in the net). Inter-rater reliability for toy choice was $r = .96$ (touch toy) and $r = .98$ (put a toy in the net). Latency was coded as the amount of time it took infants to touch a toy (either correct or incorrect toy); inter-rater reliability was $r = .97$.

Results

Looking Time. Preliminary analyses indicated no order effects, thus order was dropped from further analyses. Infants' looking time to the target toy during cue presentation was first examined. A two-way ANOVA with Age Group (14-, 18-, and 24-months-olds) and Gender (boys and girls) as the between subject variables found that there were no main effects or interactions for infants' looking time to the target toys. Across groups, the mean percentage of looking time to the target toys was very high (14-month-olds, $M = 71.42$, $SD = 14.53$; 18-month-olds, $M = 76.53$, $SD = 13.70$; and 24-month-olds, $M = 77.73$, $SD = 11.38$) and were significantly above chance levels: 14-months-olds, $t(23) = 7.22$, $p < .001$; 18-months- olds, $t(23) = 9.49$, $p < .001$; and 24-month-olds, $t(23) = 11.94$, $p < .001$ (see Figure 1). Moreover, as expected, *t*-tests confirmed that the mean percentage of looking times to the target toys were significantly above chance levels for the 14-, 18-, and 24-month-olds on each of the six trials.

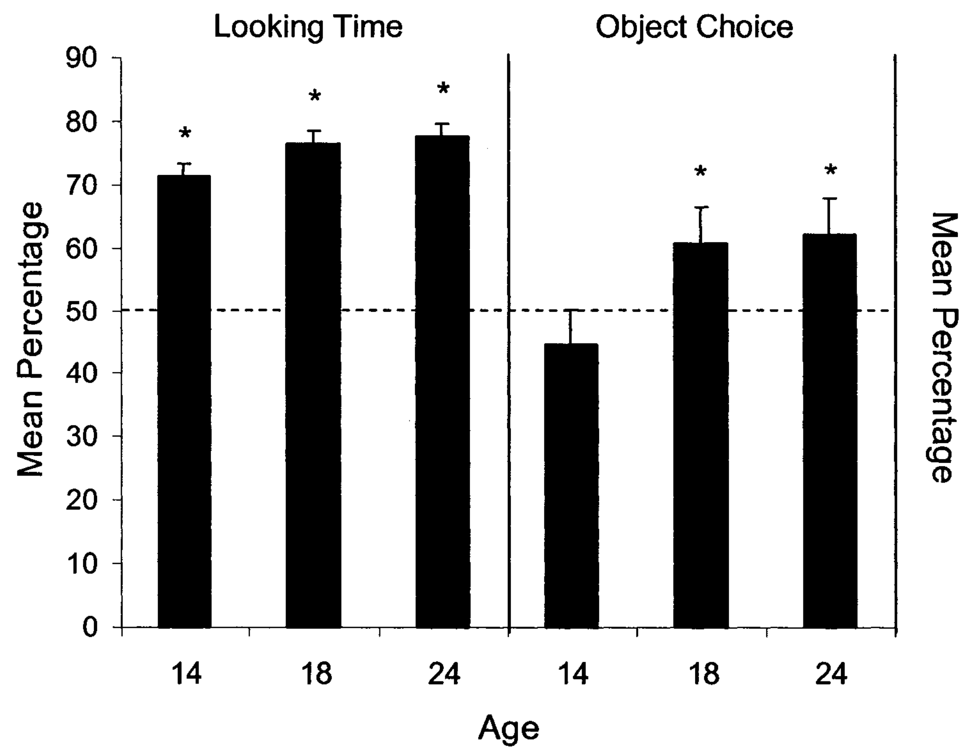

Figure 1. Mean percentage of looking time to the target toys (+*SE*) and mean percentage of correct toys given to the person (+*SE*) for the three age groups in Experiment 1.

*$p < .05$.

Toy Choice. The second set of analyses explored infants' ability to predict that a person's desire for a specific object is linked to her/his prior behavior toward that object. Infants' base rates responses were first examined, that is, the mean percentage of trials in which a toy (correct or incorrect) was given to the experimenter out of 6 trials. A two-way ANOVA (Age group x Gender) indicated there was a main effect of Age, $F(2, 66) = 11.73, p < .001$. Both 18- ($M = 84.20, SD = 29.16$) and 24- ($M = 94.96, SD = 11.41$) month-olds were significantly more likely to give toys than the 14-month-olds ($M = 53.27, SD = 42.31$).

In order to take infants' differential response rates into account across age groups when calculating correct toy choice, the mean percentage of correct toys only for trials in which a toy was given was calculated. A two-way ANOVA (Age group x Gender) indicated that there was a main effect of Age, $F(2, 66) = 3.55, p < .034$; the 18- ($M = 60.88, SD = 23.79$) and 24- ($M = 62.33, SD = 19.83$) month-olds were significantly more likely to give the target toy than the 14-month-olds ($M = 44.75, SD = 36.26$). *T*-tests indicated that the mean percentage of correct toys given was above chance levels for 18-month-olds, $t(23) = 2.24, p < .04$; and 24-month-olds, $t(23) = 3.047, p < .006$ but not for the 14-month-olds (see Figure 1).

A two-way ANOVA (Age group x Gender) also indicated that there were age differences in the amount of time it took infants to choose a toy; that is, their latency. The 14-month-olds ($M = 2.60$ seconds, $SD = 1.53$) took significantly more time to reach towards and touch a toy than did the 18- ($M = 1.28$ seconds, $SD = .713$) and the 24- ($M = 1.04$ seconds, $SD = .602$) month-olds, $F(2, 66) = 15.23, p < .000$.

In accord with other studies using the object request procedure, 14-month-olds generally did not give an object to the experimenter when asked to do so (Repacholi & Gopnik, 1997). Thus, another series of analyses was conducted to examine infants' performance on a less stringent measure of choice, that is, toy touched. The first calculations were the overall response base rates defined as the mean percentage of toys touched out of six trials. As expected, all groups performed very well: 14-month-olds ($M = 99.29$, $SD = 3.47$); 18-month-olds ($M = 100$); and 24-month-olds ($M = 100$). A two-way ANOVA (Age group x Gender) yielded no main effects or interactions. Then the mean percentage of correct toys touched out of six trials was calculated: 14-month-olds ($M = 56.96$, $SD = 20.85$); 18-month-olds ($M = 61.91$, $SD = 17.35$) and 24-month-olds ($M = 70.08$, $SD = 17.62$). A two-way ANOVA (Age group x Gender) indicated there was a marginally significant effect of Age, $F(2, 66) = 3.01, p < .06$ and a main effect of Gender, $F(1, 66) = 5.68, p < .02$ (boys, M=68.72, SD=18.75; girls=58.32, SD=18.50). To determine whether the trend for the effect of age was in the predicted developmental direction, follow-up planned pairwise comparisons were conducted using a Bonferroni correction. The only significant difference was between the 14- and 24-month-olds ($M = 12.93$, $SD = 5.30, p < .05$). As with toy choice, the mean percentage of correct toys touched was higher than chance level only for the older infants: 18-month-olds, $t(23) = 3.33, p < .003$; and 24-month-olds, $t(23) = 5.58, p < .001$.

Comparison of Cues. An important goal of the present study was to determine which cue or which combination of cues infants rely on to infer what the person prefers. Chi-square analyses were conducted to compare the proportion of infants who put the correct toy in the net against chance for each of the six trials (see Table 1). The 14-

month-olds failed to surpass chance levels on any of the trials. For 18-month-olds, the proportion of infants who made a correct choice was significantly above chance on only one trial, when all three cues were combined (gaze, gesture, positive vocal affect), x^2 (1, $N = 24$) = 5.26, $p < .02$. For the 24-month-olds, the proportion of infants who made a correct choice was above chance on two trials, when all three cues were combined, x^2 (1, $N = 24$) = 12.56, $p < .001$ as well as when gaze and positive vocal affect were combined, x^2 (1, $N = 24$) = 8.17, $p < .004$.

Table 1.

Proportion of infants in the three age groups who touched or gave the correct toy in each cue condition in Experiment 1.

	Age Group					
Cue Condition	14-Months		18-Months		24-Months	
	Touch	Give	Touch	Give	Touch	Give
Gaze, Gesture, Affect	75*	61 (n=13)	79*	74* (n=23)	96*	87* (n=23)
Gaze and Gesture	42	43 (n=14)	46	38 (n=21)	54	46 (n=24)
Gaze and Affect	63	50 (n=12)	71*	64 (n=22)	83*	79* (n=24)
Affect and Gesture	63	33 (n=12)	54	50 (n=24)	58	50 (n=24)
Gesture	54	67 (n=12)	71*	64 (n=22)	75*	61 (n=21)
Gaze	46	64 (n=11)	50	45 (n=24)	54	38 (n=24)

* $p<.05$

Discussion

The results of Experiment 1 indicate that 18- and 24-month-olds, but not 14-month-olds, used an adults' referential cues to predict which object she wanted. By giving the adult the appropriate toy, infants inferred that if a person displays attentional cues towards an object, she is more likely to want that object than another object that was not the focus of her attention. Moreover, the findings suggest that the referential cues of gaze, gesture, and vocal affect were most effective when presented together. That is, when the adult displayed these three cues towards the target toy, 18- and 24-month-olds responded reliably by picking up and giving that toy. This was not the case for trials in which cues were presented in isolation. However, at 24-months, infants successfully used one of the two cue combinations, namely, gaze and vocal affect. The orientation of head and eyes to the target toy was perceived as referential when it was paired with a positive vocalization. Interestingly, at both 18- and 24-months, gaze, on its own, was an insufficient cue. Additionally, the 24-month-olds did not perceive the reaching gesture as informative when gaze was absent. That is, infants did not link a person's preference to the target toy when she looked directly at the infant while she gestured and vocalized towards a toy.

Overall, the 14-month-olds failed to give the correct toys to the experimenter, despite the effectiveness of the adults' referential cue(s), which shifted their attention to the target toys. One possibility was that task demands were too challenging for the youngest infants. In this way, the results from the less stringent measure of object touch were considered. The results from the 14-month-olds indicated that they responded more similarly to the older infants when the touching measure was considered. However, the youngest infant's mean percentage of correct touches was not above chance levels.

The present findings extend the literature on intentional understanding in young infants in various important ways. First, the data indicates that 14-month-olds could easily follow an adult's referential cue(s) to a target toy without an understanding of the implication of these behaviors on the person's preference for an object. This finding supports the view that emerging gaze following skills in one-year-olds is not necessarily accompanied by an awareness of mental states (e.g., Barresi & Moore, 1996). Second, the findings add to and extend previous research that has demonstrated that by 18-months, infants make a link between a person's actions and an object (Poulin-Dubois, 1999; Baldwin et al., 1996). In contrast, Woodward (2001) found that 12-month-olds, and even younger infants are able to understand the relation between attentional cues and objects. The present object-request task used in the present experiment required a more sophisticated awareness of others than required in the Woodward task because infants needed to understand more than the referential specificity of people's actions. A third and central feature of the findings is that the number and type of referential cues presented plays a critical role in infants' ability to infer desire. The referential cues of gaze, gesture, and vocal affect were most effective as cues to predict desire when presented together. Several researchers construe eye gaze following as evidence for an understanding of mental states (e.g., Baron-Cohen & Cross, 1992; Tomasello, 1995). However, the present findings indicate that infants do not "read" underlying desires or intentions from gaze alone (i.e., eye and head movements). Instead, 18- and 24-month-olds were able to make desire inferences based on three kinds of attentional cues and other contextual information (i.e., experimenter's verbal request for a toy). In other words, infants seem to require information about a person's mental state from many sources (see also Lee et al., 1998).

Experiment 2

One explanation for the findings of Experiment 1 is that the older infants only linked the person's behaviors to a specific location and not to a specific toy. In other words, infants may have processed the spatial information provided by the referential cues, that is, either on the left side or the right side of the puppet theatre (see also Woodward, 1998). A more stringent test then would be to switch the position of the two toys following cue presentation. If infants perceive a desire underlying a person's referential cues it would be expected that the appropriate toys would be chosen, at higher than chance levels, even when found in a different location. However, if infants choose the location at higher than chance levels then there would be support for the alternative explanation.

Method

Participants. The final sample consisted of 48 infants, equally divided into two age groups: 18-month-olds (*M* age = 18.40, range = 17.69 to 19.16) including 14 girls and 10 boys, and 24-month-olds (*M* age = 24.18, range = 23.39 to 24.69) including 11 girls and 13 boys. From the original sample of 53 infants, three 18-month-olds were excluded due to fussiness ($n = 2$) and experimenter error ($n = 1$); and two 24-month-olds were excluded due to fussiness. Participants were recruited from birth lists provided by a governmental health center in the Montreal area and came predominantly from white middle-class homes.

Design and Procedure. The infants in Experiment 2 participated in an experimental task identical to that described in Experiment 1 except for one important difference. After cue presentation, and once the cloth covered the puppet theatre and the toys were hidden from the infant's view, the positions of the two toys were switched.

Results

The results from the 18- and 24-month-old infants in the present Experiment (Switch Condition) were compared to the results from the same-aged infants in Experiment 1 (NonSwitch Condition).

Looking Time. Preliminary results revealed no order effects, and thus order was dropped from further analyses. A three-way ANOVA with Age group (18- and 24-month-olds), Condition (Switch versus NonSwitch) and Gender (girls and boys) that compared infants' looking time to the target toys revealed main effects of Condition and Gender as well as an interaction between Gender and Age. First, the condition effect indicated that infants in the NonSwitch Condition ($M = 77.13$, $SD = 12.47$, $N = 48$) looked significantly longer at the target toys during cue presentation than did infants in the Switch condition ($M = 70.66$, $SD = 17.30$, $N = 48$), $F(1, 88) = 5.30$, $p < .02$. Despite the differences in looking time across conditions, infants' mean percentage of looking time to the target toys was above chance levels in both conditions: for the NonSwitch Condition, $t(47) = 15.07$, $p<.001$; and for the Switch Condition, $t(47) = 8.28$, $p < .001$.

Follow-up comparisons for the interaction between Gender and Age indicated that the boys in the 18-month-old age group ($M = 78.94$, $SD = 11.49$, $N = 21$) looked significantly longer to the target toys than did the girls ($M = 64.35$, $SD = 19.16$, $N = 27$), $F(1, 88) = 4.56$, $p < .04$. However, the mean percentage of looking time for boys and girls in the 18-month-old age group was significantly above chance levels: boys, $t(20) = 11.505, p < .001$; girls, $t(26) = 3.98, p < .001$.

Toy Choice. The second set of analyses explored infants' toy choice. Infants' response base rates were first examined, that is, the mean percentage of trials in which a toy (correct or incorrect) was given to the experimenter out of the six trials. A three-way ANOVA (Age group x Condition x Gender) indicated there was a main effect of Age, $F(1, 88) = 5.52, p < .02$; 24-month-olds ($M = 93.29$) were significantly more likely to give toys than 18-month-olds ($M = 80.61$). The mean percentage of trials in which the correct toy was given to the experimenter was then calculated. Only those trials in which toys were placed in a net were included. A three-way ANOVA (Age group x Condition x Gender) indicated that there was a main effect of Condition, $F(1,88)=13.361, p<.001$, as well as an interaction between Condition and Gender, $F(1, 88) = 4.46, p < .04$. In the NonSwitch Condition, boys were significantly more likely to give a correct toy ($M = 71.52$, $SD = 17.32$, $N = 21$) than the girls ($M = 53.89$, $SD = 21.86$, $N = 27$). As reported in Experiment 2, the mean percentage of correct toys given was above chance levels for the 18- and 24-month-old infants in the NonSwitch Condition. However, this was not the case for the 18- ($M = 42.58$, $SD = 30.13$, $N = 24$) and 24- ($M = 46.79$, $SD = 21.89$, $N = 24$) month-olds in the Switch Condition (see Figure 2).

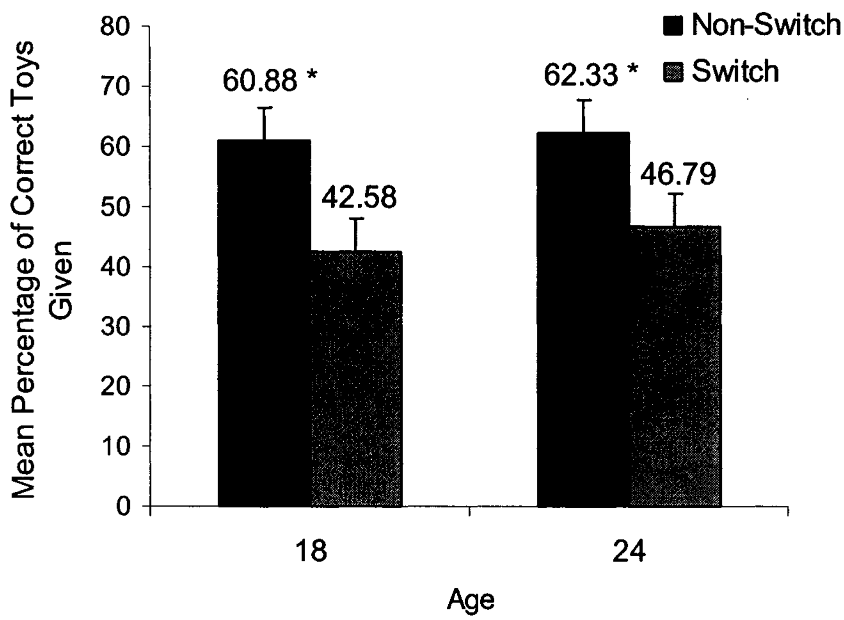

Figure 2. Mean percentage of correct toys given to the person (+*SE*) by 18- and 24-month-olds in the NonSwitch Condition and the Switch condition in Experiment 2. $*p<.05$.

Cues: Gaze, Gesture, Vocal Affect. To determine whether infants' responses of giving the correct toy, once the position of the toys were switched, varied depending on how many cues were presented during cue presentation chi-square analyses were conducted to compare the proportion of infants who gave the correct toy against chance for each of the six trials. In the Switch Condition, 18-month-olds were unsuccessful on all six trials. The 24-month-olds, in the Switch Condition, were successful on one trial: the combination of all three cues (gaze, gesture, and vocal affect) x^2 (1, N = 24) = 4.17, $p <$ .04.

Touch Toy. This set of analyses explored the less stringent measure of toy touched. First, the base rates were calculated, defined as the mean percentage of toys touched out of six trials for each age groups in the two conditions: 18-month-olds (NonSwitch: M = 100; Switch: M = 100); and 24-month-olds (NonSwitch: M = 100; Switch, M = 100). Second, the mean percentage of correct toys touched out of six trials for each age group in the two conditions were calculated: 18-month-olds (NonSwitch: M = 61.79, SD = 17.35; Switch: M = 50.00, SD = 20.96) and 24-month-olds (NonSwitch: M = 70.08, SD = 17.62; Switch: M = 54.87, SD = 18.75, N = 24). A three-way ANOVA (Age Group x Condition x Gender) yielded a main effect of Condition, F(1, 88) = 13.36, $p < .001$. Infants in the NonSwitch Condition (M = 65.94, SD = 17.80) were significantly more likely to touch the correct toys than the infants in the Switch Condition (M = 52.44, SD = 19.82). The mean percentage of correct toys touched was above chance levels only for those infants in the NonSwitch Condition, t(47) = 6.20, $p < .001$.

Cues: Gaze, Gesture, Vocal Affect. To determine whether infants' responses of touching the correct toy, once the position of the toys were switched, varied depending on how many cues were presented during cue presentation chi-square analyses were conducted to compare the proportion of infants who touched the correct toy against chance for each of the six trials. In the Switch Condition, 18-month-olds were successful on two trials; the combination of all three cues (gaze, gesture, and vocal affect), x^2 (1, N = 24) 6.00, $p < .014$ and the combination of gaze and vocal affect, x^2 (1, N = 24) 4.17, $p < .041$. The 24-month-olds, in the Switch Condition, were also successful on two trials: the combination of all three cues (gaze, gesture, and vocal affect) x^2 (1, N = 24) = 4.17, $p < .04$ and gaze and vocal affect, x^2 (1, N = 24), 6.00, $p < .014$.

Discussion

The findings of Experiment 2 indicate that 18- and 24-month-olds in the Switch Condition experienced more difficulty making predictions about desires from attentional and emotional cues in comparison to same-aged infants in Experiment 1 (NonSwitch Condition). However, because Experiment 1 showed that all three cues were critical for correct predictions about a person's preference the results from the six trials were examined separately for giving the correct toy. Indeed, 24-month-olds in the Switch Condition could infer the desired object when the person displayed all three referential cues towards that toy. In contrast, 18-month-olds performed at chance on this critical trial. This finding confirms a developmental progression in infants' ability to predict people's desires from behavioral cues.

Nevertheless, findings from the touch measure indicate that 18-month-olds in the Switch Condition possess some understanding of the implication of object-directed actions. Both the 18- and 24-month-olds successfully used the three cue combination and the combination of gaze and vocal affect to associate the person's desire with the correct object (as indicated by toy touch), even when the toy was moved from its original location. Why then did infants not give the correct toys to the person? One possible answer is that the switch of the position of the two objects confused the 18-month-olds. It is possible that they formed an expectation concerning where the person's desired object would be located, and when the 18-month-olds observed another object in its place they became unsure which object to give to the person. However, the results for the 18-month-olds are surprising given that previous research on the looker-object relation showed that younger infants still made a successful object-looker link when the position of the two toys was switched (Woodward, 1998). The discrepancy between these findings and the present data reflect the fact that the present procedure required infants to predict the goal of the person without observing many repetitions of the looker-object link. Furthermore, the object request procedure required that infants select an object in response to the person's request, which is more demanding than simply associating the looker with the appropriate object.

There are also findings from studies using a habituation procedure that demonstrate that young infants attribute goals to inanimate objects (e.g., Gergley et al., 1995; Biro & Leslie, 2004; Kuhlmeier et al., in press; cf. Woodward, 1998). If the object request procedure is a more rigorous test of infants' understanding of desire then this procedure may also shed light on inconclusive findings, in the literature, on infants' concept of agent. As noted earlier, there are two prevalent views in the literature. One view emphasizes that infant's understanding of actions as goal-directed is specific to humans, and develops from earlier experiences in which infants learn that other people are 'like me' (e.g., Woodward, 1998; Meltzoff, 1995). The other view emphasizes a cue-based approach, whereby infants respond to a specific set of cues or features (i.e., self-propelled motion, contigency, morphological features) as indicative of mentalistic agents (e.g., Johnson, 2000). Along these lines, a specific set of cues was examined that are considered to be indicative of mentalistic agents: gaze direction, gestures, and vocal affect. Experiments 1 and 2 were first conducted to clarify which cues infants rely on, and when infants understand that these cues are indicative of a human agent's desire. The present findings indicated that 18-months-old have a nascent understanding of people's actions as goal-directed and intentional. However, to further differentiate the two views on infants' concept of agent, it is necessary to examine infants' reactions to an unfamiliar non-human's object-directed actions.

Experiment 3

The main objective of Experiment 3 was to determine how infants interpret attentional and emotional cues displayed by a person and by an inanimate object. It was hypothesized that while infants at all ages would follow the cues to the target toy, regardless of agent, they would not perceive the inanimate object as an intentional agent at any age. That is, infants will not give the inanimate object the target toy because they understand that inanimate objects do not have desires. To provide a stringent test, the inanimate object used was a humanoid robot with a head and eyes that moved to either side, two arms that moved upwards, and that stood on two legs. Additionally, the robot's motion appeared self-propelled. Also, because the experimenter directed infants to give toys to the robot the inanimate object was treated as if it had object preferences.

Method

Participants. The final sample consisted of 72 participants who were divided into three equal age groups: 14-month-olds (*M* age 14.52 =, range = 13.26 to 15.49) including 15 girls and 9 boys; 18-month-olds (*M* age = 18.20, range = 17.26 to 19.03) including 11 girls and 13 boys; and 24-month-olds (*M* age = 24.10, range = 23.30 to 24.75) including 13 girls and 11 boys. Of the original sample, nine 14-month-olds were excluded due to fussiness (n=3), wariness of the robot (*n*=4); and experimenter error (*n*=2); seven 18-month-olds were excluded due to fussiness (*n*=4); wariness of the robot (*n*=2) and experimenter error (*n*=1); and one 24-month-old was excluded due to wariness of the robot. Participants were recruited from birth lists provided by a governmental health center in the Montreal area and came predominately from white middle-class homes.

Materials and Apparatus. A programmable robot was created using Lego pieces (Lego Mindstorms Inventions System 1.5). The robot stood approximately 38 cm tall and 26 cm wide, and was placed on the table facing the infant. The robot had a humanoid shape with movable body parts including two eyes and a head that turned to either side and downwards, and two arms with claws attached at the end that simultaneously opened and closed as the arms moved upwards (see Figure 3). A cassette recorder was used to play recorded robotic noises. The robot stood within a red 3-sided puppet theatre that had a window cut in the middle of the front panel that was approximately 62 cm wide and 40 cm long (see Figure 1). Below the window was a white ledge onto which two toys were placed, one at each end of the ledge. Velcro was used to attach the toys to the ledge so that infants were able to easily pull toys off. A clear thick plastic covered the window, and a red curtain was used to hide the placement of the toys from the infant's view between trials. They were four pairs of attractive small toys used, which were approximately 8 cm and 4 cm wide, and included characters from Barney, Winnie the Pooh, and Sesame Street. A small fishnet was used so that the infant could hand a toy.

Procedure and Design. Infants and their parents were first brought to a reception room. Parents were asked to complete a consent form for the study and infants were familiarized with the two female experimenters. This was followed by the testing session that took place in a large playroom. Infants were seated at a table directly across from the robot. One female experimenter sat directly beside the infant, and parents sat directly behind their infants. The second experimenter entered the room prior to the infant and was hidden from view under the table. Two cameras were used to record the session, one to record infants' behavioral responses and the other to record the robot's display of behavioral cues. Infants were first allowed to play with the four pairs of toys that were used during the session. The toys were then taken away and the curtain was removed from the puppet theatre revealing the stationary robot.

The first experimenter pointed to the Robot saying: "Look at the robot. The robot is going to play with us". Two trials were then administered to familiarize infants with the robot's vocalizations and eye and claw/arm movements (i.e., looking and reaching once to the left side and once to the right side). These two familiarization trials were similar to Johnson et al. (2001), who ensured that infants were comfortable with the orangutan toy prior to test trials by having infants observe the inanimate object perform different arm movements such as reaching, holding, and placing objects into a wooden box. Subsequent to the familiarization trials, two warm-up trials were conducted to train infants how to play the game. The first experimenter placed the curtain over the puppet

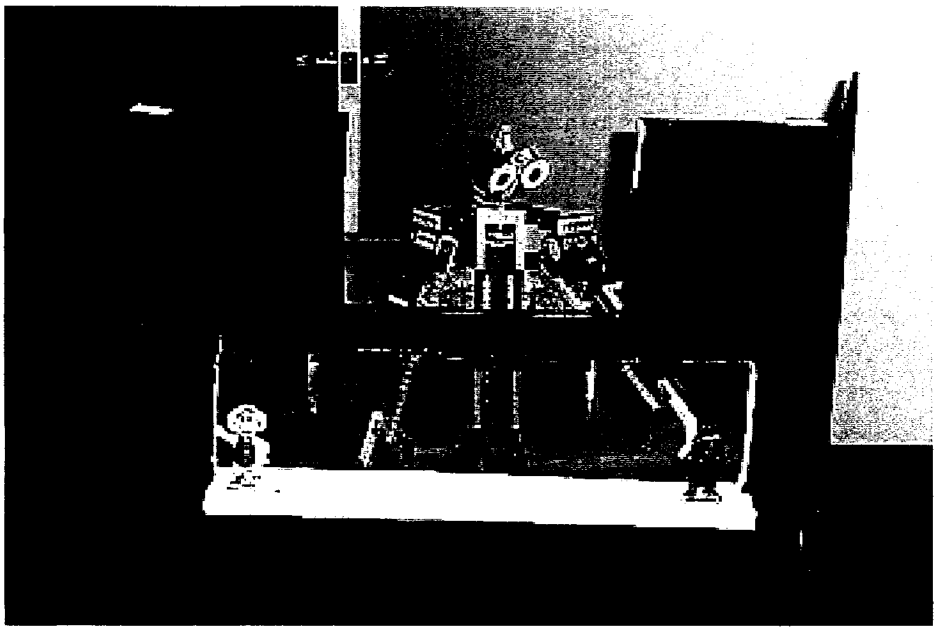

Figure 3. The humanoid robot displaying all three behavioral cues.

theatre and said “ok”, which prompted the second experimenter, hiding under the table, to reach under the plastic and through the window of the puppet theatre to place two warm-up toys (i.e., a cow and car) on the ledge. The first experimenter removed the curtain and asked the infant to pull off each toy, one at a time, and to place it in the fishnet that was in the center of the window facing the robot. Upon each successful completion, the first experimenter clapped and said, “Bravo. I’ll give the toy to the robot”. The first experimenter then put away the warm-up toys, placed a curtain over the puppet theatre, moved it out of the infant’s arm reach, and commenced the four experimental trials. The second experimenter attached the first pair of experimental toys to the ledge, behind the curtain and out of the infant’s view, and selected and initiated the programmed cue(s) for the robot for the first trial. Upon hearing a light tap under the table, the first experimenter removed the curtain and directed the infant’s attention to the robot. The robot displayed each cue(s) a total of three times, with each cue display lasting four seconds separated by a one second interval. During each interval the first experimenter directed the infant’s attention towards the robot. After the cue(s) presentation, the first experimenter placed the fishnet in the center of the window and said, “The robot wants a toy. Give a toy to the robot”. After the infant chose a toy, the first experimenter placed the toy through the window, beside the robot saying, “Bravo. I’m giving this toy to the robot”. Then the experimenters proceeded to the next trial.

Three types of behavioral cues were presented to infants: gaze (eye and head turn towards the toy); gesture (arm raised and a claw opened and closed towards a target toy in a manner that mimicked a human reaching action); and vocal affect (an audiotaped, high-pitched robotic noise that mimicked a positive vocalization made by the person).

There were four different combinations of these behavioral cues: one 3-cue presentation: gaze + gesture + positive vocal affect; two 2-cue presentations: gaze + gesture and gaze + positive vocal affect; and one 1-cue presentation (gesture alone). The order of the four trials was counterbalanced so that one-third of the sample received the 3-cue presentation first, one-third of the sample received a 2-cue presentation first, and one-third of the sample received a 1-cue presentation first. Within each of these orders, the side on which the first cue was presented, either the left side or the right side of the ledge, was counterbalanced.

Coding. Each testing session was videotaped, and one experimenter coded all the tapes using an event recording program. A second coder, blind to the hypothesis randomly coded 25% of the participants from each of the three age groups for the following dependent variables: infants' looking time at the toys during cue presentation; and toy choice, which included both touching the toy and giving a toy to the robot.

Coding of looking time was collapsed across infants' looking to the left side of the ledge, to the right side of the ledge, and at the robot. Inter-rater reliability for the three age groups was: 14-month-olds, r =.93, 18-month-olds, r =.89; and 24-month-olds, r =.96. The mean percentage of looking time to the target toy was calculated by summing the percentages for infants' looking times to target toy, and then dividing that sum by the total looking time (to both the target and nontarget toys), and then multiplying the result by 100. Toy choice was coded for the first toy that was touched and the first toy that was given to the robot. A score of 1 was given to a correct response and a score of 0 was given for an incorrect response (e.g., the infant first touched the nontarget toy, or the infant first put the nontarget toy, both toys, or no toy in the net). Inter-rater reliability for toy choice for the three age groups (i.e., collapsed across touch toy and put a toy in the net) was: 14-month-olds, $r = .95$; 18-month-olds, $r = .91$; and 24-month-olds, $r = 1.00$.

Results

Robot Agent: Looking Time. Preliminary analyses indicated that no order effects were observed therefore order was dropped from further analyses. Infants' looking time to the target toy across trials was first examined. A two-way ANOVA with Age Group (14-, 18- and 24-month-olds) and Gender (boys and girls) as the between subject variables was conducted to compare infant's looking time to the target toys. There were no main effects or interactions. *T*-tests indicated that the mean percentage of looking time to the targets toy was above chance levels for infants in all three age groups: 14-month-olds, M=67.81, SD=12.91, $t(23)$ 6.76, $p < .001$; 18-month-olds, M=71.82, SD=11.94, $t(23)$ 8.96, p<.001; and 24-month-olds, M=67.41, SD=14.77, $t(23)$ 5.77, $p < .001$.

Robot Agent: Toy Choice. The second set of analyses explored whether infants selected the desired toy to give to the robot. Infant's base rate responses for giving a toy (either correct or incorrect) to the robot were first examined. The base rate was the mean percentage of toys given out of four trials. A two-way ANOVA (Age group x Gender) indicated there was an interaction between Age Group and Gender, $F(2,66)$=12.84, p < ..001. Analysis of simple effects indicated that boys in the 14-month-old age group (M=36.11, SD=35.60) were significantly less likely to give toys than the other infants. Nevertheless, across age groups, the mean percentage of toys given was above chance levels: 14-month-olds (M=60.42, SD=40.99); 18-month-olds (M=80.21, SD=29.47); and 24-month-olds (M=97.92, SD=10.21, $t(47)$ 7.576, $p < .001$). Next, to examine possible age differences infants' responses expressed as a proportion of correct toys given out of the number of trials in which any toy was given (correct or not) was compared. A two-way ANOVA (Age Group x Gender) indicated that there were no main effects or interactions. *T*-tests indicated that the mean proportion of correct toys given was not above chance levels for any of the age groups: 14-month-olds (M=35.08, SD=34.09); 18-month-olds (M=45.12, SD=29.71); and 24-month-olds (M=41.67, SD=24.08).

Robot versus Person Comparisons. To examine infants' differential reactions to a human's and a non-human's object directed actions the data from the participants in the present Experiment was compared to the data from the three age groups in Experiment 1.

Looking Time. Preliminary analyses indicated that no order effects were present, and thus order was dropped from further analyses. We first examined infants' looking time to the target toy across experiments. A three-way ANOVA with Agent (robot versus person); Age Group (14-, 18- and 24-month-olds); and Gender (boys and girls) as the between subject variables compared infant's looking time to the target toys. There was a main effect of Agent, $F(1,132)$=8.94, $p < .003$; whereby infants in the Person Group (M=76.26, SD=13.22) looked significantly longer to the target toys than the infants in the Robot Group (M=69.02, SD=13.22). Despite these differences in looking time, *t*-tests indicated that the mean percentage of looking time to the target toys was above chance levels for infants in both the Person and Robot Conditions, $t(71)$14.31, $p < .001$, and $t(71)$ 12.20, $p < .001$ respectively. don't have t-test for looking time for 18 and 24 Robot

Toy Choice. The second set of analyses compared infants' responses when they were requested to give a toy to either the Robot or Person. Infants' base rate responses in giving a toy (either correct or incorrect) to the Agent was first examined. The base rate was calculated as the mean percentage of trials in which a toy (correct or incorrect) was given out of four trials. A three-way ANOVA (Agent x Age Group x Gender) indicated there was only a main effect of Age, $F(2,132)=24.12$, $p < .001$. The 18- (M=81.77, SD=29.05) and 24-month-olds (M=96.54, SD=10.80) were significantly more likely to give toys than the 14-month-olds (M=56.77, SD=41.49). Second, the mean percentage of correct toys given out of trials in which any toy was given (correct or incorrect) was calculated to examine agent and age differences. A three-way ANOVA (Agent x Age Group x Gender) indicated that there were two main effects. A main effect of Agent was found, $F(1, 132)=10.38$, $p < .002$; which indicated that infants in the Person Group (M=56.32, SD=31.76) were significantly more likely to give the correct toys than infants in the Robot Group (M=40.62, SD=29.46). Second, a main effect of Age was found, $F(2,132)=5.23$, $p<.007$; which indicated that the 18- (M=55.56, SD=30.93)and 24-month-olds (M=52.00, SD=24.19) were significantly more likely to give correct toys than the 14-month-olds (M=37.85, SD=36.09). *T*-tests indicated that the mean percentage of correct toys given was above chance levels only for the older infants in the Person Group: 18-month-olds (M=66.00, SD=29.07; $t(23)=2.70$, $p<.013$); and 24-month-olds (M=62.33, SD=19.83; $t\,(23)=3.05$, $p<.006$, see Figure 4).

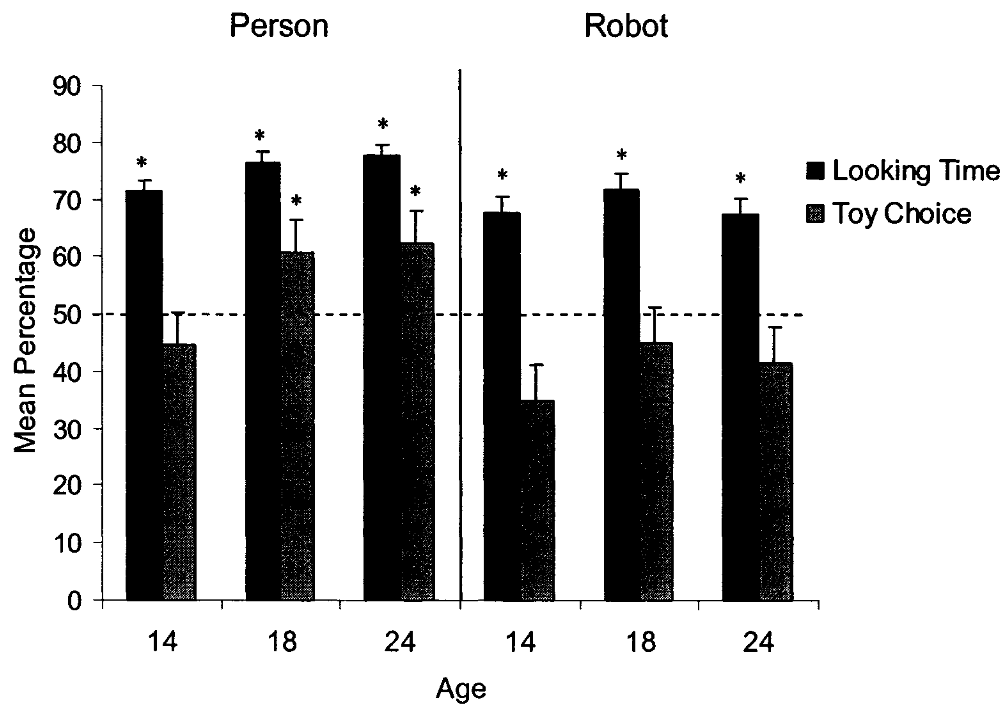

Figure 4. Mean percentage of looking time to the target toys (+SE) and mean percentage of correct toys given to the agent (+SE) by each of the three age groups in the Person Agent versus the Robot Agent Conditions in Experiment 3. *p<.05.

Touch Toy. This set of analyses explored the less stringent measure of toy touched. First, the base rates were calculated, defined as the mean percentage of touched toys out of four trials for each of the three age groups in the two agent conditions: 14-month-olds (Person: $M = 100.00$; Robot: $M = 98.96$); 18-month-olds (Person: $M = 100$; Robot: $M = 100$); and 24-month-olds (Person: $M = 100$; Robot, $M = 100$). A three-way ANOVA (Age group x Condition x Gender) revealed there were no main effects or interactions. Second, the mean percentage of correct toys touched out of four trials for of the three age groups in the two agent conditions were calculated: 14-month-olds (Person: $M = 58.33$, $SD = 26.24$; Robot: $M = 51.75$, $SD = 19.04$); 18-month-olds (Person: $M = 61.70$, $SD = 21.39$; Robot: $M = 47.92$, $SD = 20.74$); and 24-month-olds (Person: $M = 70.08$, $SD = 17.62$; Robot: $M = 52.08$, $SD = 21.10$). A three-way ANOVA (Age Group x Condition x Gender) yielded a main effect of Condition, $F(1, 151) = 13.98, p < .001$. Infants in the Person Agent Condition ($M = 63.12$, $SD = 22.16$) were significantly more likely to touch the correct toys than the infants in the Robot Agent Condition ($M = 50.58$, $SD = 19.99$).

Discussion

The results from Experiment 3 indicate that 14-, 18-, and 24-month-olds did not use a robot's referential cues to infer that it wanted a specific object, despite the fact that all the infants followed the robot's referential cues to the target toys. These results are strikingly different from those reported with the human agent in Experiment 1. Across the age groups, infants in the Robot Condition were less likely to give the desired toy than same-aged infants in the Person Condition. Moreover, while infants' understanding of people's object-directed actions as predictive of desires emerged at 18-months, infants in the Robot Condition did not perform above chance levels. These results thus indicate that infants did not perceive the similar object-directed actions exhibited by a non-human agent, as indicative of its desires.

Johnson and her colleagues (1998, 2001) propose that objects that possess a specific set of cues or features will elicit gaze-following in infants. The present experiments provide some support for such a cue-based interpretation. That is, infants were found to follow gaze to the target objects in response to similar object-directed actions by both a human and a non-human agent. That is, directional cues such as head and eye turn, and self-propelled movements elicited gaze following to both agents in the three age groups. However, the present experiments included an additional stringent measure by requiring infants to give the desired toy to the agents. Thus, it was found that even though infants were willing to follow the robot's cues they did not use them to infer desires at any age. Along the same lines, Legerstee and Berillas (2003) examined infants' gaze following responses to a human and non-human agent but also included a communication measure. They found that 12-month-olds directed significantly more social behaviors (i.e., pointed, vocalized, and looked to) to the person than to the inanimate agent (a doll). These findings along with the findings from the present Experiment seem to suggest that infants perceive people in a special way that is not extended to inanimate objects.

Experiment 4

One reservation about the discrepancy in findings from Experiments 1 and 3 may be that, unlike the human agent, the robot itself did not request a toy from the infant. In other words, infants may be less likely to perceive the robot as an agent because someone else made requests for the toys on its behalf. To rule out this possibility, we replicated

Experiment 1 with a new group of 18-month-olds. In the present experiment, infants were requested to give toys to the person who had exhibited the cues by a different female experimenter, as in Experiment 3. If infants understand that object-directed actions are indicative of an agent's desire then it would be predicted that infants would perform similarly across the two experiments (1 and 3). In the present experiment, data from participants in two groups were compared. One was the Control Group that consisted of a new sample of 18-month-olds; these infants observed one female experimenter display object-directed actions, and another female experimenter making the request for toys on her behalf. The second group was designated the Noncontrol Group; these infants were randomly selected from the 18-month-old participants in Experiment 1.

Method

Participants. The final sample for the Control Group consisted of thirteen 18-month-olds (*M* age = 17.94, range = 17.07 to 18.56), which included 9 girls and 4 boys. Of the original sample for the control participants, five were dropped due to fussiness. The data from the Control group were compared to the data from an equal number of 18-month-olds who participated in Experiment 1 (*M* age = 17.93, range = 18.20 to 18.89), which included 6 girls and 7 boys. That is, eleven participants from the original 18-month-old group in Experiment 1 were randomly selected, and excluded to ensure equal sample sizes. The remaining thirteen participants thus represented the Noncontrol Group. Participants were recruited from birth lists provided by a governmental health center in the Montreal area and came predominately from white middle-class homes.

Materials. Refer to Experiment 1 for a description of materials.

Design and Procedure. Refer to Experiment 1 for a description. There is one key methodological difference, however, between the two groups: Control and Noncontrol. In the Control group, while one female experimenter sat directly across from the infant and displayed attentional and emotional cue(s) to the target toy it was the second female experimenter, sitting directly beside the child, who then instructed the infant to place a toy in the fishnet saying, "Kara (i.e., the first experimenter) wants a toy. Give a toy to Kara". In Experiment 1, there was no second experimenter. The experimenter who displayed the cues in Experiment 1 was the person who requested a toy from the child. The methodological difference is analogous to what infants observed in the robot agent group. That is, the robot displayed the cues to the target toys and a female experimenter, sitting directly beside the infant, instructed the infant to give toys to the robot.

Coding. Refer to Experiment 1 for details on coding for participants in the Noncontrol group. In the Control group, each testing session was videotaped, and the main experimenter coded all the sessions. A second coder, blind to the hypothesis, randomly coded 25% of the participants for the following dependent variables: infants' looking time at the toys during cue presentation, and toy choice including both touching the toy and giving the toy to the person.

For infants in the Control group, coding of looking time included looking to the left side of the ledge, to the right side of the ledge, and at the experimenter; inter-rater reliability was collapsed across these three measures, and was $r = .95$. The mean percentage of looking time to the target toy was calculated by summing the percentages, for infants' looking time to the target toy, and dividing that sum by the total looking time (to both the target toy and the nontarget toy) and then multiplying the result by 100. Toy choice was coded for the first toy that was touched, and the first toy that was given to the experimenter. A score of 1 was given to a correct response and a score of 0 was given for an incorrect response (e.g., the infant first touched the nontarget toy, or the infant first put the nontarget toy, both toys, or no toy in the net). Inter-rater reliability for toy choice was $r = 1.00$ (collapsed across touch toy and put a toy in the net).

Looking Time. Preliminary analyses indicated that no order effects were present thus order was dropped from further analyses. We first examined infants' looking time to the target toy during cue presentation. A two-way ANOVA with Condition (Control group and Noncontrol group) and Gender (boys and girls) as the between subject variables compared infant's looking time to the target toys. There were no main effects or interactions. *T*-tests indicated that the mean percentages of looking times were very high and significantly above chance levels: Noncontrol group (M=77.28, SD=18.62; $t(12)$ 8.96, $p < .001$) and Control group (M=83.92, SD=9.82; , $t(12)$ 12.46 $p < .001$).

Toy Choice. We first examined infants' base rate responses for giving a toy, correct or incorrect, to the experimenter. The base rate was calculated as the mean percentage of trials in which a toy (correct or incorrect) was given out of four trials. A two-way ANOVA (Condition x Gender) indicated there were no main effects or interactions. The means for the two groups were: Control group (M=94.23, SD=14.97) and Noncontrol group (M=80.77, SD=34.08). We then calculated the mean percentage of correct toys given out of those trials in which a toy was given to the experimenter. A two-way ANOVA (Condition x Gender) indicated there was a main effect of Gender, $F(1,22)$=12.99, $p < .002$. The boys (M=77.27, SD=17.52) were significantly more likely to give correct toys than the girls (M=40.53, SD=26.14). There were no other main effects or interactions. The mean percentage of correct toys given for the two groups were: Control group (*M*=46.77, *SD*=19.42) and Noncontrol group (*M*=65.38, *SD*=34.67).

Touch Toy. This set of analyses explored the less stringent measure of toy touched. First, the base rates were calculated, defined as the mean percentage of touched toys out of four trials for the 18-month-olds in the two conditions: 18-month-olds (Control Group: $M = 100$; Noncontrol Group: M=100). Second, the mean percentage of correct toys touched out of four trials for 18-month-olds in the two conditions were calculated: 18-month-olds (Control Group: $M = 60.23$, $SD = 25.29$; Noncontrol Group: $M = 59.61$, $SD = 19.20$). A two-way ANOVA (Condition x Gender) yielded a main effect of Gender, $F(1, 22) = 5.83, p < .024$.

Discussion

Infants in the Control and Noncontrol groups did not differ in their responses for giving a toy. These results demonstrate that regardless of whether the experimenter who displayed the cues made the requests for a toy herself or whether a different experimenter did so on her behalf, infants' responses were the same. This finding then rules out the possibility that infants did not perceive the robot as an agent because it did not make requests for the toy.

General Discussion

The second year of life has been the recent focus of attention by researchers investigating the emergence of precursors to mental state attributions (e.g., Poulin-Dubois, 1999, Poulin-Dubois et al., in press; Poulin-Dubois, Sodian, Metz, Tilden & Schoeppner, 2004; Repacholi, 1998; Repacholi & Gopnik, 1997; Moses et al., 2001). The present paper examined infant's early understanding of desire in four experiments.

Specifically, the tasks examined whether infants' understanding of joint visual attention abilities affords them with an awareness that people have internal, psychological attitudes towards objects and the world. An interactive object-request paradigm was designed that examined infants' desire understanding by asking them to give the experimenter the desired toy on the basis of prior object-directed behaviors. An important goal was to determine which referential cue or combination of cues was effective in guiding infants to make correct predictions about a person's preference. The results revealed a developmental progression in infants' ability to use behavioral cues to make predictions about a person's preference. In contrast to the 14-month-olds, only the 18- and 24-month-olds were capable of giving the desired toy to the experimenter. That is, these older infants demonstrated that they perceived the adult's referential cues as providing information about her/his preference for one of the two toys, which then enabled the infants to predict the adult's preferences later on when there were no cues present to guide them in their decision-making. These results support and add to the findings from several other studies that demonstrate a grasp of intentions and desires "in action" by 18 months (Repacholi & Gopnik, 1997; Moses et al., 2001; Baldwin & Moses, 1996). The present results also extend the existing literature by showing that a rich array of referential cues including gaze, gesture, and vocal affect is essential for prediction at 18-months. At this age, infants only gave the correct toy when the experimenter displayed all three referential cues towards that toy. Twenty-four-month-olds also gave the correct toy when the experimenter displayed all three cues, and they also did so when only gaze and vocal affect cues were displayed. In the second experiment, a more rigorous test for 18- and 24-month-olds was designed that involved switching the position of the two toys following cue presentation, before requesting a toy. Using the combination of all three cues, only the 24-month-olds chose the correct toy in its new location, thereby demonstrating a clear understanding of the adult's object preference. The results from this switch in Experiment 2 suggest that 18-month-olds have a nascent understanding of desires that is not as well developed as the 24-month-olds.

There is considerable evidence that infants not only enjoy grasping objects from a young age, but that they also attend to others' grasping objects as goal-directed actions (Thelen, Corbetta, Kamm, Spencer, Schneider, & Zernicke, 1993; Woodward, 1998; Baillargeon, 1995). Likewise, the infants in the present study followed the referential cue(s) of gesture and the combination gesture and gaze to the specified toy, regardless of age and condition. However, infants did not use the grasping cue, on its own or in combination with gaze, as providing information about a person's underlying desire. These findings seem to suggest that infants' scheme of people's hands is restricted to that of a vehicle to grasp or move objects (see Woodward, 1998). In addition to the gesture cue, also examined was infants' ability to construe gaze alone, as indicative of a person's desire. The gaze cue in the present task involved a dynamic presentation of head and eye orientation towards one of two toys. Since an adults' eye turn on its own only prompts a following response around 18-months-old head and eye movement were paired together in the present experiments (Corkum & Moore, 1995). Moreover, head orientation seems to facilitate gaze following around 10-months-old (Corkum & Moore, 1995; Butterworth & Jarrett, 1991). Therefore, the enriching of the gaze cue with head turn was hypothesized to facilitate infants' ability to make predictions about a person's preference. However, while infants easily followed a person's gaze direction to the target toy, they did not interpret gaze as indicative of desire at any age. That is, when gaze was the only cue available, even 24-month-olds did not give the desired toy to the experimenter above chance levels. This result does not correspond with previous findings that 2-year-olds used eye gaze information either alone or in combination with a head turn to make inferences about a person's desire (Lee et al., 1998). The discrepancy between these two studies may arise for several methodological reasons. First, the experiments by Lee and colleagues were conducted with small samples, and therefore their results could be attributed to chance. Second, contradictory results could be attributed to differences in age across the two studies. The 24-month-olds in our sample were recruited around their second birthday (*M*=23.96 months) whereas the 2-year-olds in Lee et al.'s sample were, on average, 2.5 years old. Third, the measures used to indicate desire understanding were different. In Lee and colleague's experiments, the infant's responses were coded as correct if they pointed to the correct object on the television screen, as opposed to giving a toy to the person. However, even with the less demanding measure of touching a toy in the present results, the 24-month-olds failed to use the gaze cue alone.

The present results also found a dissociation between gaze following and desire understanding early in the second year. Why did the youngest infants not perform as well as the older infants? Specifically, clear findings from previous research demonstrate that 12- and 14-month-old infants connect human movements (e.g., a grasp) as well as emotional expressions to objects (e.g., Woodward, 1998; 2001; Phillips et al., 2002; Moses et al., 2001). However, the present object-request task posed additional demands on infants. That is, not only were infants required to attend to the experimenter's directional cues, facial expressions, and verbal demands, they also had easy access to attractive toys. Since infants could easily pick up their own desired toy(s), the task was quite difficult.

The findings with respect to the youngest infants are open to several interpretations. It is possible that task demands were too challenging, or that 14-month-olds were not motivated to give objects (see Repacholi & Gopnik, 1997). However, by 10 months of age, infants generally enjoy giving and requesting objects from others (Trevarthen & Hubley, 1978; Carpenter, Nagell, & Tomasello, 1998). Additionally, while the task demands were high, ample evidence exists to show that the task was age appropriate for the 14-month-olds. Not only did the youngest infants, overall, follow the adult's referential cue(s) significantly more often to the target toy overall, they also used their previous looking behavior to guide them in choosing the target toy, at least, on one trial. That is, 75% of the 14-month-olds touched and picked up the target toy when the person displayed all three cues towards that toy. However, the youngest infants demonstrated difficulty in giving toys, even on the 3-cue trial.

Carlson and Moses (2001) recently described young infants' general difficulty with inhibitory responses, what they labeled as "executive function expression accounts". Their account may clarify the cognitive stumbling blocks the youngest infants had to overcome to succeed on the giving task. For example, in the present study, the 14-month-olds predominately chose to either use the 3-cue combination as information to predict an adults' desire (i.e., 33% of infants placed the target toy in the fish-net) or to use the information for their own purposes (i.e., 46% of the infants kept the target toy to play with, and did not put any toy in the net). This latter response was not typical for the older infants, who tended to give toys to the experimenter. That is, only a very small minority of infants in the two older age groups chose to place neither toy in the net. Carlson and Moses' (2001) account indicates that the 14-month-olds who failed to give the correct toy might have done so because they were unable to curb their own desire towards the toy that was highlighted by the experimenter's cues. In this way, the experimenter's positive attention to one of the two toys perhaps made it more attractive than the other. Further, this small sample of 14-month-olds may have been aware of the adults' desire but their own desire dominated their behavior. Such a rich interpretation of the findings would lead to the idea that the 14-month-olds already understand something about others' desires. Indeed, a rich interpretation concurs with theoretical explanations about 12- and 14-month-olds' construal of peoples' emotional messages – namely, an understanding of referential intention (e.g., Moses et al., 2001; Repacholi, 1998). However, this seems to be a generous explanation for the 14-month-olds in the present study. In other words, our findings do not conclusively support the idea that the 14-month-olds have a grasp of desire understanding. A more plausible interpretation for the youngest infants in the present study is that they appreciated that the referential cues applied to one of the two toys, (i.e., referential specificity; see Mumme & Fernald, 2003). In other words, the 14-month-olds responded to the adult's referential cues in the immediate context and they did not encode it for later use.

Other recent evidence suggests a developmental progression of intention understanding in the second year. In one study, Bellagamba and Tomasello (1999) found that 18-month-olds were successful at reproducing an actor's goal even when the actor's action failed. In contrast, 12-month-olds did not infer an actor's goal from the failed intentional act but they were successful at reproducing the action when they saw the intended outcome. That is, the younger infants were successful when the actor performed the entire act (see also Phillips et al., 2002). In contrast, both age groups were poor at reproducing acts when they did not see the intentional action and only saw the outcome. In another study, Olineck and Poulin-Dubois (in press) compared 14- and 18-month-olds' ability to differentiate between intentional and accidental actions. Using a paradigm similar to Carpenter, Akhtar, and Tomasello (1998), Olineck and Poulin-Dubois (2004) found that 18-month-olds were more advanced than 14-months-olds in their ability to differentiate intentional actions from accidental actions. However, even the 14-month-olds tended to reproduce the intentional action when only a single action was reproduced, on average 73% of the time. This finding demonstrates that, although weaker than the 18-month-olds, 14-month-olds possess some understanding of other's intentions.

The current series of experiments also examined infants' concept of agent. The findings clearly demonstrated that when infants attribute mentalistic abilities to agents, they do so specifically to people and not broadly to all entities. That is, the earliest signs of mentalism in the experiments emerged at 18-month-olds, where the infants did not consider the robot as a psychological agent. This finding conflicts with those from several other studies (e.g., Johnson et al., 1998, 2001; Gergely et al., 1995; Kuhlmeier, Wynn, & Bloom, in press; Biro & Leslie, 2004). However, it seems most likely that these authors interpret their findings richly. This appears to be the case in light of the present evidence that 14-month-olds likely have a weak understanding of people as psychological agents. In particular, a nonmentalistic framework (e.g., conditioning) seems to provide a better and leaner explanation to the findings for 12-month-olds.

However, Johnson et al. (2001) found that 15-month-olds inferred an orangutan's intention from a failed action. Why would infants perceive the orangutan's actions as goal-directed and not do so three months later with the robot? Similar to Johnson and her colleagues (2001) features were added to the robot that infants might consider as corresponding to mentalistic agents: (1) treating it as an agent; (2) humanoid characteristics such as head and eyes; and (3) self-propelled motion. It is possible that the imitation paradigm is an easier task for young infants to grasp either at a nonmentalistic or mentalistic level than the object-request paradigm. Another possibility is that texture provided infants with a cue. Although this feature was not directly studied in either the present experiments or in Johnson, Booth, and O'Hearn's (2001) study, one inanimate object was soft and cuddly (i.e., the orangutan), whereas the other object was plastic and more machine-like (i.e., the robot). It seems most likely that 15-months-olds have had experiences with soft toy animals as interactive play partners (e.g., mother playfully instructs infant to give teddy bear a hug or to wave goodbye to it) than with remote-controlled machines and Lego pieces. In this way, something cuddly and soft such as the orangutan toy could have been perceived as highly familiar to the infants and also subsequently seen as a play partner. This may have predisposed infants to model the orangutan's actions without necessarily responding to it at a mentalistic level.

Direct empirical findings on infants' perception of a texture cue and inanimates are lacking. Nevertheless, there are recent studies by Woodward (2001), which indicate that texture plays an important role in infants' perception of peoples' actions. In these studies, she examined whether infants would respond differently to a person's hand grasp when it appeared as it should or when its texture was changed so that it appeared metallic and strange. In these experiments, 7- and 12-month-old infants did not treat a human's arm as goal-directed when it was seen on its own wearing a gold evening glove. In contrast, when the gloved hand was paired with the person 12-month-olds perceived the grasping action as goal-directed. These findings seem to suggest that infants understood the hand grasp as goal-directed when it was combined with other cues such as texture and a person's body with facial features (Woodward, 2001). Future empirical work is needed to determine the role of texture in infants' perception of actions by inanimate objects.

In sum, the present experiments revealed a developmental progression in infants' understanding of desire in the second year of life. More importantly, the present results indicate that a rich array of referential cues including gaze, gesture, and vocal affect are critical to guide 18-month-olds' predictions of a person's preference. Gaze alone (head and eye turn) did not provide sufficient information regarding a person's preference at any age. Infants seem to have a limited referential understanding of gesture, which develops between 18- and 24-months. The present experiments have illuminated a developmental progression in mental state understanding during the second year of life. Nevertheless, future research is needed to clarify the extent to which 14-month-olds understand desires. What is quite clear from the present experiments is that infants develop their joint attention skills prior to developing an understanding of mental states. Moreover, none of the infants perceived the robot as a mentalistic agent. Consequently, it is most likely that infants' early recognition of people later evolves into a more mature understanding of humans as mentalistic agents, which is present by 18 months of age. Notably, the various sorts of psychological understandings that emerge in infancy are not attributed to inanimate objects even when infants attend to the entities' behavioral cues.

Chapter 3. Conclusions

The present thesis addressed two important questions on infants' understanding of the mind. The first question asked, "What do children understand about the mind at various ages?" In Chapter 2, interpretations were presented on the present findings as potential answers to this question. However, left unanswered, is, "What are the mechanisms that account for the origins of, and the rapid transformations, in infants' theory of mind understandings?" The object request procedure was not designed to determine the mechanisms underlying infants' developing understanding of desire. Therefore, the present data does not provide direct answers to the second question. Nevertheless, the findings from the present experiments may highlight three key weaknesses in Modular accounts. Also, contrary to Modular accounts, the findings suggest that there is a developmental progression of understanding of desire in the second year of life. Thus, Chapter 3 will endeavor to illustrate that the present findings are more compatible with a Theory theory account than with a Modular one.

The two prominent theoretical accounts were described earlier in Chapter 1. Briefly, modular theorists suggest that evolution bestowed upon infants a series of specialized and innate modules/mechanisms for 'mind-reading' (e.g., Baron-Cohen, 1994, 1995). Conversely, Theory theorists propose that evolution endowed infants with theory construction abilities. This latter account recognizes that there is an initial starting-state that impels infants to identify with people but that natural 'scientific devices' (e.g., theory formation and testing, interpretation, explanation, prediction, causal attributions) ensure first conceptions are revised and elaborated upon by personal experiences (see Gopnik & Meltzoff, 1997; Wellman, 2002 for recent reviews). Since both accounts attempt to explain the ontology of theory of mind abilities it is often difficult to differentiate them on the basis of developmental data (see earlier comments in Chapter 1).

Gaze following

This seems to be the case for one robust finding from Experiments 1 and 2 in Chapter 2. That is, modular and theory theorists could equally explain why the person's object-directed behaviors elicited gaze following in infants from all ages. For example, a EDD mechanism/module automatically directs infants to orient to what the person is attending to in the environment, and a TOMM module that matures around 6 to 8 months allows infants to understand the notion of goal-directedness (Leslie, 1994; Baron-Cohen, 1995. Moreover, once SAM matures and can processes information from the EDD, 12-month-olds are able to form triadic representations in which he/she perceives that both self and other are attending to the same object (Baron-Cohen, 1995). One alternative constructivist account is also equally appealing, whereby repeated and familiar interactions enable infants to learn that a person's head turn signals an interesting sight (Corkum & Moore, 1995). Hence, the data on gaze following could be compatible with either account and are a poor candidate for differentiating the two theories. However, the data on correct toy choice may differentiate these two theories because it highlights three prediction weaknesses made by modular accounts: over generalization of cues, central importance of the eye gaze cue, and over generalization of agent.

Over generalization of cues

Modular theorists claim there is a 'hard-wired' module that detects self-propelled motion leading infants to over generalize intentionality to a variety of human behaviors (see e.g., Woodward, 1998; for a review; Premack, 1990; Baron-Cohen, 1995). Thus, these theorists would have presumably predicted that infants in Experiment 1 would not place any differential weight on the referential cues when they attribute desires to others. This is because on all six trials there were obvious indications of a person's self-propelled motion when she turned her head and/or she made a grasping motion towards a toy. The present pattern of results would not support this prediction. That is, 18-month-olds required the combination of gaze, gesture, and vocal affect to infer a person's desire. The 24-month-olds were also successful on the 3-cue combination, as well as the combination of gaze and vocal affect. Certainly, if infants use self-propelled motion as a trigger cue to intentionality they would have done so even in the single-cue trials (i.e., gesture or gaze) but desire inferences were not made at any age on these trials. Along the same lines, Woodward (1998) found that infants did not over generalize the notion of goal-directedness to human behaviors that were unintentional (e.g., the back of the hand falling onto an object).

Conversely, the present data on the relative weight infants placed on the cues when making desire inferences seem compatible with a theory formation account. For example, consider the data on the 24-month-olds in the first experiment. The oldest infants responded to the vocal affect cue when combined with gaze information as indicative of a person's desire but did not when the grasping cue was paired with the gaze cue. Why would infants have developed an earlier ability to infer desires from a person's vocal cue than a grasping cue? One possible explanation is that infants have more frequent occasions to observe people's vocal cues in a variety of contexts than a grasping cue and a grasping cue may also be perceived as less salient. In other words, infants may have accumulated more evidence about the desire aspects of a vocal affect cue that perhaps lead to more opportunities to test their first notions about people's affect.

However, even though a vocal cue may be more salient than a grasping one obviously infants have numerous social experiences with the latter. For instance, infants learn about the goal-directed nature of hands when caregivers play, feed, and comfort them (Rakison & Poulin-Dubois, 2001). These sorts of activities enable infants to learn that a grasping motion has physical results for the object (e.g., the object is put on top of another) thus facilitating them to also understand the person's underlying purpose (e.g., building a tower of blocks; Woodward, 1998). However, people's affective displays (facial and vocal) certainly frame these activities conveying a particular emotional tone, which facilitates perhaps a more enhanced understanding of how a vocal affect cue relates to a person's goal (e.g., the parent exclaims "Wow! Look at that!" when a block is placed on top of another). Additionally, infants are exposed to a vocal affect cue in isolation from a grasping motion (e.g., a parent speaks to the infant from another room or speaks to the infant from behind). Thus, infants have numerous experiences to observe how people's affective displays relate to objects, events, and activities either at a distance or proximal in ways that they do not with a grasping gesture. Relevant to this issue, while the present findings indicate that 24-month-olds do not perceive grasping gestures as indicative of underlying desires they do so with a pointing gesture (Lee et al., 1998). This is even though infants understand a grasping gesture as an object-directed action six months prior to their understanding of pointing as such (Woodward, 1998; Woodward & Guajardo, 2002). These findings suggest that those infants' experiences with own and others' points are somehow more rich and salient than those experiences with a grasping gesture.

Central Importance of Eye Gaze

In his mind-reading model, Baron-Cohen claims that eye gaze is the most important cue for 'mind-reading'. The present findings challenge this claim. That is, even though eye gaze direction was enhanced with a head turn infants did not perceive the gaze cue as indicative of a person's desire at any age. This result is consistent with the view that it takes numerous experiences to understand what someone is looking at from eye gaze direction (see e.g., Doherty & Anderson, 2000). For instance, it is only around 18 months that infants are able to follow a person's eye gaze cue to a target object, however, when eye gaze is combined with a head turn infants follow gaze much earlier around 10-months-old (Corkum & Moore, 1995). Also, recent findings indicate that the ability to use eye gaze direction to determine what someone is looking at and to infer desires develops in the preschool years (Lee et al., 1998; Doherty & Anderson, 1999).

Moreover, contrary to Baron-Cohen's assertion that SAM primarily obtains information from the EDD, there are recent findings that indicate that other non-verbal cues are more salient indicators of a person's desire, such as pointing and head orientation (e.g., Lee et al., 1998; Doherty & Anderson, 2000). Indeed, Lee et al. (1998) found that when an eye gaze cue conflicted with a pointing cue preschoolers favored the latter even when it was incorrect. Even though various findings refute Baron Cohen's claim that eye gaze is the most important cue that facilitates mind reading, the present findings do suggest that eyes play a special role. That is, eye gaze potentially enhanced the attribution of desire inference for the 3-cue combination as well as the two-cue combination of gaze and vocal affect for the 24-month-olds. However, eye gaze did not act to enhance the oldest infant's ability to attribute desire on gaze and gesture. One possibility is that vocal affect plays such a critical role that its presence is also necessary for desire attribution (i.e., gaze and gesture). However, it also seems that infants find anomalous a person looking directly at them when she displays object-directed behaviors (e.g., vocalization and gesture). That is, infants may have interpreted the person's gaze direction as conflicting with her vocal affect and grasping motion (e.g., the gaze orientation seems to mean look at experimenter whereas the grasping motion seems to mean look at toy). In this way, at least with these two cues, gaze needs to correspond for desire attribution.

Over generalized concept of Agent

In addition to predicting over generalization of cues that are intentional, Modular theorists also predict that infants broadly attribute intentionality to all kinds of entities. For instance, Baron-Cohen (1995) wrote:

> "the visual input might look as shapeless as an amoeba, as weird as a giraffe, or as minimal as a stick insect. Because of their self-propelled motion, all these are instantly interpretable as agents with goals and desires". (p. 34)

However, the findings from Experiment 3 along with findings from several other studies do not support this prediction (e.g., Meltzoff, 1995; Woodward, 1998: Legerstee & Berillas, 2003). That is, infants did not attribute desires to the robot despite their responsiveness to its referential actions at any age and even though its object-directed behaviors elicited as much gaze following to the target toy as a person did. Moreover, infants did not perceive the robot as a mentalistic agent although it possessed humanoid characteristics (e.g., eyes, arms). The present finding seems to provide a stronger argument against the modular theorist's prediction of over generalization than the findings that infants did not respond to mechanical devices such as rods and pincers as mentalistic agents (Woodward, 1998; Meltzoff, 1995). Infants may not have known how to respond to these latter inanimate objects as they are highly unfamiliar.

However, there is research demonstrating that infants sometimes respond to an inanimate object as a mentalistic agent. In their study, Johnson et al. (2001) argued that since 15-month-olds inferred the outcome from the toy orangutan's failed intended act that they have a broad understanding of mentalistic agents. Earlier in chapter 2, it was noted that infants are highly familiar with stuffed toy animals as 'social' partners in various human-like activities (e.g., feeding, bathing, waving hello and goodbye). An alternative possibility is that infants perceived the toy orangutan as an actual animal, which may suggest they responded to it as an animate being with goals (Rakison & Poulin-Dubois, 2001). It is less clear how to interpret the sort of meaning 12-month-olds attribute to actions by circles and by rods since older infants probably do not perceive inanimate objects as mentalistic beings (e.g., Biro & Leslie, 2004; Gergely et al., 1995). It is possible that 12-month-olds perceived the actions by a rod as goal-directed simply because they were given three training trials, which enabled them to make an association between the object and its action (e.g., Biro & Leslie, 2004).

Infants Aged 12 to 18 months

In addition to illuminating three weaknesses in Modular accounts, the present findings clearly demonstrate that there is a developmental progression of understanding of desire in the second year of life. However, the findings do not support the developmental timeline set out by Carpenter and her colleagues (1998) regarding infants' emerging ability to perceive others as intentional agents. That is, an understanding of desire does not seem to emerge around 9 months of age but rather in the middle half of the second year of life. Moreover, rich and dense social experiences with humans from 12 to 18 months of age may foster the development of desire attribution. The starting-point is thus the new set of social skills that emerges around 12-months-old.

Around their first birthday, infants reliably follow into a person's attentional focus or emotional stance and direct people's attention to objects with their points or words (e.g., Carpenter, Nagell, & Tomasello, 1998; see Tomasello, 1995, for a review). In particular, the latter ability emerges between 12 and 13 months and seems particularly well designed for infants to "tune in" to their intentional states as people generally respond to their communications (i.e., points or words) as if they were intentional or goal-directed (Tomasello, 1995). Indeed, infants may not initially consider their production of points or words as indicative of their internal experiences but come to do so through social interactions with others. For instance, an infant enters a room and sees his/her favorite book that he/she then points to or acknowledges with a word (e.g., 'ba'). Initially, there may be no intention, on the infant's part, to direct the adult's attention to it or to do something with it. However, a parent who generally sees underlying intentions in people's actions routinely interprets their infant's action as indicating a desire for something. She then picks up the desired book and queries, "Do you want to read this one?" These kinds of social interactions allow infants to construct how their communications represent their experience of wanting something and, moreover, getting the adult to attend to the same object for a particular goal (e.g., reading a book).

There are various other social interactions in which the parent (or sibling) intentionally transmits messages to the infant about a common topic, which promotes learning about how other's attentional and vocal cues are connected to underlying intentional states. For example, between 14 and 18 months of age, there are advances in infant's ability to differentiate between people's accidental and intentional actions (Olineck & Poulin-Dubois, in press). In other words, infants become better able at determining that only certain attentional and vocal cues are indicative of a person's intentional action and this is most likely attributed to their earlier experiences with others.

As suggested earlier, emotions are salient to infants. Moreover, their growing ability to produce, understand and respond to linguistic symbols during the second year is a powerful tool for fostering their understanding about emotions. Also, an understanding about feelings grows early in the second year from an "affective tuning" to people's distress and joy (Dunn, 1991), to the ability to act in accordance with people's emotional expressions to novel and ambiguous objects (e.g., Mumme & Fernald, 2001), and from a natural desire to test what effects their actions will produce. For instance, the latter takes place, over and again, in everyday family interactions whereby an infant's goal-directed actions (e.g., climbing on the kitchen table) produce certain behaviors or language (e.g., grabbing them off the table coupled with "I don't want you there!") and expressed feeling states (e.g., anger, despair) in their parents and, at the same time, their actions bring about internal emotional consequences (e.g., frustration at being pulled off the table or perhaps delight as the goal was to get the parent to run over). Indeed, the naturally curious infant constructs through her repeated personal experiences the understanding that there are connections between desires, actions, and outcomes (e.g., emotional consequences). As this example also illustrates infants are growing up in a family. This means that it is not only the behavior or the language that is directed to them that influences the development of the understanding of emotional states (Dunn, 1991).

Infants are tremendously interested in monitoring what is said and what is emotionally expressed between siblings and their parents (Dunn, 1991). Indeed, early experiences of observing mothers who are highly responsive and affectionate to a sibling associated with these infants performing better at affective labeling and perspective taking at a later age than infants whose mothers and siblings did not interact in this way (Dunn, Brown, Slomkowski, Tesla, & Youngblade, 1991). There is even some indication that infants begin to understand the causes of feeling states early in the second year. For example, simple acts of teasing seem to suggest that infants understand that their actions (e.g., grabbing a favorite toy from the sibling) produce anger and distress in the older child. As well, 14-month-olds may understand that a person's feeling state is related to her prior object-directed behaviors (Phillips et al., 2002). Therefore, it seems most likely that the tendency for infants to observe and monitor as well as play an active learner role, coupled with their family members actively socializing and guiding their behavior (e.g., with emotion language) facilitates the understanding that unobservable emotional states (e.g., desires) explain and predict observable behaviors by the middle of the second year of life.

Future Directions for Research on the Causal Aspect of Mind

The present object request procedure was designed to provide a more stringent test of infants' understanding of desire than other procedures such as habituation or preferential looking. However, since an implicit (rather than explicit) understanding of mind was examined even the object request procedure poses some limitations regarding interpretations of the present findings. Relevant to this issue, evidence on 24-month-olds' explicit answers clearly demonstrates that they have an understanding of desire (Bartsch & Wellman, 1995). However, it is more difficult to establish whether nonverbal infants' performance (e.g., following the agent's gaze to the desired toy or toy touched) differentiates between associative and causal explanations. This is especially the case for the 14-month-olds and the 18-month-olds in the Switch Condition. In other words, more needs to be known about whether their reactions to a person's object-directed behaviors indicates that they attribute internal mental states to people or whether they simply associated the person's referential cues (e.g., gaze direction, gestures, and vocal affect) with the toy. The findings on the referential cues also lead to several suggestions for future studies. That is, infants of all ages did not perceive a grasping gesture alone nor a gaze cue alone as indicative of peoples' desires. More needs to be known about whether other nonverbal cues are understood as predictive of peoples' desires. For example, Lee et al.'s (1998) findings indicate that 24-month-olds understand the causal aspects of a point gesture. In this way, research could explore whether younger infants have a similar understanding of pointing. In addition, investigators who conduct future research on the combination of gesture and vocal affect will have to consider the confound of gaze. One possible manipulation is to have a live actor close her eyes prior to gesturing towards and vocalizing about the target toy. This may eliminate infants' confusion over where to look.

The present object request procedure clearly demonstrated that the humanoid inanimate object was not perceived as an intentional agent. To provide further evidence for this finding, investigators could attempt to replicate Johnson et al.'s (2001) imitation procedure with the robot. As suggested earlier in Chapter 2, it is possible that the imitation task is an easier one than the present object-request task for infants to grasp either at a mentalistic or a nonmentalistic level. Nevertheless, findings that infants do not reproduce actions by a mechanical device demonstrate that an easier imitation procedure is not sufficient for attribution of intentions to inanimates (Meltzoff, 1995). It would seem that the strangeness of the mechanical device also played a role in this study. Alternatively, since the robot is humanoid (i.e., has a face) infants may find it less strange than a mechanical device. In this way, the finding that infants do not reproduce acts by the robot would provide further evidence that infants attribute special meaning to people's actions. A potentially fruitful avenue for future researchers may be the comparison of autistic children's responses to a human and a non-human agent. In other words, such a study could provide an indirect source of evidence for the view that infants do not perceive inanimates as social agents because autistic children may prefer to observe and/or follow the actions by a non-human than by a human. There is some evidence that suggests that 20-month-old autistic infants show differential behaviors to people and to mechanical toys. For example, they used gaze to examine physical aspects of the mechanical toys and did not use gaze declaratively with an adult (i.e., they did not use gaze to share what was going on with the adult; Charman et al., 1998). Moreover, even when autistic children looked at a person's face they were impaired at decoding simple mental states such as 'attend' or 'goal' in the eyes (Baron-Cohen & Cross, 1992).

In summary, the present findings are more compatible with a theory formation account than a modular one. The present experiments do not specifically examine infant's natural theory construction and testing abilities, nevertheless, the present data does not support three predictions made by modular theorists. The favored view is that infants make sense of intentional actions from their early ability to 'read' people, from the development of abilities such as joint attention, and from rich and dense social experiences with humans during the second year.

Appendix A

Source Tables for Analysis of Variance for Experiment 1

Looking Time at Target Toys

Base Rate Responses for Giving Toys (Correct or Incorrect) to the Person

Giving the Correct Toys to the Person

Base Rate Responses for Toys Touched (Correct or Incorrect)

Correct Toys Touched

Latency to Touch the Correct Toy

Table A.1. Source Table for Age Group (14-, 18-, and 24-month-olds) x Gender (boys and girls) for Looking Time at Target Toys for Experiment 1.

Source of Variation	SS	DF	MS	F	Significance of F
Age Group	634.85	2	317.42	1.81	.171
Gender	2.45	1	2.45	.014	.906
Age Group x Gender	604.51	2	302.25	1.73	.186
Error	11547.31	66			

Table A.2. Source Table for Age Group (14-, 18-, and 24-month-olds) x Gender (boys and girls) for Base Rate Responses for Giving Toys (Correct or Incorrect) to the Person in

Experiment 1.

Source of Variation	SS	DF	MS	F	Significance of F
Age Group	22308.37	2	11154.18	11.74	.000
Gender	15.14	1	15.14	.02	.900
Age Group x Gender	972.84	2	486.42	.51	.015
Error	62732.01	66			

Table A.3. Source Table for Age Group (14-, 18-, and 24-month-olds) x Gender (boys and girls) for Giving the Correct Toys to the Person in Experiment 1.

Source of Variation	SS	DF	MS	F	Significance of F
Age Group	5213.84	2	2606.92	3.55	.034
Gender	2067.61	1	2067.61	2.81	.098
Age Group x Gender	1780.19	2	890.09	1.21	.304
Error	48489.32	66	734.69		

Table A.4. Source Table for Age Group (14-, 18-, and 24-month-olds) x Gender (boys and girls) for Base Rate Responses for Toys Touched (Correct or Incorrect) in Experiment 1.

Source of Variation	SS	DF	MS	F	Significance of F
Age Group	9.45	2	4.73	1.88	.311
Gender	4.71	1	4.71	1.18	.281
Age Group x Gender	9.45	2	4.73	1.19	.311
Error	262.73	66			

Table A.5. Source Table for Age Group (14-, 18-, and 24-month-olds) x Gender (boys and girls) for Correct Toys Touched for Experiment 1.

Source of Variation	SS	DF	MS	F	Significance of F
Age Group	2014.31	2	1007.16	3.01	.056
Gender	1901.41	1	1901.51	5.68	.020
Age Group x Gender	73.29	2	36.64	.11	.896
Error	22085.84	66			

Table A.6. Source Table for Age Group (14-, 18-, and 24-month-olds) x Gender (boys and girls) for Latency of Looking Time at the Target Toys in Experiment 1.

Source of Variation	SS	DF	MS	F	Significance of F
Age Group	33.41	2	16.71	15.23	.000
Gender	3.75	1	3.75	.03	.854
Age Group x Gender	1.28	2	.64	.58	.561
Error	72.43	66	1.10		

Appendix B

Source Tables for Analysis of Variance for Experiment 2

NonSwitch/Switch Comparisons:

Looking Time at Target Toys

Base Rate Responses for Giving Toys (Correct or Incorrect)

Giving the Correct Toys to the Person

Correct Toys Touched

Table B.1. Source Table for Condition (NonSwitch and Switch) x Age Group (18-, and 24-month-olds) x Gender (boys and girls) for Looking Time at Target Toys for Experiment 2.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	1005.20	1	1005.20	5.30	.024
Age Group	607.61	1	607.61	3.20	.077
Gender	1717.34	1	1717.34	9.05	.003
Age Group x Gender	864.74	1	864.74	4.56	.036
Age Group x Condition	476.05	1	476.05	2.51	.117
Condition x Gender	494.82	1	494.82	2.61	.110
Age Group x Gender x Condition	145.05	1	145.05	.76	.384
Error	16694.99	88			

Table B.2. Source Table for Condition (NonSwitch and Switch) x Age Group (18-, and 24-month-olds) x Gender (boys and girls) for Base Rate Responses for Giving Toys (Correct or InCorrect) to the Person for Experiment 2.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	652.75	1	652.75	.950	.332
Age Group	3792.99	1	3792.99	5.52	.021
Gender	67.58	1	67.58	.098	.755
Age Group x Gender	411.02	1	411.02	.598	.441
Age Group x Condition	87.35	1	87.35	.127	.722
Condition x Gender	53.31	1	53.31	.078	.781
Age Group x Gender x Condition	382.69	1	382.69	.557	.457
Error	60443.30	88			

Table B.3. Source Table for Condition (NonSwitch and Switch) x Age Group (18-, and 24-month-olds) x Gender (boys and girls) for Giving the Correct Toys to the Person in Experiment 2.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	7602.83	1	7602.83	13.36	.000
Age Group	145.56	1	145.56	.25	.614
Gender	1244.83	1	1244.83	2.19	.143
Age Group x Gender	102.53	1	102.53	.18	.672
Age Group x Condition	109.47	1	109.47	.19	.662
Condition x Gender	2536.74	1	2536.74	4.46	.038
Age Group x Gender x Condition	26.64	1	26.64	. 05	.829
Error	50073.25	88			

Table B.3. Source Table for Condition (NonSwitch and Switch) x Age Group (18-, and 24-month-olds) x Gender (boys and girls) for Correct Toys Touched in Experiment 2.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	4701.14	1	4101.14	13.36	.000
Age Group	862.60	1	862.60	2.45	.121
Gender	1071.38	1	1071.38	3.04	.084
Age Group x Gender	60.92	1	60.92	.173	.678
Age Group x Condition	62.57	1	62.57	.178	.674
Condition x Gender	162.02	1	162.02	.461	.499
Age Group x Gender x Condition	.834	1	.834	.002	.961
Error	30959.86	88			

Appendix C

Source Tables for Analysis of Variance for Experiment 3

Robot Agent

Looking Time at Target Toys

Base Rate Responses for Giving Toys (Correct or Incorrect) to the Robot

Giving the Correct Toys to the Robot

Table C.1. Source Table for Age Group (14, 18-, and 24-month-olds) x Gender (boys and girls) for Robot Agent: Looking Time at the Target Toys in Experiment 3.

Source of Variation	SS	DF	MS	F	Significance of F
Age Group	239.54	2	119.97	.711	.495
Gender	245.76	1	245.76	1.46	.232
Age Group x Gender	740.23	2	370.11	2.19	.120
Error	11134.50	66	166.70		

Table C.2. Source Table for Age Group (14, 18-, and 24-month-olds) x Gender (boys and girls) for Base Rate Responses for Giving Toys (Correct or Incorrect) to the Robot Agent in Experiment 3.

Source of Variation	SS	DF	MS	F	Significance of F
Age Group	20300.51	2	10150.26	12.84	.000
Gender	2862.24	1	2862.24	3.62	.061
Age Group x Gender	6158.27	2	3079.13	3.89	.025
Error	52187.84	66	790.72		

Table C.3. Source Table for Age Group (14, 18-, and 24-month-olds) x Gender (boys and girls) for Giving the Correct Toys to the Robot Agent in Experiment 3.

Source of Variation	SS	DF	MS	F	Significance of F
Age Group	1209.35	2	604.67	.668	.516
Gender	368.84	1	368.84	.408	.525
Age Group x Gender	283.97	2	141.99	.157	.855
Error	59699.59	66			

Appendix D

Source Tables for Analysis of Variance for Experiment 2

Robot Agent/Person Agent Comparisons

Looking Time at the Target Toys

Base Rate Responses for Giving Toys (Correct or Incorrect) to the Agent

Giving the Correct Toys to the Agent

Base Rate Responses for Toys Touched (Correct or Incorrect)

Correct Toys Touched

Table D.1. Source Table for Condition (Robot and Person) x Age Group (14, 18-, and 24-month-olds) x Gender (boys and girls) for Looking Time at Target Toys in Experiment 3.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	1863.42	1	1863.42	8.94	.003
Age Group	504.65	2	252.32	1.21	.301
Gender	342.77	1	342.77	1.64	.202
Age Group x Gender	809.73	2	404.87	1.94	.147
Age Group x Condition	198.52	1	99.26	.477	.622
Condition x Gender	14.16	1	14.16	.068	.795
Age Group x Gender x Condition	266.73	2	133.36	.640	.529
Error	27496.93	132			

Table D.2. Source Table for Condition (Robot and Person) x Age Group (14, 18-, and 24-month-olds) x Gender (boys and girls) for Base Rate Responses for Giving the Toys (Correct or Incorrect) to the Agent in Experiment 3.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	4.66	1	4.66	.005	.942
Age Group	42378.26	2	21189.13	24.12	.000
Gender	1403.07	1	1403.07	1.56	.209
Age Group x Gender	4132.11	2	2066.06	2.35	.195
Age Group x Condition	327.56	2	163.78	.186	.830
Condition x Gender	1487.58	1	1487.58	1.69	.195
Age Group x Gender x Condition	2584.06	2	1292.03	1.47	.233
Error	115945.39	132			

Table D.3. Source Table for Condition (Robot and Person) x Age Group (14-, 18, and 24-month-olds) x Gender (boys and girls) for Giving the Correct Toys to the Agent in Experiment 3.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	7602.83	1	7602.83	13.36	.000
Age Group	145.56	1	145.56	.25	.614
Gender	1244.83	1	1244.83	2.19	.143
Age Group x Gender	102.53	1	102.53	.18	.672
Age Group x Condition	109.47	1	109.47	.19	.662
Condition x Gender	2536.74	1	2536.74	4.46	.038
Age Group x Gender x Condition	26.64	1	26.64	. 05	.829
Error	50073.25	88			

Table D.5. Source Table for Condition (Robot and Person) x Age Group (14, 18-, and 24-month-olds) x Gender (boys and girls) for Correct Toys Touched in Experiment 3.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	6261.43	1	6261.43	14.09	.000
Age Group	1380.77	2	690.38	1.55	.215
Gender	30.17	1	30.17	.068	.795
Age Group x Gender	507.28	2	253.64	.571	.566
Age Group x Condition	597.06	2	298.53	.672	.513
Condition x Gender	145.15	1	145.15	.327	.569
Age Group x Gender x Condition	530.51	2	265.25	.597	.552
Error	58655.53	132			

Appendix E

Source Tables for Analysis of Variance for Experiment 4:

Looking Time at Target Toys

Base Rate Responses for Giving Toys (Correct or Incorrect) to the Agent

Correct Toys Given to the Agent

Correct Toys Touched

Table E.1. Source Table for Condition (Control Group and NonControl Group) x Gender (boys and girls) for Looking Time at Target Toys for Experiment 4.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	215.33	1	215.33	1.19	.288
Gender	298.34	1	298.34	1.64	.213
Condition x Gender	.002	1	.002	.000	.997
Error	3994.09	22			

Table E.2. Source Table for Condition (Control Group and NonControl Group) x Gender (boys and girls) for Base Rate Responses for Giving Toys (Correct or Incorrect) to the Agent in Experiment 4.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	859.46	1	859.46	1.18	.289
Gender	1.47	1	1.47	.002	.965
Condition x Gender	622.77	1	622.77	.856	.365
Error	16001.98	22			

Table E.3. Source Table for Condition (Control Group and NonControl Group) x Gender (boys and girls) for Giving Correct Toys to the Agent in Experiment 4.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	939.66	1	939.66	1.84	.189
Gender	6647.75	1	6647.75	12.98	.002
Condition x Gender	678.12	1	678.12	1.33	.262
Error	11253.32	22			

Table E.4. Source Table for Condition (Control Group and NonControl Group) x Gender (boys and girls) for Correct Toys Touched for Experiment 4.

Source of Variation	SS	DF	MS	F	Significance of F
Condition	279.32	1	279.32	.667	.423
Gender	2443.42	1	2443.42	5.83	.024
Condition x Gender	610.98	1	310.98	1.46	.240
Error	9217.90	22			

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