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Calculating the Attentional Orientation of an Unfamiliar Agent in Infancy

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Abstract

By the end of the first year, infants are able to recognize both goal-directed and perceptually guided behavior in the actions of non-human agents, even faceless ones. How infants derive the relevant orientation of an unfamiliar agent in the absence of familiar markers such as eyes, ears, or face is unknown. The current studies tested the hypothesis that infants' calculate an agent's "front" from the geometry of its behavior in the spatial environment. In the first study, 14- to 15-month-old infants observed a symmetrical, faceless agent either interact contingently with a confederate or act randomly. It then turn toward one of two target objects. Infants were more likely to look in the direction the agent turned than the opposite direction, but only in the contingent condition. In the second study, the location of the confederate and target objects was varied, which in turned influenced which end of the agent infants interpreted as the front. Finally, implications for infants' early gaze-following behaviors with humans are tested and implications for theory of mind development more broadly are discussed.

By the end of the first year, infants reliably follow the directional orientation of others' with their own eyes. That is, if they see a person shift her directional orientation, infants are apt to shift their own gaze in the same direction (Scaife & Bruner, 1975; Carpenter, Nagell, & Tomasello, 1998).

Whether (or when) this initial ability to follow another's "gaze" also reflects the attribution of intentionality, specifically attention or perception has been a matter of debate among developmentalists (Brooks & Meltzoff, 2002, 2005; Butler, Caron, & Brooks, 2000; Butterworth & Jarrett, 1991; Caron, Butler & Brooks, 2002; Caron, Kiel, Dayton, & Butler, 2002; Corkum & Moore, 1998; Johnson, Slaughter, & Carey, 1998; Lempers, Flavell & Flavell, 1977; Moore & Corkum, 1998; Moll & Tomasello, 2004). In this paper we examine infants' attributions of intentionality in the philosophical sense of "aboutness" that is implied by any target- or "goal"-directed behavior. More specific intentional terms such as attention, perception, and goal are used to capture the directional aspects of different mind-world relations, rather than to imply that infants attribute internal, conscious experiences to agent.

Recent evidence suggests that at least by 9 months, if not earlier, infants encode the relationship between an actor's head/eye turns and a specific target and thus might be said to attribute attention or perception to others. Johnson, Luo and Ok (2007) found that infants habituated to

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the sight of an actor turning to look at one of two possible target objects, later recovered more interest to the sight of the actor changing the target of her looks than the sight of the actor changing the direction of her looks. Woodward and others found the same ability in 12-month-olds (Phillips, Wellman & Spelke, 2002; Woodward, 2003).

Additional support for infants' intentional attributions has come from studies that did not directly test infants' interpretation of gaze-following, yet nonetheless required the infant to recognize and encode the target of an actor's perception/attention. For instance, Tomasello and Haberl (2003) found that 12-month-olds understood which of several objects an adult had previously seen and could use this information to share only previously unseen objects with the adult. In a related study, 14-month-olds were able to map an actor's previous perceptual access to an object onto the possible referent of that actor's later utterances, as indexed by the infants' searching behavior (Moll, Koring, Carpenter & Tomasello, 2006).

In a nonverbal analogue to the false belief task, Onishi and Baillargeon (2005) found that 15-month-olds were surprised when a human actor correctly searched for a hidden target object if it had been hidden out of the actor's view, but not if it was hidden in the actor's view. Relatedly, Luo and Baillargeon (in press) showed that 12-month-olds were surprised when an actor changed her preferred goal of two possible goal-objects, but only when the actor had had perceptual access (either currently or in the recent past) to both objects.

Despite these successes, infants' gaze-following behaviors are not without error. For instance, younger infants often have difficulty locating the correct target of another's attentional focus if there is more than one candidate available (Butterworth & Jarrett, 1991.) They also sometimes fail to appreciate the significance of occluders placed in an actor's line of sight, even following headturns to objects hidden from the actor's view (Brooks & Meltzoff, 2002; Butler et al., 2000; Caron et al., 2002; Lempers et al., 1977). Even in the absence of occluders, infants make mistakes. For instance, infants sometimes follow head movements rather than eye movements, even if the eyes are closed; or if the eyes move without any accompanying head movement, infants will often not follow at all (Brooks & Meltzoff, 2002, 2005; Caron et al., 2002; Corkum & Moore, 1998).

What are we to make of infants' errors in the context of gaze-following, given their success in other tasks? One possibility is that (1) although infants construe adults' directional orientation as intentional, (2) infants' early gaze-following ability is not based on that competence. A second possibility is that (1) infants construe adults' directional orientation as intentional, (2) their gaze-following abilities *are* based on that construal, but (3) they are slow to isolate the eyes as the most relevant and/or necessary indicator of that intention. Indeed, in all the reports of infant success described above, eye, head, and body orientation were correlated.

Work on infants' interpretation of non-human agents supports this second possibility. Several studies have shown that eyes are not a necessary cue for infants' intentional attributions. In Johnson et al. (1998) and Johnson (2003), 12-month-old infants followed the "gaze" of a novel agent that had no eyes at all, as long as it first interacted contingently with them or another person. In addition, other studies with "live" eyeless/faceless novel agents have elicited goal-attributions from infants using Woodward's method. Johnson, Shimizu and Ok (2007) showed that 12-month-olds encode the goal-objects of a faceless green blob if it interacts contingently with an adult confederate first or if it moves in apparently perceptually-guided ways (see also Shimizu & Johnson, 2004). Luo and Baillargeon (2004) showed that 5-month-olds will do the same for a faceless, self-moving box. Work by Gergely and others has shown similar attributions by young infants to apparently perceptually-guided animated shapes (Csibra, Gergely, Biro, Koos & Brockbank, 1999; Gergely & Csibra, 2003; Gergely, Csibra, Nasdasdy

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& Biro, 1995), including at least one non-human version of the non-verbal false belief task (Surian, Caldy & Sperber, 2007).

How infants in these studies determined where the novel agent's front was, in the absence of a visible face or eyes, is a bit of puzzle however, particularly so in the context of the gaze-following studies in which there was no diambiguating translational movement. Nonetheless, in the "gaze"-following studies of Johnson and colleagues, infants systematically selected one end of the morphologically ambiguous object over the other as the more relevant end to follow.

Infants may have solved this problem in the studies by Johnson and colleagues (Johnson et al., 1998; Johnson, 2003) in a variety of non-mutually exclusive ways. For instance, in the original studies, the novel agent had an asymmetric body shape; roughly dome shaped with a head-like bulge on the end facing the infant. When the object rotated during test turns, infants may have assumed that the "pointed" end of the object was the front. Alternatively, they may have simply assumed, egocentrically, that the side facing them was the "face".

Another possibility is suggested by the goal-attribution work of Gergely and colleagues (Csibra et al., 1999; Gergely & Csibra, 2003; Gergely et al. 1995). This work shows that infants attend to the physical constraints of the environment in which an agent's behavior occurs and assume that the behavior will conform to the most "rational" or "efficient" means for accomplishing any particular goal. Reasoning backwards, one might assume that the most efficient means of detecting and attending to a target is to "face" it. Therefore the orientation of an agent's *behavior* relative to its physical and/or social environment may itself signal the location of that agent's front, even if the agent's morphology does not. Such an ability would be consistent with the claim that infants' are capable of recognizing object-directed, intentional behavior in others, *before* they have isolated the eyes as the most reliable index of others' attentional focus. This could, in turn, shed new light on younger infants' willingness to follow head orientation when monitoring human adults, rather than eye direction alone.

To test these possibilities, we created a novel agent, symmetrical front to back and side to side, with no distinguishing marks anywhere on its surface. We hypothesized that we would be able to control which end of the agent infants designated as the front, and thus which direction infants would look in a "gaze"-following procedure, by manipulating the location of the agent's presumed perceptual targets. We predicted that if the targets (an interactive confederate and a pair of small inanimate toys) were located on the proximal side of the agent, infants should designate the proximal end as the front, and follow clockwise turns to the left; if the targets were located on the distal side of the agent, infants should designate the distal end as the front, and follow clockwise turns to the right. Such a result would imply that when infants perceived that the novel object's behavior was directed at the world -- they were able to use that information to infer the location of its front. This would also rule out body asymmetry and egocentrism as necessary components of the inference.

This line of reasoning rests on the assumption that infants recognize the novel object as an intentional agent in the first place. Therefore, preparatory to a geometric manipulation in Study 2, we first extended Johnson et al. (1998) and Johnson (2003) in Study 1 to show that infants' would in fact treat this new, symmetrical novel object as an agent. As in the original studies, such an interpretation rests on infants' simultaneous failure to follow the orientation of the object when it does *not* display strong evidence of its intentionality. Only then can we rule out alternative, low-level interpretations of infants' following behavior. In this case, a control condition that involved the same agent activity (but in a non-contingent context), the same rotational movement cues and the same potential target objects was used. A positive result would also rule out body asymmetry as a necessary condition of gaze-following.

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Finally, Study 3 tests the implications of Study 2 in a novel test of infants' ability to monitor human attention in non-canonical orientations.

Study 1

Participants

Twenty-eight 14- to 15-month-old infants participated in either a Contingent (N = 16; seven males and eight females, M = 14;26, range, 13;27 to 15;22) or Non-contingent condition (six males and six females; M = 14;16 days, range 13;25 to 15;10).

The Agent and Targets

The agent was 12 inches long by 8 inches wide and 3 inches high, draped in bright green fiberfill. It was roughly oval in shape with no articulated parts and no distinguishing marks. An internal beeper was remotely operated. It was mounted on a hidden magnet. The magnet was located at the midpoint of the agent's front-back axis. Therefore, when it rotated during test trials, the front and back ends subtended equal visual angles, though in opposite directions. The targets were two small toys.

The Set-up

The agent was placed in the center of a black fiberboard platform 48 inches by 48 inches. An experimenter seated under the platform was hidden by a floorlength skirt around the platform. The experimenter controlled the agent's movement via a strong magnet. For this purpose, a view of the agent and targets was fed to a TV monitor mounted underneath the platform. A camera positioned opposite the infant was focused on the infant's face for coding purposes.

The targets were place in the two near corners of the platform, approximately four inches in from each edge and 40 inches apart.

The platform itself sat in the middle of a large testing room, with open space on all four sides.

Procedure

Contingent condition—Infants were seated on their caretakers' laps in front of, but out of reach of the platform on which the toy targets and agent were situated (see Figure 1). A cloth hid the agent. Caretakers were requested to close their eyes and refrain from interacting with their infants. To ensure infants noticed the two targets on the platform, infants were handed and allowed to play with each for 15 seconds. After the second target was replaced on the platform, the confederate remarked "What's this?" and lifted the cloth to reveal the agent. The agent responded with a slight rotation toward the confederate and a loud beep. The confederate then engaged the agent in a scripted "conversation" of small talk lasting approximately 60 seconds. The confederate spoke English; the agent responded with a standard pattern of beeps. At the conversation's completion the confederate left the room and the agent returned to midline. Four test trials, two to each side, followed. For each trial, the agent made a loud, attention-grabbing beep, then rotated sharply towards the target on the left or right. The agent remained "fixated" on the target for approximately seven seconds before returning to midline. The order of turns was counterbalanced.

Non-contingent condition—This condition was identical to the Contingent condition with the exception that the experimenter did not respond to the agent's beeps. Both the experimenter and agent remained silent during what would have been the experimenter's "turn" during the interaction. The experimenter stared at the floor.

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Coding

The looking behavior of each infant was coded from videotapes by a trained primary coder who was blind to the condition and the movement of the agent. The direction of the first look within each trial window was coded as either to the right or left of the midline anywhere in the vertical plane. Infants' looks had to begin at midline in order to be counted. Smooth, uninterrupted looks directly from the agent to the caretaker and looks directly up or down along the midline were excluded. Only looks judged by the coder to extend beyond the body of the agent were included. A secondary coder recoded 14 percent of the infants, achieving a kappa of .714.

Results

Preliminary analysis showed no effects of sex or order of trials so these variables were removed from the analysis.

A mean difference score was calculated for each infant by subtracting the number of trials in which the infant looked in the opposite direction from the agent's turn from the number of trials in which she looked in the same direction and dividing by 4 (the number of trials). Because infants could choose to look to a side in all four trials or in no trial at all (e.g., by looking instead at their caregiver or by not looking away from the agent at all), this score could range from −1 to 1. If infants' looking behavior was systematically influenced by the behavior of the agent, the difference score should be reliably different from zero. Infants in the Contingent condition looked more often in the same direction as the agent, producing a mean difference score of 0.28 ($SD = 0.27$), $t(15) = 4.14$, $p < .001$. Infants in the Non-contingent condition did not, producing a mean difference score of 0.21 ($SD = 0.50$), $t(11) = 1.45$, n.s..

Eleven of the 16 infants in the contingent condition looked more often in the same direction as the agent turned than in the opposite direction, one infant looked more often in the opposite direction, and four infants looked equally in both directions, $p < .001$ by a sign test. In the Non-contingent condition, four infants of the 12 infants looked in the same direction as the agent turned more often than not, three looked in the opposite direction, and five looked equally in both directions, $p > .99$ by a sign test.

In a direct comparison of the two conditions, an analysis of variance (ANOVA) on the difference scores with condition as the independent variable revealed no difference, $F < 1$. However, a non-parametric comparison of the number of infants who looked more often in the predicted direction versus those who did not yielded a $\chi^2(1, n=28) = 3.46$, $p = .0315$ (one-tailed, based on previous findings), suggesting that the two conditions did vary from each other in how well they elicited "gaze"-following, as well as differing in how each compared to chance.

These results show that, as in previous work (Johnson et al., 1998; Johnson, 2003), when infants observe a novel, ambiguous object interact contingently with another agent they in turn treat the object itself as an agent and follow its "gaze". Alternative explanations based on both the shape and the movement characteristics of the object can be ruled out by the results in the Non-contingent condition. In the Non-contingent condition, exactly the same, though non-contingent, behavior by the agent (self-generated beeping and movement) failed to elicit systematic "gaze"-following. Infants were either unable to disambiguate the agent's front well enough to systematically follow its attentional shifts or they failed to categorize it as an agent at all.

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Study 2

Study 2 manipulated the spatial locations of the novel agent's presumed targets in order to examine infants' ability to infer the perceiving end of a morphologically ambiguous agent with no obvious perceptual organs such as eyes, ears, or nose.

Methods

Participants

Seventeen 14- to 15-month-old infants participated in each of either a Proximal condition (Six females, eleven males; M = 14;25, range 14;1 to 15;25) or Distal condition. (Six females, eleven males; M = 14;22, range = 14;3 to 15;29.)

The Agent and Targets

These were identical to the agent and targets in Study 1.

The Set-up

The setup was identical to that in Study 1.

Procedure

The Proximal condition was identical to the Contingent condition in Study 1. The Distal condition differed in only one way: the location of the possible objects of interest in the agent's environment. In the Proximal condition, the confederate stood next to the infant while talking to the agent and the two targets were placed on the corners of the table closest to the infant. In the Distal condition, the confederate stood across the table from the infant and the two targets were placed on the two corners of the table farthest away from the infant (see Figure 1). Whether the confederate stood to the right or left of infant was counterbalanced.

Coding

Looks away from the agent were coded as in Study 1. A secondary coder recoded 15 percent of the infants, achieving a kappa of .84.

Results

Preliminary analysis showed no effects of sex or order of trials so these variables were removed from the analysis.

Each look was first recoded as going in the same direction as either the proximal end or the distal end (see Figure 2). Looks in the same direction as the proximal end's turns were considered predicted in the Proximal condition, but unpredicted in the Distal condition. Similarly, looks in the same direction as the distal end's turns were considered predicted in the Distal condition, but unpredicted in the Proximal condition. As in Study 1, a mean difference score was calculated for each condition by subtracting the unpredicted looks from the predicted looks. Infants' scores in each condition were then compared to the chance value of zero.

Infants in the Proximal condition produced a mean difference score of 0.24 (SD = 0.38), $t(26) = 2.55$, $p < .03$. Of the 17 infants in the Proximal condition, nine produced positive difference scores, two produced negative difference scores and six produced difference scores of zero, $p < .07$ by a sign test. Infants in the Distal condition produced a mean difference score of 0.38 (SD = 0.53), $t(16) = 2.97$, $p < .01$. Fourteen of the 17 infants in the Distal condition produced a positive difference score, two produced a negative score and one looked equally in both directions, $p < .005$ by a sign test.

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Thus, infants in both conditions systematically followed the orientation of the agent, though that orientation was different in each.

To directly test whether our manipulation of the spatial arrangement had a reliable effect, we performed an ANOVA on the difference scores with condition as a between-subject variable. In order to reflect the absolute difference in orientation between the two conditions, the signs of the difference scores in the Distal condition were reversed. This yielded a reliable effect of condition, $F(1, 32) = 15.21$, $p < .001$, $\eta^2 = .322$. Thus, we can conclude that infants' interpretation of the agent's orientation was strongly influenced by the spatial configuration of the event in which its behavior was embedded.

In effect, infants in the Distal condition behaved as though they were watching an agent from behind. This interpretation, if correct, has further testable implications. If infants can infer the attentional orientation of a novel agent from behind, they should be able to make the same inference for familiar agents, such as people. Alternatively, if infants can not correctly follow the attention of another person from behind, then the interpretation of their behavior in the parallel case with the novel green agent would be undermined. A final set of 12-month-old infants were tested to examine this possibility.

Study 3

Methods

Participants—Twenty 12-month-olds participated in each of either a Face-visible condition (13 females, 7 males; M = 12;13, range 12;0 to 13;27) or a Back-of-head condition (12 females, 8 males; M = 12;13, range 12;0 to 13;2).

The Agent and Targets—The agent was an adult human male. In both conditions, he wore a bulky hunting cap with large earflaps. This was designed to obscure any possible view of the face that might otherwise be revealed when he turned toward the target in the Back-of-head condition, particularly the nose and proximal eye. The hat had no bill or otherwise distinguishing marks on the front. The targets were two brightly colored cloth rainbows.

The Set-up—Infants were tested in an experimental room, approximately 9 feet by 15 feet. The walls were painted white and were blank with the exception of brown wooden shutters that hid observational windows on each of the two long walls. The room was empty except for a camera, the targets, and a chair for the caretaker and infant. The targets were pinned to the wooden shutters. The positions of the targets and infant were invariant. The actor's location varied in order to keep the angle of his headturn equal in the two conditions without using a 90 degree headturn in either case (Figure 3). Even with the hat, a 90 degree headturn would have resulted in part of the actor's face (the nose and one eye) becoming visible during the turn in the back-of-head condition.

Procedure—Infants were seated on their caretakers' laps. Caretakers were asked to keep their eyes closed and to avoid interacting with their infants. Once an infant was settled, the actor began a series of moves around the room that were choreographed to appear as natural as possible given the constraints of the experiment. The actor walked first to one target, touched it and said "Look (baby's name), look at this," then crossed directly to the opposite target and repeated the attentional tag. The actor then turned and took the few steps toward the actor's position midway between the targets. As the actor reached his mark, he dropped to his knees, seemingly to tie his shoe. Once in this position, the actor was below the level of the camera that was focused on the infant's face. In the Face-visible condition, the actor knelt facing the infant. In the Back-of-head condition, the actor knelt facing directly away from the infant. While kneeling, the actor then remarked, "What was that?" and looked up in the direction of

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one or the other target. Thus infants always saw a headturn accompanied by a pragmatically appropriate, but uninformative vocalization. The actor remained fixated on the target for approximately seven seconds before stooping again to his shoe. This was repeated four times while the actor remained kneeling. Each infant saw all four trials in the same direction. The direction of turns was counterbalanced across infants and conditions.

Coding—Because infants have considerably more experience monitoring the behavior of people than that of green blobs and we wanted to avoid any potential ambiguities over infants' behaviors in this study, a stricter coding criteria was adopted in this study. Infants were credited with following the attention of the actor only if they fixated on the correct target in their first look away from the actor. In fact, when infants followed the actor's orientation they almost invariably fixated on the target. Two coders coded the looking behaviors. Agreement between the two coders was 100 percent and was thus perfectly reliable.

Results

As in the previous two studies, we calculated an average difference score for each infant by subtracting the number of first looks in the unpredicted direction from the number of first looks in the predicted direction and dividing by four (the number of trials). Preliminary analyses showed no effects of sex, trial, or the counterbalancing variable of which side of the room the experimenter turned toward, justifying the removal of these variables analyses.

Infants' mean difference scores differed significantly from zero in both conditions. The mean difference score was .32 (SD = .32) in the Face-visible condition, $t(19) = 4.47$, $p < .001$, and .25 (SD = .33) in the Back-of-head condition, $t(19) = 3.34$, $p < .005$. Sign tests also confirmed that, individually, infants were more likely to look in the predicted direction than the unpredicted direction in both conditions. In the Face-visible condition, 15 infants looked more often in the predicted direction, four looked more often in the unpredicted direction and one showed no difference, $p < .0005$. In the Back-of-head condition, the numbers were 12, three, and five respectively, $p < .05$.

A one-way ANOVA examined whether the absolute direction of infants' looks differed across the two conditions. As in Study 2, the difference scores of the infants in the backwards condition (i.e., Back-of-head) were reversed in order to reflect the absolute rather than relative direction of the infants' looks. The results confirmed that the absolute direction of infants' looks depended on the direction the human actor faced, $F(1,38) = 30.4$, $p < .0001$, $\eta^2 = .444$.

Discussion

As seen in other work (Johnson, 2003; Johnson et al. 1998), infants in Study 1 followed the directional orientation of a novel, ambiguous object if it interacted contingently with another agent, in this case a confederate actor. They did so despite the absence of observable perceptual organs to guide their inferences about the agent's attentional orientation. They also failed to do so when the novel object was equally active, attention-grabbing and self-generated, but not contingently so. This helps rule out low-level interpretations of infants' behavior based on movement information, attentional entrainment, or signal releasors and replicates earlier work by Johnson et al. (1998) and Johnson (2003). It also extends the earlier work by showing that body asymmetry is not a necessary condition for the elicitation of following behavior.

As predicted, in Study 2 infants appear to have used the agent's behavior relative to the geometry of its physical and/or social environment to determine the agent's geometry, i.e., its front. When the agent interacted with and turned toward a confederate and targets positioned at its proximal end, infants treated that end as its front. That is, they shifted their own eyes in the direction that the proximal end turned. When the confederate and targets were positioned

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at the agent's distal end, infants treated that end as its front, turning themselves in the direction that the distal end turned. In effect, infants in the Distal condition behaved as though they were watching an agent from behind.

The objective spatiotemporal movement of the agent was identical across conditions, therefore, as in Study 1, it is not possible that infants reacted solely to the movement of the agent, independent of the relational information in its behavior. These results are remarkable not only because infants did not need eyes or other facial features to guide their looking, but they were also able to override any potential prepotent egocentric tendencies to treat the side facing them as the front.

In Study 3 infants easily followed the attentional orientation of a human actor from a position behind the actor, even though the actor's face was out of sight. This performance supports the claim that infants of this age do not need to see an agent's perceptual organs to reason accurately about their attentional orientation. It also demonstrates (unnecessarily perhaps) that monitoring head direction alone can be a successful strategy, particularly in naturalistic settings where perceptual access to the details of someone else's face may be poor.

In Study 3, it is unlikely that infants used the agent's behavior alone to determine attentional orientation as they did in Study 2, though they could have. The human actor moved through the room along coherent, directed trajectories toward goal-objects, making it theoretically possible for infants to induce the human actor's front on the spot. It seems more probable however (though we have no independent evidence of this) that infants relied on prior familiarity and knowledge of human morphology in Study 3, knowledge not available in the novel agent case.

Study 2 manipulated two aspects of the novel agent's environment in tandem –the position of the interactive partner and the position of the targets. According to the original hypothesis, any spatially-directed behavior that implies a novel entity's ability to detect and respond to its environment may license the analysis of a "front". Whether either of the current manipulations could have elicited the same effect alone is therefore unknown. On the one hand, the agent's target-directed turns failed to elicit following behavior in the control condition of Study 1, suggesting that they would be insufficient on their own. However, the control condition included additional negative information about the object's behavior (i.e., its apparently random beeping) that may have outweighed any information derived from the turns. Regardless, for the current argument it does not matter whether the detected target is another agent or a stationary object. Future work aimed at fleshing out Gergely and colleagues' notion of "rational" or "efficient" means may provide additional insight into how infants analyze an agent's behavior relative to its physical and/or social environment.

The weight of the three studies presented lean toward the conclusion that one-year-old infants do not need to understand or focus on eyes alone in order to successfully follow the directional orientation of either human or non-human agentive behavior. Even in the absence of familiar morphological markers such as eyes, infants are capable of instead using the geometry of an unfamiliar agent's behavior relative to its environment to disambiguate its perceptual "front". This is consistent with the notion that what infants are willing to consider as an agent and/or a perceptual organ is relatively unconstrained.

Our questions about how infants infer the front of a novel agent are built on the presupposition that infants' following behavior reflects intentional attributions (in the presumed form of attention/perception). This presupposition, while supported by the findings of Study 1, is motivated largely by the related work showing that at least by 9 months, infants do encode the relationship between a looker and her target (Johnson et al., 2007) and that infants also make intentional attributions to the object-directed behaviors of other non-human agents (Csibra et

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al., 1999; Gergely & Csibra, 2003; Gergely et al., 1995; Johnson et al., 2007; Luo & Baillargeon, 2005; Shimizu & Johnson, 2004; Surian et al., 2007). That is, infants encode the relationship between an agent and its goal-target, even if the agent has no visible or obvious perceptual front.

It is important to note that these results do not contradict the far more established finding that infants are *also* attending quite keenly to eyes before and during this period. Even newborns are sensitive to the presence of eyes, which have strong attention capturing properties. Newborns will preferentially track objects with eye-like configurations (Morton & Johnson, 1991) and shortly thereafter infants will shift their attention in the direction of another's eye movements (D'Etremont, Hains, & Muir, 1997; Farroni, Massaccesi, Pividori, Simion, & Johnson, 2004; Hood, Willen & Driver, 1998), which by at least four months leads to enhanced processing of the target of the other's eyes (Reid, Striano, Kaufman, & Johnson, 2004). Futhermore, Gergely and colleagues have recently shown that infants' interpretation of adults' communicative and pedagogical intent is modulated by the presence or absence of eye contact between the infant and adult (Gergely, Egyad & Kiraly, 2007). The current results are not offered as evidence against any of these findings. Rather they are offered to highlight the possibility of a parallel set of less well studied abilities for recognizing intentional behavior, also available to infants during this formative period of development.

Similarly, some have argued that infants' early ability to reason about an agent's behavior as directed at or about the world is grounded in specific, first person experiences that are only later generalized into the more abstract notions of intentionality (Sommerville & Woodward, 2005; Meltzoff, 2007). The evidence reviewed here however suggests an additional, perhaps complementary source of information for infants' developing conceptions. Based on the work with non-human agents, infants also seem able to recognize intentional behavior very broadly, in that they are able to gloss over (1) the identity of the agent (Biro & Leslie, 2007; Csibra et al, 1999; Gergely et al., 1995; Johnson, 2003; Johnson et al., 1998; Johnson, Booth, & O'Hearn, 2001; Johnson, Shimizu & Ok, 2007; Kamewari, Kato, Kando, Ishiguro, & Hiraki, 2005; Luo & Baillargeon, 2005; Shimizu & Johnson, 2005), (2) the modality of the perceptual organs (the current work), and (3) potentially even the intentional states themselves (see Johnson, Luo and Ok, 2007, for a case in which the notions of *goal* and *perception/attention* seem to collapse onto each other). These findings suggest that at least some of infants' early inferences about others' intentional states are not grounded in personal experience.

Seen in this light, the difficulty infants have assigning a coherent role to the eyes in guiding others' behavior (Brooks & Meltzoff, 2002, 2005; Butler et al., 2000; Caron, Butler et al., 2002; Caron, Kiel et al., 2002; Corkum & Moore, 1998; Lempers et al., 1977), may not reflect the lack of a notion of perception or attention. It may instead reflect the presence of a more global notion of perception and attention in the absence of a notion of specific modalities, in particular vision. Indeed the developmental challenge for the infant and child may be one of differentiating amongst the different types of agents, intentional states, and modalities, rather than abstracting across them.

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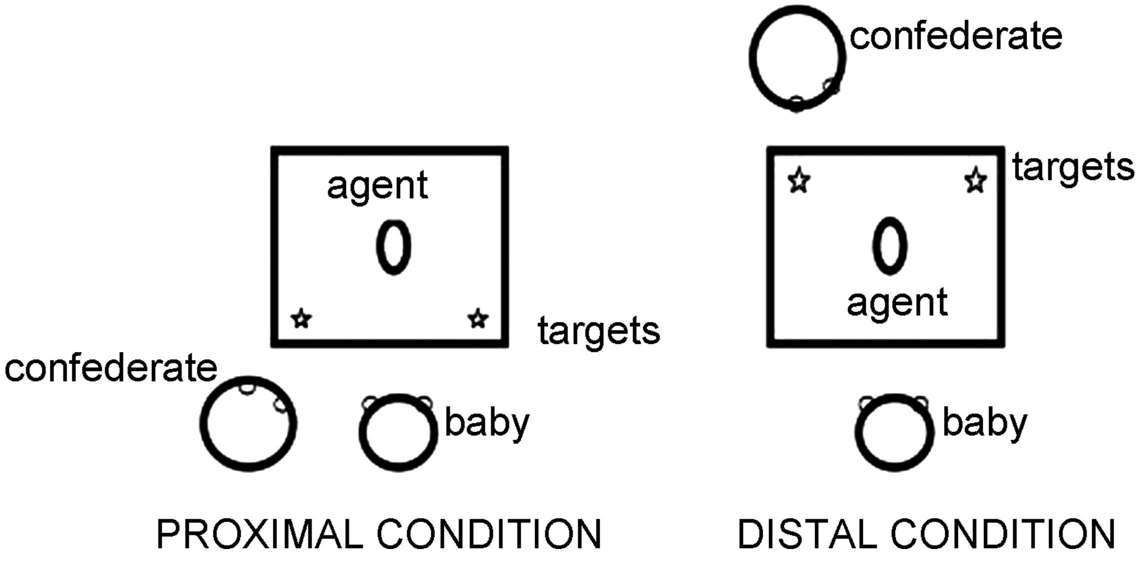

Figure 1.
The configuration of infant, novel agent, confederate and targets in the Proximal and Distal condition of Study 2. Both conditions in Study 1 used the Proximal configuration.

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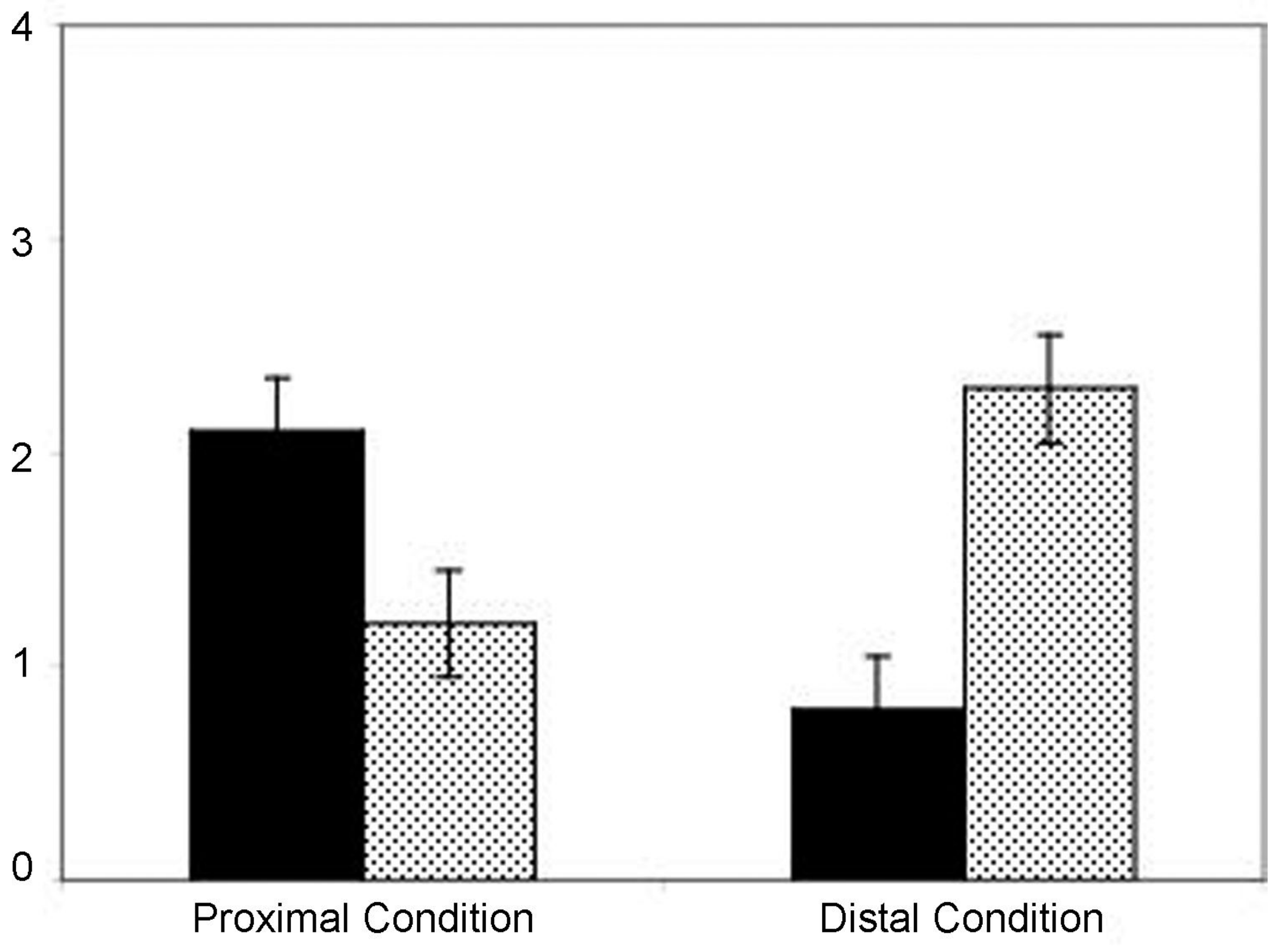

Figure 2.

The mean number of first looks away from the novel agent in each direction. Dark bars represent looks in the direction in which the proximal end of the agent turned. Light bars represent looks in the direction in which the distal end turned. Error bars represent standard errors.

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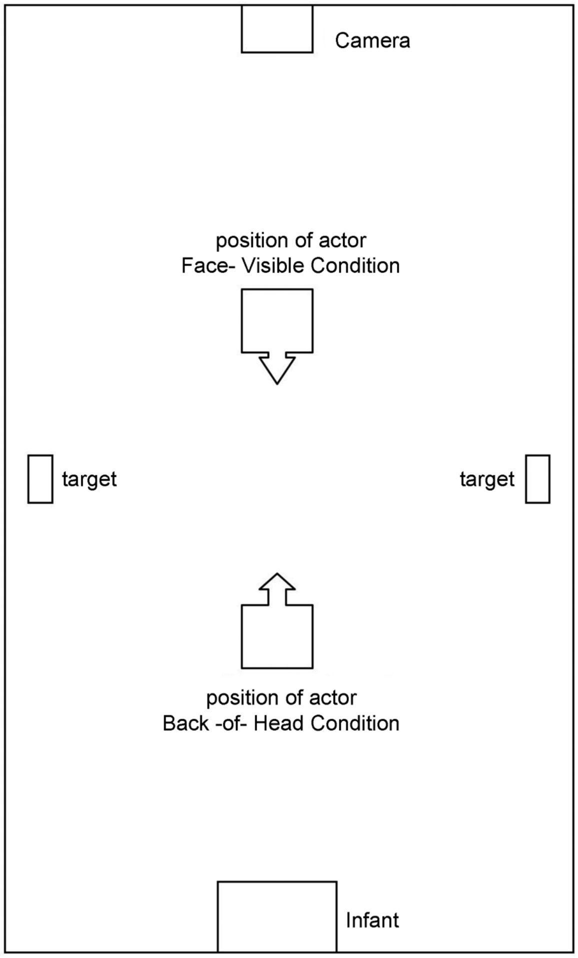

Figure 3.
The configuration of the infant, agent, and targets in Study 3.