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Actors and actions:

The role of agent behavior in infants' attribution of goals

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Abstract

Twelve-month-old infants attribute goals to both familiar, human agents and unfamiliar, non-human agents. They also attribute goal-directedness to both familiar actions and unfamiliar ones. Four conditions examined information 12-month-olds use to determine which actions of an unfamiliar agent are goal-directed. Infants who witnessed the agent interact contingently with a human confederate encoded the agent's actions as goal-directed; infants who saw a human confederate model an intentional stance toward the agent without the agent's participation, did not. Infants who witnessed the agent align itself with one of two potential targets before approaching that target encoded the approach as goal-directed; infants who did not observe the self-alignment did not encode the approach as goal-directed. A possible common underpinning of these two seemingly independent sources of information is discussed.

Research over the past decade has shown that infants construe people's behavior as directed at the world. By the end of their first year, infants selectively encode human behaviors such as grasping (Woodward, 1998), pointing (Woodward & Guajardo, 2002), looking (Johnson, Luo, & Ok, in press; Phillips, Wellman, & Spelke, 2002; Woodward, 2003), and emoting (Moses, Baldwin, Rosicky, & Tidball, 2001; Repacholi, 1998) relative to possible targets in the world. Where and how they draw the line between intentional actors like people and non-intentional objects like rocks is debated.

Some have proposed that infants attribute intentionality quite broadly, based on mechanisms designed to detect any goal-directed action, regardless of the identity of the actor (e.g., Baron-Cohen, 1995; Csibra et al., 1999; Johnson, 2000, 2003; Leslie, 1994, 1995; Luo & Baillargeon, 2005; Premack, 1990.) Conditions which have been argued to successfully elicit goal-attributions include the equifinality of actions (Gergely, Nadasdy, Csibra, & Biro, 1995; Kamewari et al., 2005); action effects (Biro & Leslie, in press; Kiraly et al., 2003); the appearance of rationality (Gergely, Bekkering, & Kiraly, 2002; Gergely et al., 2005); self-propelledness (Baron-Cohen, 1995; Luo & Baillargeon, 2005; Premack, 1990); temporal and spatial contingencies (Bassili, 1976; Johnson, 2000, 2003; Johnson, Slaughter, & Carey, 1998; Shimizu & Johnson, 2004; Watson, 1972); or internally driven changes in trajectory (Tremoulet & Feldman, 2000; Shimizu & Johnson, 2004; Luo & Baillargeon, 2005). The current studies examine characteristics of agents and actions that lead 12-month-olds to construe them as goal-directed.

A variety of methods have been developed to test infants attribution of goals, relying largely on measures of visual attention (e.g., Gergely et al., 1995; Woodward, 1998) and imitation

(Meltzoff, 1995). Using such techniques, data collected from infants as young as 5 months now show positive evidence of goal-attribution to non-human actors (Luo & Baillargeon, 2005).

For instance, Gergely and colleagues (Csibra et al., 1999; Gergely, Nadasdy, Csibra, & Biro, 1995) habituated infants to a small circle approaching a big circle on a computer screen. In subsequent test trials, infants ignored large changes in the small circle's trajectory, as long as those changes were "rational" means to the original end (i.e., goal) presented in habituation.

In a study by Premack and Premack (1997), 12-month-olds dishabituated to changes in the perceived "value" of goal-directed interactions between computer-animated circles. If infants were habituated to an interaction with a positive goal such as "helping", they dishabituated to a negative interaction such as "hitting", but not if they had been habituated to an interaction with a negative goal such as "hindering". A similar study by Kuhlmeier, Bloom, and Wynn (2004) showed that infants can track the helping and hindering behavior of animated shapes across distinct events and use it to reason about subsequent interactions between the characters.

Johnson, Booth, and O'Hearn (2001) used Meltzoff's imitation method to show that 15-month-olds would reenact the unseen goals of an interactive orangutan puppet. Infants were far more likely to hook a plastic doughnut on a pole if they first watched the puppet try to do it but fail than if they did not.

Two sets of researchers (Luo & Baillargeon, 2005 and Shimizu & Johnson, 2004) have used the method designed by Woodward (1998) to gather further evidence of infants' ability to attribute goals to non-human objects as well as people. This method also uses visual habituation to test whether infants encode actions in terms of the goals of the actor, or solely in terms of the spatiotemporal movements involved. Infants are habituated to an actor approaching one of two toys on a stage. The position of the two toys on the stage are then reversed, and infants watch tests events that alter the actor's behavior in one of two ways: either, (1) the spatiotemporal path of the actor is changed with no change in the target object, or (2) the actor's target object is changed with no change in the path. Woodward reasoned that if infants encode the actor's action as *goal*-directed (reflecting an agent-world relationship), test trials in which the target object changes should be more novel, and therefore more interesting, than those in which the path changes.

Indeed, in Luo and Baillargeon's study infants as young as 5 months of age looked longer at the change in the actor's target relative to the change in the actor's path when the actor showed clear characteristics of agency. The "actor" was a small self-moving box that appeared to stop and start and change its trajectory in the absence of external forces.

In Shimizu and Johnson's (2004) study, 12-month-olds were introduced to an amorphous, fuzzy green self-moving object and tested for their goal-attributions. In an agentive condition infants received cues about both the agent and the action itself that suggested that the novel agent's approach to a target was goal-directed. First, before the habituation procedure began, infants were allowed to observe the agent engage in a conversation with a human confederate (the human spoke, the novel agent beeped), thus demonstrating its ability to detect and respond to things in its environment. Second, in the habituation procedure itself infants observed the agent "choose" its target in each trial by rotating its body so that the front pointed in the direction of the target it approached, again demonstrating its ability to detect and respond to things in its environment. Thus, infants were first given information about the agentive status of the novel green object, and then also shown an action in habituation that itself implied goal-directedness. In a control condition without the human confederate, infants first observed the same self-moving object behave in an apparently random manner (by beeping the same way, but for no apparent reason). Subsequently, in the habituation trials the object was revealed on the stage already aligned with its target, thus giving the infants no information about how the alignment came about. In this condition, infants failed to encode the identity of the green object's target.

Whether only one or both of the characteristics used in the Shimizu and Johnson (2004) study (social contingency cues to the object's agency or movement cues within the action itself) were responsible for the goal attributions in that paper is unknown. Study 1 of the current paper therefore examines the ability of each characteristic to elicit goal-attributions on its own. In further attempts to refine the characterization of information that elicits goal attributions in 12-month-olds, Studies 2 and 3 report conditions that control for social modeling aspects of the confederate's behavior (Study 2) and self-movement without trajectory changes (Study 3).

Study 1

Method

Participants—Forty-five full-term infants, 23 males and 22 females, from the San Francisco Bay Area participated. Parents were contacted through mailings and phone calls. Twenty-one infants were assigned to the Contingent Interaction condition (*M* = 12 months 22 days, SD = 10.9 days). Twenty-four infants were assigned to the Changed Trajectory condition (*M* = 12 months 8 days, SD = 6.5 days). An additional six infants were excluded for fussiness from each condition.

Materials

The agent: The agent was twelve inches long by eight inches wide and three 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 targets: A red plastic cup and a blue plastic fish approximately the size of tennis balls were used as targets.

The stage: The infant was seated on a caregiver's lap in front of a large stage. The floor of the stage was made of black fiberboard. The sides and back of the stage were white. A white screen could be moved across the front opening of the stage to hide the agent and objects from view between trials.

The cameras and observers: A camera was mounted in the rear wall of the stage to capture the infant's face for on-line coding by two observers. A second camera was mounted behind the infant to capture the events on the stage for archival purposes. A third camera was mounted above the stage to provide visual feedback to the person operating the agent from under the table.

The two observers monitored the infant's looking behavior on separate tv screens in an adjacent room. Both observers were blind to the events on the stage. A computer with specialized software was used to record the observers' judgements of when the infant looked at the stage (Pinto, 1996).

Procedure—An infant-controlled visual habituation procedure was used. Trials in both the habituation and test phases started when the infant looked continuously at the stage for more than half a second and ended when the infant looked away continuously for two seconds. Infants were considered habituated when the total looking time to three consecutive trials declined to half the total looking time of the first three consecutive trials whose sum exceeded 12 seconds.

The habituation phase continued until the infant either habituated (a minimum of 6 trials) or completed 14 trials. Four test trials followed.

The aspects of the procedure shared by both conditions will be described first. In the habituation phase, the screen opened to reveal the two target objects placed on small pedestals at either side of the stage and to the rear. The agent was placed toward the front of the stage, midway between the two toys. The infant watched the agent approach one of the two toys. Observers were cued to begin recording the infant's looks when the agent reached the approached toy. When the infant looked away for two consecutive seconds the trial ended and the screen was closed. The experimenter replaced the agent at its starting point and the screen was opened for the next trial. The agent approached the same toy throughout the habituation phase. Which toy was approached and which side the target toy was on was counterbalanced across infants.

After the infant habituated, the screen was closed and the location of the two target objects was switched. Infants then received one trial to observe the new locations without the agent present. Four test trials followed. In two trials the infant saw the agent approach the same object approached in the habituation trials, now at a new location (New Location trials). In the other two trials the infant saw the agent approach the other object, now in the same location approached in habituation (New Target trials). The trials were presented in alternation. The type of test trial that was presented first was counterbalanced across infants.

Contingent Interaction condition: The relevant information in this condition came in an introductory phase before the habituation procedure began. The infant observed the experimenter and agent engage in a brief (approximately 60 seconds) "conversational" exchange of "small talk". Each followed a standard script in which the experimenter greeted the agent and asked, in English, how it was, where it had been lately, and so on. The agent responded at each turn with an “utterance” composed of a short series of beeps, roughly equivalent in length to the experimenter’s utterance. At the end of the interaction, the experimenter left the room and the habituation trials began. The agent began each trial with its main front-to-back axis already aligned with its approach toy.

Changed Trajectory condition: Infants received no preliminary introduction to the agent in this condition. Instead, the relevant change in the agent's trajectory was produced at the beginning of each habituation trial. Each trial began with the agent situated at the front of the stage, midway between the two target toys. The agent's main front-to-back axis was aligned with the infant's. At the start of each habituation trial, the infant observed the agent's distal end silently rotate toward and stop when aligned with the approach toy.

Coding—Two observers simultaneously coded the infants' looking behavior on-line using software that measured to a tenth of a second. The average agreement across the two conditions was 90 percent with an average Cohen's Kappa of .75.

Results

Habituation—The number of trials to habituation did not vary by condition. Infants took 7.2 trials (SD = 1.4) to habituate in the Contingent Interaction condition and 7.2 trials (SD = 1.9) to habituate in the Changed Trajectory condition, n.s. No infant failed to habituate. The total amount of time looking at the display in the two conditions also did not vary. Infants looked for a total of 76.8 seconds (SD = 43.6) in the Contingent Interaction condition and 62.1 seconds (SD = 22.9) in the Changed Trajectory, n.s.

New Target vs. New Location Test Trials—Three of the 84 data points in the Contingent Interaction condition and three of the 96 data points in the Changed Trajectory condition were more than 2.5 standard deviations greater than the means of their respective conditions and were replaced. Summed looking times were then calculated for each infant for each test trial type (New Target and New Location). A preliminary analysis of variance (ANOVA) found no effects of sex or order of presentation so these variables were removed from further analyses.

On average infants in the Contingent Interaction condition looked at the New Target displays for 16.2 seconds (SD = 6.3) and the New Location displays for 13.3 seconds (SD = 6.6) and infants in the Changed Trajectory condition looked at the New Target displays for 16.3 seconds (SD = 8.6) and the New Location displays for 11.8 seconds (SD = 5.1). The data are shown in Figure 1. A repeated measures ANOVA with condition as a between-subject variable and test trial (New Target vs. New Location) as the within-subject variable revealed an effect of test trial, $F(1,43) = 14.12$, $p = .0005$, $\eta^2 = .247$, but no effect of condition, $F(1, 43) = 0.16$, $p = .69$, $|^2 = .004$. There was no interaction between condition and the type of test trial. Nonparametrics yielded the same pattern of results. Overall, 30 infants looked longer at the New Target events than the New Location events, 13 did the reverse, and 2 infants looked equally at both, Wilcoxon $z = 3.36$, $p = .0008$.

As predicted, 12-month-olds were able to encode the goals of an unfamiliar agent if it demonstrated either socially contingent interactions or self-generated changes in trajectory. Both together were not necessary; each alone was sufficient.

Study 2

In Study 1, infants were able to use the socially contingent behavior of the novel agent in the introduction to later encode its behavior in the habituation phase as goal-directed. Socially contingent interactions carry considerable information in them. Which aspects of that information are relevant? One might argue that the relational aspect is the most important. Action that is spatiotemporally related (e.g., contingent) to some aspect of its environment, such as the interaction with a confederate, may imply that the actor can detect and respond to its environment, i.e., that the actor is intentional. The categorization of an actor as an intentional agent would then license the attribution of goal-directedness to subsequent actions the actor produced, even if those actions were themselves more ambiguous.

Alternatively, the confederate treated the novel agent as though it were an agent. Perhaps infants inferred the goal-directedness of the novel agent indirectly by following the lead of the *known* agent, the confederate, rather than deriving it from the agent's own behavior. Study 2 examines this possibility.

Method

Participants—Twenty full-term infants, nine males and eleven females, from the San Francisco Bay Area participated in a Social Modeling condition. On average the infants in this condition were 12 months 21 days old (SD = 9.6). An additional eight infants fussed out and two were lost to experimenter errors.

Materials—The agent, targets, and setup were the same as in Study 1.

Procedure—The procedure in the Social Modeling condition was the same as the Contingent Interaction condition in Study 1, with one exception. When the experimenter spoke to the agent during the introduction phase, the agent remained silent and non-responsive.

Coding—Two observers simultaneously coded the infants' looking behavior on-line using software that measured to a tenth of a second. The average agreement across the condition was 85 percent with an average Cohen's Kappa of .78.

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Results

Habituation: Infants habituated in 9.5 trials (SD = 3.7) in the Social Modeling condition. This was significantly longer than in Study 1, $F(1, 63) = 11.76$, p = .0011, $|^2 = .157$. Unlike Study 1 in which no infant failed to habituate, 7 infants in the Social Modeling condition failed to so.

Test Trials: Three of the 80 data points were more than 2.5 standard deviations from the mean and were replaced. A preliminary ANOVA revealed no effects of sex or order of presentation so those variables were removed from further analysis.

Looking times were summed for each type of test trial (New Target vs. New Location). Infants looked 16.5 seconds (SD = 10.7) in the New Target trials and 15.3 seconds (SD = 7.5) in the New Location trials. (See Figure 2.) A one-way repeated ANOVA yielded no significant difference between types of test trial, $F(1,19) = 0.23$, $p = .63$,$|^2 = .012$.

Twelve of the 20 infants looked longer at the New Target event. A Wilcoxon Signed Ranks test nonetheless showed that they did not do so to a degree different from chance, $z = -0.605$, $p = .54$.

As predicted, the relational aspect of the socially contingent interaction in Study 1 was necessary to produce the goal interpretation in 12-month-olds. Infants who observed the human confederate model an intentional interpretation of the novel agent, did not themselves infer that the agent was goal-directed.

Study 3

Also in Study 1, infants encoded the novel agent's behavior as goal-directed if it made a self-generated change in its approach trajectory. Again, this is a rich behavior that includes a variety of subcomponents of information. Which are relevant — the self-generated movement, the approach to a target, or perhaps the change in trajectory alone? Based on the notion that actions that display some spatiotemporal relationship to the actor's environment are themselves cues to directedness, either the approach to a target or the change in trajectory might be sufficient.

Interestingly, the Social Modeling condition in Study 2 included a simple approach to a target. It was nonetheless insufficient for generating goal-directed interpretations, as was the non-contingent condition in Shimizu and Johnson (2004). However, both of these alternatives included additional, conflicting information that could have nullified any attributions of goal-directedness infants might otherwise have made. In the non-contingent condition of Shimizu and Johnson, the novel object beeped randomly, suggesting that its behavior, though equally complex, was *not* directed at its environment. In Study 2 of the current paper, the novel object failed to respond to the overtures of a known agent, suggesting that it could not detect its environment.

Therefore to test whether the change in trajectory was necessary for a goal attribution, infants were shown the novel agent approach its target straight on, with no other introductory information.

Method

Participants—Twenty full-term infants, nine males and eleven females, from the San Francisco Bay Area participated in a Straight Trajectory condition. On average the infants in the Straight Trajectory condition were 12 months 9 days old (SD = 7.5). An additional seven infants fussed out, one was excluded because of the mother's interference, and two were lost to experimenter error.

Materials—The agent, targets, and setup were the same as in Study 1.

Procedure—The procedure in the Straight Trajectory condition was the same as the procedure in the Changed Trajectory condition of Study 1, with the exception that the agent began each trial already aligned with its target.

Coding—Two observers simultaneously coded the infants' looking behavior on-line using software that measured to a tenth of a second. The average agreement across the condition was 91 percent with an average Cohen's Kappa of .76.

Results

Habituation: Infants habituated in 9.0 trials (SD = 2.9) in the Straight Trajectory condition. This was not different from the infants in the Social Modeling condition of Study 2, but was significantly longer than the infants in Study 1, $F(1, 63) = 9.71$, $p < .005$, $|^2 = .134$. Three infants failed to habituate at all.

Test Trials: Three of the 80 data points in each condition were more than 2.5 standard deviations from the mean and were replaced. A preliminary ANOVA revealed no effects of sex or order of presentation so those variables were removed from further analysis.

Looking times were summed for each type of test trial (New Target vs New Location). In the Straight Trajectory condition infants looked for 18.4 seconds (SD = 9.9) in the New Target trials and 20.4 seconds (SD = 12.6) in the New Location trials. (See Figure 2.) A one-way repeated ANOVA yielded no significant difference between them, $F(1,19) = 0.51$, $p = .49$, $|^2 =.026$.

Eleven of the 20 infants looked longer at the New Target trials, yet, as in Study 2, did not do so to a degree different from chance, Wilcoxon $z = -0.37$, $p = .71$.

Apparently, a direct approach to a target by an unfamiliar, though self-generated, object is not sufficient evidence for a 12-month-old to encode the behavior as goal-directed.

Comparison of Studies 2 & 3 to Study 1

A two-way repeated measures ANOVA comparing the looking times of infants in Studies 2 and 3, revealed no main effects of condition ($p > .2$) or type of test trial ($p > .7$) and no interaction between them ($p > .3$). Therefore the data from these two non-agentive conditions was combined into a single set for comparison to the data from the apparently agentive conditions of Study 1.

Infants in the combined agentive conditions of Study 1 looked at the New Target trials for 16.3 seconds (SD = 7.6) and the New Location trials for 12.5 seconds (SD = 5.8). Infants in the combined non-agentive conditions of Studies 2 and 3 looked at the New Target trials for 17.4 seconds (SD = 10.2) and the New Location trials for 17.8 seconds (SD = 10.6) (See Figure 3). A two-way repeated measures ANOVA revealed that infants in the non-agentive conditions looked slightly longer than did those in the agentive conditions, $F(1, 83) = 4.07$, $p < .05$, $|^2 = .047$. More importantly, the analysis revealed an interaction between condition and looking times to the two types of test trials. Infants tended to look longer at the New Target trials in the agentive conditions, but longer at the New Location trials in the non-agentive conditions, $F(1, 83) = 4.65$, $p < .05$, $|^2 = .053$, reconfirming the difference in interpretation made by infants in these different conditions.

Habituators vs. Non-Habituators

Recalling that infants in the non-agentive conditions of Studies 2 and 3 showed different habituation patterns from those in the agentive conditions of Study 1, we conducted one further analysis. It is not uncommon in infant studies for fast and slow habituators to show different looking behavior in test trials. It is sometimes claimed that this is due to a difference in encoding speed — that slow encoders take longer to fully process a scene or event, may still be processing the habituation events even as the test trials start, and therefore are drawn more to the familiar than the novel test events (Baillargeon, 1987;Bornstein & Benasich, 1986;DeLoache, 1976;McCall, 1979). In the current case, perhaps the majority of infants in Studies 2 and 3 encoded the relationship between the agent and its target in habituation, but because the events were actually subsets of those in Study 1, and therefore perhaps somewhat more ambiguous, it took some infants longer to fully analyze them. This may have led to the relatively large number of infants who completed 14 habituation trials without habituating (10 out of 40 infants; 7 in the social modeling condition and 3 in the straight trajectory condition). Infants who completed their encoding of the event (as indexed by reaching their habituation criteria) might well have shown the pattern seen in Study 1, that is, longer looking to the New Target events.

To examine this possibility, the mean looking times of the habituators alone were calculated (see Figure 3). In fact, similar to the group as a whole, habituators looked less at the New Target events (M = 16.5, SD = 9.9) than the New Location events (M = 19.3, SD = 11.5), resulting in a stronger (rather than weaker) interaction between the agentive and non-agentive conditions, $F(1, 73) = 9.89$, $p = .002$, $|^2 = .119$. It would appear that the failure of infants to encode the relationship between the agent and its target during the habituation events of Studies 2 and 3 was not due to the introduction of noise from non-habituators.

Discussion

When 12-month-old infants were habituated to an unfamiliar agent approaching one of two possible target objects, they looked longer in test trials where the agent approached a different target object in the same location than test trials where it approached the same target object in a new location. They did so if the unfamiliar agent first interacted socially with a human confederate or if the agent self-aligned its approach to its target object in habituation (Study 1). They did not do so if the human confederate merely modeled an intentional attribution toward the agent without the agent's active participation (Study 2), or if the agent's alignment with its target was accomplished out of the infant's view (Study 3).

These results add to the growing list of conditions under which infants will attribute goals to unfamiliar, non-human agents. Many questions remain however, including possible relationships between the various eliciting conditions, both developmentally and mechanistically. With the exception of contingent interactivity, all of the documented conditions for goal-attribution have been found in infants well before the end of their first year ("rationality", changes in trajectory, equifinality, etc.). Though infants have been shown to detect and respond to contingent interactivity as early as 2 months (Watson, 1972), no study has yet tested the ability of infants younger than 12 months to use this information to attribute goals.

An accurate account of the relative emergence of eliciting conditions will help us better characterize the mechanisms underpinning goal-attribution. For instance, some have proposed that contingent interactivity and trajectory information initially serve quite different functions in the infant mind, only the latter being involved in goal attribution early on (Csibra, 2003). Tests of contingenty interactivity at younger ages are needed to test this claim.

Alternatively both contingent interactivity and changes in trajectory (and other information as well) may be processed by a single underlying mechanism. For instance, the agent’s behavior in both the contingent interaction and changed trajectory conditions might be construed as examples of non-random relatedness between the agent and its environment; non-random spatial and temporal contingencies that imply that the object producing the behavior can both detect and respond to its environment. A single mental process that calculates the probability of events in these terms may be all that is needed for the infant to begin the process of detecting goal-directed actions and thereby agents. Future work aimed at testing this possibility is needed.

Possible evidence for infants' ability to integrate both spatial and temporal contingencies in an actor's behavior to infer directedness comes from another study with the same green agent. In this study (Johnson, under review), 14-month-old infants used the spatial configuration of the agent’s environment to determine where the agent’s front end was, and thus which end to monitor and follow in a gaze-following task.

Not all kinds of seemingly relevant information induce agentive interpretations of novel objects in infants. Social modeling has a powerful influence on infants' behavior with objects in many contexts, including enhanced attention to objects (Huang, Heyes, & Charman, 2002), approach and withdrawal behaviors to and from novel objects (Moses et al., 2001, Repacholi, 1999) and imitation on objects (Meltzoff, 1995, Nadel & Butterworth, 1999). Yet social modeling produced no result in the current case. Why?

There could be a variety of reasons for this. For one, even the richest interpretations of social referencing and imitation which credit the infant with so-called first-order mental state attributions (i.e., “Mom *feels happy/scared about* the spider” or “The adult *wants* the toy inside the box”) would not be sufficient for the current case. The current case requires a second-order mental state inference (“The adult *believes/thinks/sees/pretends* that the object *sees/hears*.”) Children typically succeed with second-order mental states inferences later than first-order mental states (Sullivan, Zaitchik, & Tager-Flusberg, 1994).

Converging evidence from a related study suggests this may be a general constraint on imitation in infancy. Johnson, Booth, and O'Hearn (2001) worried that communicative gestures directed toward a non-human agent by 15-month-olds were due to infants' imitation of a human confederate's intentional stance toward the agent, rather than the infant's own interpretation of the agent. To test if that were even possible, they ran a control condition in which the confederate directed an intentional stance along with the communicative gestures in question to an inanimate object that displayed no agentive qualities of its own. Even though the target behaviors (the communicative actions of requesting, pointing, and showing) were directly modeled for the infant (unlike the visual attention measures in the current case) infants were not induced to interact with the object themselves. The confederate's modeled attribution of a mental state to the novel object, in the absence of positive evidence from the object itself was not sufficient.

In addition, as in the current case, the failure of the agent to interact during the social modeling condition may have provided infants with positive evidence *against* the agent's ability to detect and respond to its environment. That is, when the human confederate spoke to it, it gave no indication of having heard. Perhaps if infants were to observe a confederate talking to an unseen figure behind a curtain, they could use the information in the confederate's behavior to posit the presence of an (unseen) agent. Further studies are needed to disentangle the contributions of these two points.

Evidence from the straight trajectory condition suggests that simple movement toward an object is also not in itself sufficient to elicit a goal interpretation, not even when performed by a self-propelled object. Rather, it is appears to be somewhat ambiguous. When performed by a known agent (such as a human hand) or a suspected agent (such as a contingently interactive green thing), infants appear to assume the simple approach is goal-directed. However, when performed by an object whose agentive status is either unknown (such as the self-moving green object) or possibly rejected outright (such as the non-contingent or non-responsive objects), infants are less likely to make this assumption.

These complex interactions between the familiar and the unknown suggest a relatively sophisticated reasoning ability in 12-month-olds. We concur with others who have argued that by this age, infants may be reasoning to the best possible explanation (Saxe, Tenenbaum, & Carey, 2005). In the case of goal attribution and the categorization of novel agents, 12-month-olds appear to go well beyond both what they could reasonably be expected to have experienced themselves (such as the goal-directedness of human hands) or what might be plausibly built in by evolution (such as the goal-directedness of self-moving objects). Indeed, the more information available that a given action could be non-random and internally driven, the more likely they appear to encode it as goal-directed. Relevant information may come from a variety of sources, including both the identity of the actor and the nature of the action itself.

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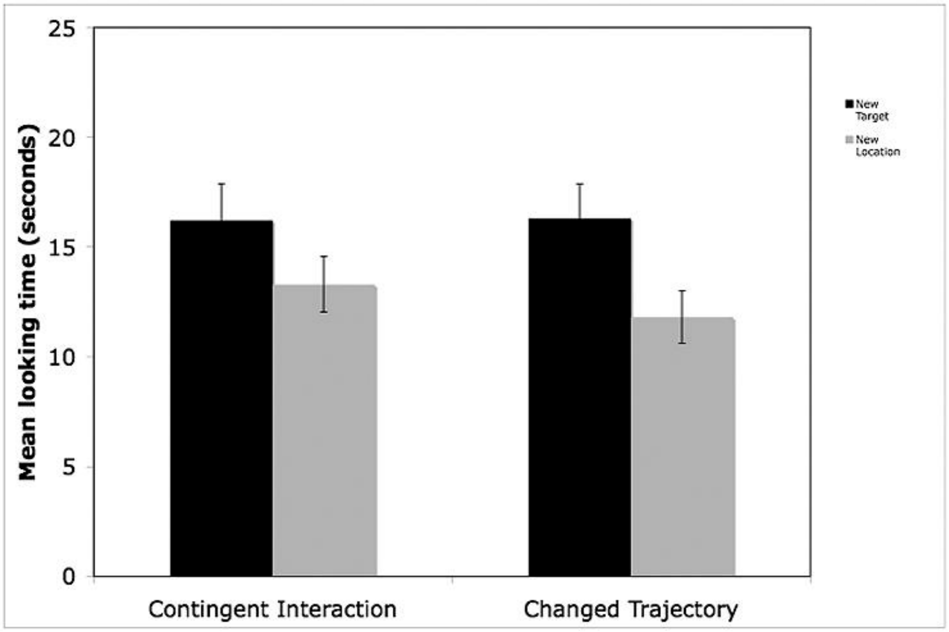

Figure 1.
Mean looking times summed over trials in Study 1.

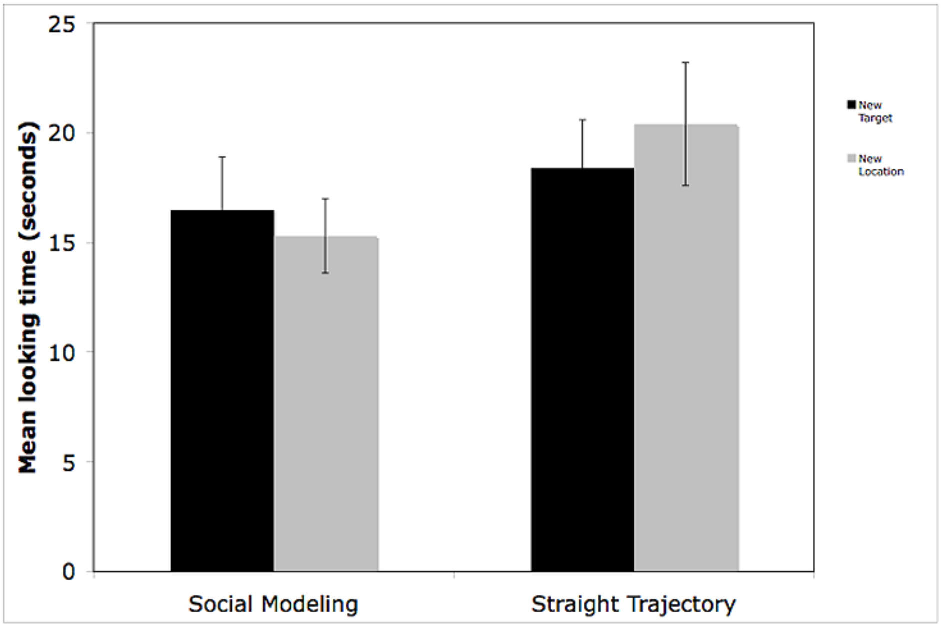

Figure 2.
Mean looking time scores summed over trials in Studies 2 and 3.

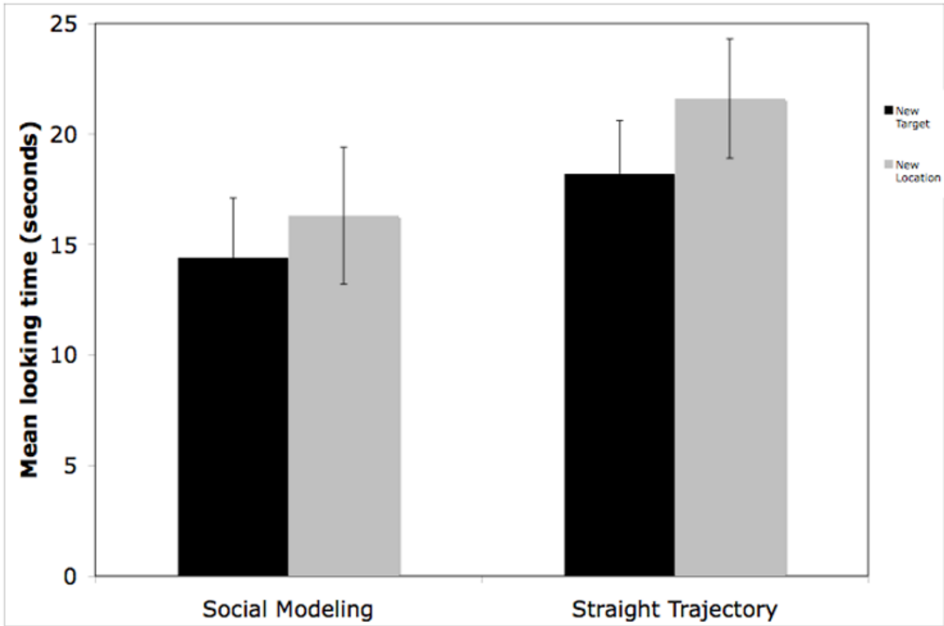

Figure 3.
Mean looking time scores of habituators only summed over trials in Studies 2 and 3.