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ScienceDirect
Acta Psychologica 124 (2007) 79–105
acta psychologica
www.elsevier.com/locate/actpsy

Can 9.5-month-old infants attribute to an agent a disposition to perform a particular action on objects?

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Available online 7 November 2006

Abstract

The present research examined whether 9.5-month-old infants can attribute to an agent a disposition to perform a particular action on objects, and can then use this disposition to predict which of two new objects—one that can be used to perform the action and one that cannot—the agent is likely to reach for next. The infants first received familiarization trials in which they watched an agent slide either three (Experiments 1 and 3) or six (Experiment 2) different objects forward and backward on an apparatus floor. During test, the infants saw two new identical objects placed side by side: one stood inside a short frame that left little room for sliding, and the other stood inside a longer frame that left ample room for sliding. The infants who saw the agent slide six different objects attributed to her a disposition to slide objects: they expected her to select the ‘‘slidable’’ as opposed to the ‘‘unslidable’’ test object, and they looked reliably longer when she did not. In contrast, the infants who saw the agent slide only three different objects looked about equally when she selected either test object. These results add to recent evidence that infants in the first year of life can attribute dispositions to agents, and can use these dispositions to help predict agents' actions in new contexts.

PsychINFO classification: 2820

Keywords: Infant cognition; Disposition; Action comprehension; Psychological reasoning

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0001-6918/$ - see front matter
doi:10.1016/j.actpsy.2006.09.008

1. Introduction

When we observe the actions of others, we do not merely attempt to identify the immediate goals that underlie their actions: we often speculate about the various factors that might have led them to perform these particular goal-directed actions. Understanding *why* others chose to pursue one goal as opposed to another can often help us predict and interpret their subsequent actions. In many cases, our speculations about why an individual chose to perform a particular action involve reflecting on the individual's prior history, in the same or other contexts, and then using this information to attribute to the individual a specific *disposition*: for example, a partiality for a certain object, agent, or activity.

To illustrate, consider the following situation: we are attending a family reunion and pass the time studying the antics of our relatives. At one point, we observe Cousin Harry approach the buffet table and, ignoring all the other desserts on display, make a beeline for the strawberry cheesecake. We immediately interpret Harry's actions as directed toward the goal of obtaining a slice of cheesecake. But our musings do not stop there: since this is the third slice of strawberry cheesecake we have seen Harry eat this evening, we attribute to Harry a particular disposition, a fondness for strawberry cheesecake.

At another point in the evening, we observe Cousin Emma approach a table with her laden dinner plate, in search of a seat. She glances briefly at the two remaining empty seats, one next to Uncle Joe and the other next to Uncle Albert, and chooses the seat next to Uncle Joe. Although we readily see Emma's actions as goal-directed—she went and sat next to Uncle Joe—we also ponder why she chose this particular seat. We remember that Uncle Joe was particularly helpful when Emma's brother came up for parole, whereas Uncle Albert refused to get involved, and conclude that Emma's seat selection reflects her positive disposition toward Uncle Joe and negative disposition toward Uncle Albert.

At yet another point in the evening, we observe Cousin Hilary jump out of her chair and approach Uncle Sam as the musicians resume their seats after a break. Since Hilary has been dancing energetically all evening with a succession of cousins and uncles, we attribute to Hilary a particular disposition, a predilection for dancing, and assume that she has chosen Uncle Sam to be her next partner.

In all the cases discussed above, we view our relatives' actions as intentional and readily detect the immediate goal that underlies them: obtaining a slice of cheesecake, selecting a seat at a table, and securing a dance partner. In each case, we also identify factors that might have led our relatives to perform these particular actions: a fondness for a particular food, a partiality for a particular relative, or a predilection for a particular activity. In other cases, of course, we might observe actions that appear intentional, and readily detect the goal that underlies them, but still be unclear as to why they were performed. For example, if we saw sensible Aunt Bertha open her purse, take out a marble, inspect it closely, and then pop it into her mouth, we might view her actions as directed toward the goal of placing the marble into her mouth—but be perplexed as to why she chose to do so.

Identifying the factors that cause an agent to perform certain goal-directed actions is advantageous in that it can sometimes help us predict the agent's actions in other contexts. For example, if we later met Uncle Harry at a restaurant that serves strawberry cheesecake, we might expect him to choose this dessert over others. Similarly, we might expect Cousin Emma to invite Uncle Joe, rather than Uncle Albert, to tour the Virgin Islands on her yacht.

Research over the past 10 years indicates that infants aged 5 months and older give evidence, in some situations at least, that they view others' actions as intentional and detect the immediate goals that underlie these actions. These goals are typically simple ones such as obtaining or contacting an object (e.g., Luo & Baillargeon, 2005a; Shimizu & Johnson, 2004; Thoermer & Sodian, 2001; Woodward, 1998), drawing attention to an object (e.g., Woodward & Guajardo, 2002), displacing an object (e.g., Jovanovic et al., in review; Király, Jovanovic, Prinz, Aschersleben, & Gergely, 2003), transforming an object (e.g., Gergely, Bekkering, & Király, 2002; Meltzoff, 1995, 2007), reaching an agent (e.g., Csibra, Gergely, Bíró, Koós, & Brockbank, 1999; Gergely, Nádasdy, Csibra, & Bíró, 1995), chasing an agent (e.g., Csibra, Bíró, Koós, & Gergely, 2003; Rochat, Striano, & Morgan, 2004; Schlottman & Surian, 1999), and so on. Researchers have also begun to uncover some of the neural correlates underlying these abilities (Reid, Csibra, Belsky, & Johnson, 2007).

More recent findings suggest that infants sometimes interpret others' goal-directed actions as stemming from particular dispositions, such as a predilection for a particular object, agent, or action (e.g., Kuhlmeier, Wynn, & Bloom, 2003, in review; Luo & Baillargeon, 2005a, 2005b, in review; Luo & Johnson, 2006; Repacholi & Gopnik, 1997; Song, Baillargeon, & Fisher, 2005, in progress). In the next sections, we briefly review these findings. We next introduce the present research, which built on these efforts and asked whether 9.5-month-old infants could attribute to an agent a disposition to perform a particular action on objects.

1.1. *A predilection for a particular object*

In a seminal series of experiments, Woodward (1998, 1999; Guajardo & Woodward, 2004) habituated infants aged 5 months and older to an event in which a human agent faced two distinct objects on an apparatus floor, object-A on the left and object-B on the right; the agent reached for and grasped object-A. In the test events, the objects' positions were reversed, and the agent reached for either object-A in its new position (expected event) or object-B in the position formerly occupied by object-A (unexpected event). The infants looked reliably longer at the unexpected than at the expected event. This and control results suggested that the infants (1) construed the agent's actions during habituation as directed toward the goal of obtaining object-A; (2) expected the agent to continue seeking object-A when the toys' positions were reversed; and (3) were surprised when this expectation was violated. Similar results were also obtained with infants aged 9.5 months and older when more complex, means-end actions were required to obtain object-A (e.g., Onishi, Baillargeon, & Woodward, in preparation; Sommerville & Woodward, 2005; Woodward & Sommerville, 2000).

These results make clear that infants who watch an agent repeatedly reach for and grasp one of the two distinct objects view the agent's actions as directed toward the goal of obtaining that object. But is this *all* that infants attribute to the agent in such cases? Adults in a similar situation might well attribute to the agent a particular disposition, a preference for object-A over object-B. After all, trial after trial, the agent reaches for object-A while ignoring object-B; clearly, she can have little interest in object-B. Do infants also attribute to the agent a preference for object-A?

The results summarized above cannot answer this question: they can only tell us that infants detect the immediate goal underlying the agent's actions, obtaining object-A.

However, recent data from our laboratory provide evidence that infants aged 5 months and older do attribute preferences to agents, in situations similar to that discussed here (e.g., Luo & Baillargeon, 2005a, 2005b, in review; Luo & Johnson, 2006; Song et al., in review). In one experiment (Song et al., in review), 7.5-month-old infants were assigned to an experimental or a control condition. The experimental condition was modeled after Woodward (1998), and the control condition—the key condition here—was identical except that only object-A was present during the familiarization trials.

We reasoned that if the infants in the experimental condition simply detected the goal underlying the agent's actions—obtaining object-A—and expected her to continue pursuing that goal when the objects' positions were reversed, then the infants in the control condition, who saw the agent perform exactly the same actions, should respond in exactly the same manner. In both conditions, the infants should look reliably longer at the unexpected than at the expected event. On the other hand, if the infants in the experimental condition interpreted the agent's actions as reflecting not only a particular goal, obtaining object-A, but also a particular disposition, a preference for object-A over object-B, then the infants in the control condition might respond differently. During familiarization, these infants would no doubt interpret the agent's actions as directed toward the goal of obtaining object-A. However, because object-B was absent, the infants could have no information as to which object, A or B, the agent might prefer. Thus, when object-B was introduced in test, the infants could not predict the agent's behavior: she might again reach for object-A, or she might now reach for object-B.

As in Woodward (1998, 1999; Guajardo & Woodward, 2004), the infants in the experimental condition looked reliably longer at the unexpected than at the expected event; in contrast, the infants in the control condition looked about equally at the two events. These results suggested that the infants in the experimental condition did not simply construe the agent's actions during familiarization as directed toward the goal of obtaining object-A: they also attributed to the agent a preference for object-A over object-B. The infants in the control condition also construed the agent's actions during familiarization as directed toward the goal of obtaining object-A; however, because only object-A was present, the infants had no information as to which object, A or B, the agent might prefer. Thus, when object-B was introduced in test, the infants could not predict how the agent would respond.

The same results were obtained with 5-month-old infants in an experiment in which the human agent was replaced with a non-human agent, a self-propelled box; lacking arms, the box simply approached and contacted object-A or object-B (Luo & Baillargeon, 2005a). Similar findings were also obtained in experiments with 5- to 12.5-month-old infants that used a modified control condition in which object-B was present during the familiarization trials, but was hidden from the (human or non-human) agent by an opaque screen (e.g., Luo & Baillargeon, 2005b, in review; Luo & Johnson, 2006). Although the infants could see both objects, the agent saw only object-A until the opaque screen was removed in the test trials. As in Song et al. (in review), the infants attributed to the agent a preference for object-A over object-B only when she could see both objects during the familiarization trials.

There is thus consistent evidence that infants who watch an agent repeatedly grasp or contact one of the two distinct objects in a scene attribute to the agent not only the goal of obtaining that object, but also a preference for that object over the other object. In contrast, infants who watch an agent repeatedly grasp or contact the sole object in a scene attribute to the agent only the goal of obtaining the object. To return to our family reunion example, we attributed to Cousin Harry a fondness for strawberry cheesecake because we saw him repeatedly select it over other desserts; had strawberry cheesecake been the only dessert on offer, we would have been less likely to make the same attribution.

1.2. A predilection for a particular agent

Premack and Premack (1997) asked whether 12-month-old infants can distinguish between positive and negative interactions between agents. Infants were first habituated to a computer-animated event in which two identical non-human agents (identical self-propelled circles) interacted either positively (e.g., one circle helped the other pass through an aperture) or negatively (e.g., one circle prevented the other circle from passing through an aperture). Following habituation, all of the infants watched a test event in which one circle hit the other. The infants habituated to the positive interaction dishabituated to the test event, whereas those habituated to the negative interaction did not. These results suggested that, by 12 months of age, infants are able, in simple situations at least, to distinguish between positive and negative interactions between agents. In a recent series of experiments, Kuhlmeier and her collaborators (e.g., Kuhlmeier, Wynn & Bloom, 2003, in review) built on these results and asked whether 9- and 12-month-old infants who observe two agents interact positively (or negatively) might attribute to each agent a positive (or negative) disposition toward the other agent.

In one experiment (Kuhlmeier et al., in review), 9-month-old infants were habituated to two computer-animated events involving three non-human agents with expressionless faces: a self-propelled circle, triangle, and square. In both habituation events, the circle first attempted and failed to climb a hill, while the triangle and square looked on. In one event, the triangle then pushed the circle to the top of the hill; in the other event, the square pushed the circle to the bottom of the hill. During test, the hill was removed, and the infants saw the circle approach either the helpful triangle (approach-triangle event) or the unhelpful square (approach-square event). Another group of infants saw the same events except that the roles of the triangle and square were reversed. The infants who had seen the helpful triangle looked reliably longer at the approach-square than at the approach-triangle event; conversely, the infants who had seen the helpful square looked reliably longer at the approach-triangle than at the approach-square event.

These results suggested that the infants detected the goals underlying each of the three agents' actions during the habituation trials: they attributed to the circle the goal of reaching the top of the hill; they attributed to the helpful agent (triangle for the first group of infants, square for the second) the goal of helping the circle attain the top of the hill; and they attributed to the unhelpful agent (square and triangle, respectively) the goal of preventing the circle from reaching the top of the hill. Had the infants simply detected the goal underlying each agent's actions, and expected each agent to pursue the same goal across trials, they could not have responded appropriately during test: the hill was gone, and very different events were now presented in which the circle simply approached one of the other agents. To succeed, the infants had to use the history of the circle's interactions with the triangle and square to determine which agent the circle was more likely to be positively disposed toward, and hence which agent the circle was more likely to approach.

These results (and consistent results with 12-month-old infants; Kuhlmeier et al., 2003) suggest that, by 9 months of age, infants can attribute to others a positive disposition toward one agent and a negative disposition toward another agent, based on the history of their interactions. In a similar manner, we attributed to Cousin Emma in our family reunion example a positive disposition toward helpful Uncle Joe, and a negative disposition toward unhelpful Uncle Albert, and used these dispositions to make sense of her seat selection.

1.3. A predilection for a particular action

In a recent experiment (Song et al., 2005), we asked whether 13.5-month-old infants could attribute to an agent a disposition involving a particular action. Specifically, after watching an agent perform the same action on various objects, would infants attribute to the agent a disposition to perform this recurring action, and would they then use this information to predict which of two objects—one that could be used to perform the action and one that could not—the agent would grasp next?

The infants first watched three familiarization events in which a human agent repeatedly slid an object forward and backward on an apparatus floor. Different objects—a toy fish, a box, and a baby shoe—were used in the three trials. During test, the infants saw two identical trucks placed side by side: one stood inside a short frame that left little room for sliding, and the other stood inside a longer frame that left ample room for sliding. The agent grasped the truck inside either the short (short-frame event) or the long (long-frame event) frame.

The infants who saw the short-frame event looked reliably longer than those who saw the long-frame event. This and control results suggested that the infants readily detected, in each familiarization trial, the immediate goal underlying the agent's actions: sliding the fish, box, or shoe. Had the infants attributed to the agent only these specific goals, however, they could not have responded appropriately during test: the infants now saw very different events in which the agent grasped one of two identical trucks, without engaging in any further action. To succeed, the infants had to consider the agent's actions across trials, and use this information to attribute to the agent a particular disposition, a predilection for sliding objects. This disposition would have led the agent, during test, to grasp the "slidable" as opposed to the "unslidable" truck.

These results thus suggest, that by 13.5 months of age, infants who watch an agent perform the same action with different objects can disentangle the action performed from the objects used to perform it, and can attribute to the agent a disposition to perform that action. Infants can then use this disposition to predict and interpret the agent's subsequent actions. In a similar manner, after observing Cousin Hilary, in our family reunion example, dance merrily with a succession of male relatives, we attributed to Hilary a predilection for dancing, and interpreted her approaching Uncle Sam, as the musicians returned from their break, in light of that disposition.

1.4. The present research

The research summarized in the previous sections suggests that infants aged 5 months and older can attribute to an agent a predilection for a particular object (e.g., Luo & Baillargeon, 2005a, in review; Luo & Johnson, 2006; Repacholi & Gopnik, 1997; Song et al., in review); that infants aged 9 months and older can attribute to an agent a predilection for a particular agent (Kuhlmeier et al., 2003, in review); and that infants aged 13.5 months and older can attribute to an agent a predilection for a particular action (Song et al., 2005).

The present research which built on these findings and asked whether 9.5-month-old infants might succeed in attributing to an agent a disposition involving a particular action. Since by 9 month infants can already attribute dispositions involving objects and agents, it seemed plausible that they would also succeed in attributing dispositions involving actions.

Experiment 1 used a procedure similar to that of Song et al. (2005). The infants first received three *familiarization* trials in which they saw a human agent grasp an object on an apparatus floor and slide it forward and backward twice; a toy fish, a box, and a baby shoe were used in the first, second, and third trial, respectively (see Fig. 1). Next, the infants received a static *display* trial in which they saw two identical toy trucks resting side by side on the apparatus floor (see Fig. 2). The truck on the right (from the infants' perspective) stood inside a short frame that was barely longer than the truck, making it impossible for the agent to slide the truck inside the frame. The truck on the left stood inside a longer frame that left sufficient room for the agent to slide the truck. Finally, the infants received two identical *test* trials in which they saw the agent reach for and grasp the truck inside either the short (short-frame event) or the long (long-frame event) frame; the agent then paused until the trial ended (see Fig. 2).[1]

If the infants (1) interpreted the agent's actions during familiarization trials as revealing a predilection for sliding objects, (2) expected the agent to maintain this disposition during test, and (3) realized that the truck inside the long but not the short frame could be slid forward and backward, then they should expect the agent to grasp the "slidable" as opposed to the "non-slidable" truck, and they should be surprised in the short-frame event when this expectation was violated. The infants who saw the short-frame event should thus look reliably longer than those who saw the long-frame event. On the other hand, if the infants had difficulty attributing to the agent a disposition for sliding objects, could not determine which truck was "slidable" and which not, or were confused by the fact that the agent simply paused after grasping the "slidable" truck, then they should tend to look equally at the two test events.

We were aware that positive or negative results in Experiment 1 would call for further investigation; Experiments 2 and 3 were conducted for this purpose.

2. Experiment 1

2.1. Method

2.1.1. Participants

Participants were 12 healthy term infants, 5 male and 7 female ($M = 9$ months, 19 days, range = 9 months, 5 days to 10 months, 5 days). Half of the infants saw the short-frame event, and half saw the long-frame event. Another four infants were tested but eliminated

[1] In each familiarization trial in Song et al. (2005), the agent slid the object repeatedly until the trial ended. Pilot data suggested that this procedure was ill-suited for testing 9.5-month-olds: the infants apparently found it confusing that the agent continually repeated her actions during the familiarization trials, but grasped a truck and then paused during the test trials. This result was not particularly surprising, in that we have often observed that younger infants are more likely to succeed when similar procedures are used in the familiarization and test trials (e.g., actions are repeated in all trials, or actions are performed once or twice followed by a paused scene in all trials). Accordingly, all of the data in this paper were collected using a modified procedure in which the agent slid the object forward and backward twice in each familiarization trial and then paused; the agent thus paused at the end of each familiarization and test trial.

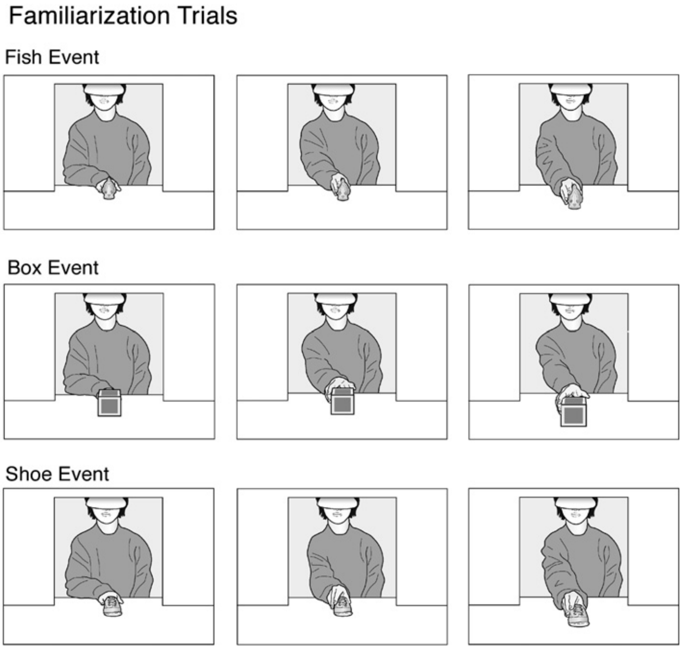

Fig. 1. Schematic drawing of the events shown during the three familiarization trials in Experiment 1. The infants saw the fish, box, and shoe events in successive trials.

because they were inattentive (3) or looked over three SD from the mean of their condition in the test trials (1).

The infants' names in this and the following experiments were obtained primarily from purchased mailing lists and from birth announcements in the local newspaper. Parents were offered reimbursement for their transportation expenses, but were not compensated for their participation.

2.1.2. Apparatus

The apparatus consisted of a wooden display booth 98 cm high, 101 cm wide, and 60 cm deep, mounted 76 cm above the floor. The infant faced an opening 42 cm high and 93.5 cm wide in the front of the apparatus; between trials, a curtain consisting of a muslin-covered frame 61 cm high and 99.5 cm wide was lowered in front of this opening. The side walls of the apparatus were painted white and the floor was covered with pastel patterned contact paper. The back wall was made of white foam board; a window 42 cm high and 42.5 cm wide extended from its lower edge, 11 cm from the right wall.

In each familiarization trial, an object stood on the apparatus floor 10 cm in front of the window; the center of the object was positioned 30.5 cm from the left wall. The object used in the first familiarization trial was a plastic toy fish 7.5 cm high, 5 cm wide, and 9.5 cm long; it was bright pink and decorated with black stripes. The object used in the second familiarization trial was a cardboard box 6.5 cm high, 8 cm wide, and 14 cm long; it was covered with green contact paper and its edges were outlined with yellow tape. The object used in the third familiarization trial was a baby shoe 5 cm high, 6.5 cm wide,

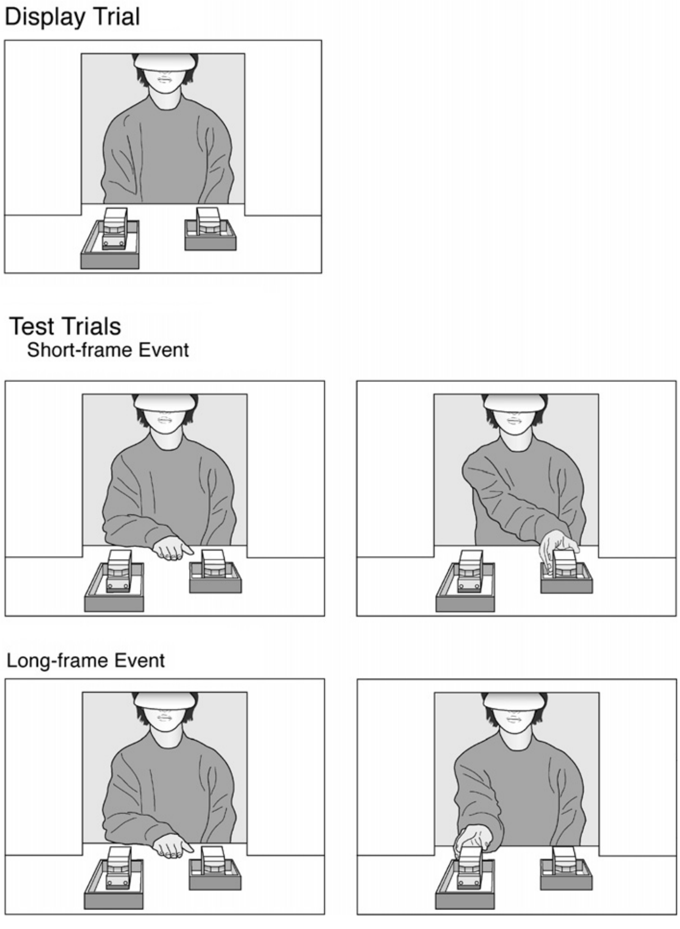

Fig. 2. Schematic drawing of the events shown during the display and test trials in Experiment 1. The infants received two identical test trials in which they saw either the short- or the long-frame event.

and 11.5 cm long; it was made of blue denim fabric and had a white shoelace and a white rubber sole.

During the display and test trials, two identical toy trucks were placed side by side on the apparatus floor. Each truck was 7 cm high, 5 cm wide, and 17.5 cm long; it was made of yellow plastic and had blue windows and black wheels. The trucks stood inside frames positioned 10.5 cm apart, 10 cm in front of the back wall. Both frames were 2.5 cm high, 10.5 wide, made of 0.5 cm-thick Plexiglas, and covered with wood pattern contact paper. The short frame on the right was placed 15 cm from the right wall and was 20 cm long; the gap between the front of the truck and the frame was 1.5 cm. The long frame on the left was placed 54.5 cm from the left wall and was 31.5 cm long; the gap between the front of the truck and the frame was 13 cm.

The agent sat on a wooden chair centered behind the window in the apparatus's back wall; she wore a blue shirt and a white visor which hid her eyes from the infants. A muslin curtain behind the agent hid the test room.

The infants were tested in a brightly lit room. Three 20-W fluorescent light bulbs were attached to the front and back walls of the apparatus to provide additional light. Two frames, each 180.5 cm high and 69.5 cm wide and covered with white cloth, stood at an angle on either side of the apparatus; these frames served to isolate the infants from the test room.

2.1.3. Trials

In the following descriptions, the numbers in parentheses indicate the number of seconds taken to perform the actions described. To help the agent adhere to the events' scripts, a metronome beat softly once per second. A camera mounted behind and next to the infant projected an image of the events onto a TV screen in a different part of the test room; a supervisor monitored the events to confirm that they followed the prescribed scripts.

Familiarization trials. Each of the three familiarization trials consisted of an 18-s pre-trial followed by a main-trial. At the start of the pre-trial, the agent sat at the window in the back wall of the apparatus, facing forward, with her bare right hand resting on the floor 4 cm behind the object used in the trial (fish, box, or shoe, as noted above). After a 4-s pause (to give the infants the opportunity to inspect the object), the agent reached for and grasped the object (1 s). She then repeated the following sequence of actions twice: she slid the object forward 15 cm (2 s), paused (1 s), slid the object back to its original position (2 s), and again paused (1 s). Finally, the agent returned her hand to its initial position on the apparatus floor (1 s). During the main-trial, the infants watched this final paused scene until the trial ended (see below).

Display trial. During the display trial, the two trucks stood on the apparatus floor, the right truck inside the short frame and the left truck inside the long frame. The agent sat at the window, with both hands out of view on her lap. This trial was designed to introduce the infants to the trucks and their frames, and to give the infants the opportunity to determine which truck was "slidable" and which truck was not.

Test trial. Each test trial consisted of a 5-s pre-trial followed by a main-trial. At the start of the pre-trial, the agent sat at the window with her bare right hand on the apparatus floor, as in the familiarization trials. There was again a 4-s pause, and then the agent reached for and grasped the truck (1 s) inside the short (short-frame event) or the long (long-frame event) frame. During the main-trial, the agent paused with her hand on the truck until the trial ended.

2.1.4. Procedure

During the experiment, the infant sat on a parent's lap centered in front of the apparatus; the infant's head was approximately 50 cm from the curtain. Parents were instructed to close their eyes and to remain silent and neutral during the entire experiment.

The infant's looking behavior was monitored by two observers who viewed the infant through peepholes in the cloth-covered frames on either side of the apparatus. Each observer held a button linked to a computer and depressed the button when the infant looked at the event. The looking times recorded by the primary observer were used to determine when a trial had ended (see below).

The infants first received the three *familiarization* trials described above. Examination of the infants' looking times during the 18-s pre-trial at the start of each trial revealed that they were highly attentive during the agent's actions: the infants looked on average for

16.9/18 s during the first trial, 16.7/18 s during the second trial, and 14.8/18 s during the third trial. The main-trial portion of each trial ended when the infant (1) looked away for 2 consecutive seconds after having looked for at least two cumulative seconds, or (2) looked for 60 cumulative seconds without looking away for two consecutive seconds.

Next, the infants received the static *display* trial described above. This trial had no pre-trial and ended when the infants (1) looked away for two consecutive seconds after having looked for at least three cumulative seconds, or (2) looked for 30 cumulative seconds without looking away for two consecutive seconds.

Finally, the infants received two identical *test* trials in which they saw the event (short- or long-frame) appropriate for their condition. The infants were highly attentive during the 5-s pre-trial at the start of each trial and looked on average for 4.4/5 s during the first trial and 4.1/5 s during the second trial. The main-trial portion of each trial ended when the infant (1) looked away for 2 consecutive seconds after having looked for at least 2 cumulative seconds, or (2) looked for 30 cumulative seconds without looking away for 2 consecutive seconds.

To assess interobserver agreement during the main-trial portions of the familiarization, display, and test trials, each trial was divided into 100-ms intervals, and the computer determined in each interval whether the two observers agreed on whether the infant was or was not looking at the event. Percent agreement was calculated for each trial by dividing the number of intervals in which the observers agreed by the total number of intervals in the trial. Agreement was measured for all 12 infants and averaged 95% per trial per infant.

Preliminary analyses of the familiarization, display, and test data revealed no significant interaction involving event condition and sex, all $Fs(1,8) < 2.45$, $p > .15$; the data were therefore collapsed across sex in subsequent analyses.

2.2. Results

The infants' looking times during the main-trial portions of the three *familiarization* trials were averaged and analyzed by means of a one-way analysis of variance (ANOVA) with event condition (short- or long-frame) as a between-subjects factor. The main effect of event condition was not significant, $F(1,10) < 1$, suggesting that the infants in the two conditions tended to look equally during the familiarization trials (short-frame: $M = 14.1$, $SD = 7.7$, long-frame: $M = 13.4$, $SD = 7.5$). Analysis of the infants' looking times during the *display* trial produced similar results, $F(1,10) < 1$, suggesting that the infants in the two conditions also looked about equally during the display trial (short-frame: $M = 13.8$, $SD = 6.9$, long-frame: $M = 12.8$, $SD = 7.6$).

The infants' looking times during the main-trial portions of the two *test* trials (see Fig. 3) were averaged and analyzed as above. The main effect of event condition was again not significant effect, $F(1,10) < 1$, suggesting that the infants who saw the short-frame event ($M = 10.1$, $SD = 5.1$) and those who saw the long-frame event ($M = 11.6$, $SD = 2.8$) looked about equally during the test trials.[2]

[2] The test data were also subjected to an analysis of covariance (ANCOVA), using as covariates the infants' average looking times during the three familiarization trials and their looking times during the display trial. The results of the ANCOVA replicated those of the ANOVA: the main effect of event condition was again not significant, $F(1,8) < 1$.

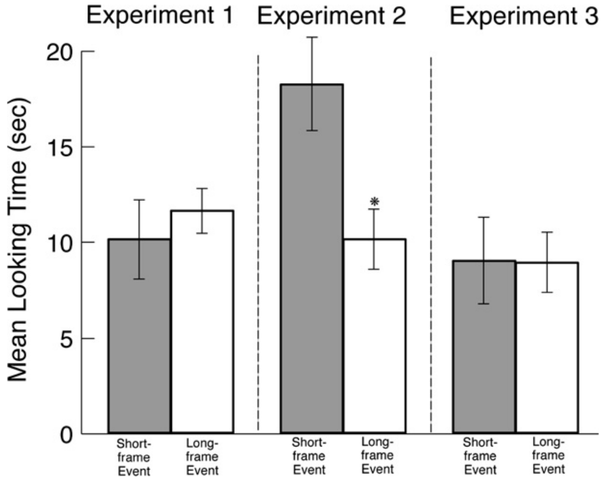

Fig. 3. Mean looking times at the short- and long-frame test events of the infants in Experiments 1, 2, and 3.

A non-parametric Wilcoxon rank-sum test confirmed this negative result, $W_S = 32$, $p > .20$.

2.3. Discussion

In contrast to the 13.5-month-old infants in Song et al. (2005), the 9.5-month-old infants in Experiment 1 who saw the short- and long-frame events tended to look equally. As we alluded to earlier, there were several possible interpretations for this negative result. For example, it could be that infants this age are able to attribute to others dispositions involving particular objects or agents (e.g., Kuhlmeier et al., in review; Luo & Baillargeon, 2005a, 2005b; Luo & Johnson, 2006; Song et al., in review), but not actions. Alternatively, it could be that infants this age *are* able to attribute to others dispositions involving particular actions, but can only do so under optimal conditions. All of the successful disposition experiments with infants aged 9 months and younger described in the Introduction (e.g., Kuhlmeier et al., in review; Luo & Baillargeon, 2005a, 2005b; Luo & Johnson, 2006; Song et al., in review) used at least four familiarization trials; perhaps the three familiarization trials the infants received in Experiment 1 were not sufficient to allow them to extract the agent's recurring sliding action.

There were of course other possibilities: perhaps the infants in Experiment 1 succeeded in attributing to the agent a disposition to slide objects, but had difficulty using this information to predict her actions in the test trials (e.g., the infants might have been unable to judge which truck was "slidable" and which was not, or they might have reasoned that both trucks were "slidable" since the agent could slide the truck inside the short frame *with* the frame). Or it could be that the infants correctly predicted that the agent would grasp the truck in the short frame, but became puzzled when she paused after doing so—why did she not slide the truck forward and backward as before?

In Experiment 2, we chose to examine the second possibility discussed above: that the infants in Experiment 1 did not have sufficient opportunity in three familiarization trials to disentangle the agent's sliding actions from the various objects she used to perform them, and hence could not attribute to the agent a disposition for sliding objects. The infants were tested using the same procedure as in Experiment 1, except that they received a second block of three familiarization trials, for a total of six trials. The first block of trials involved a toy fish, a box, and a baby shoe, as before, and the second block of trials involved an hourglass-shaped toy, a doll's straw hat, and a small baby bottle topped with a cap (see Fig. 4). If the infants in Experiment 1 failed because they were not able within three familiarization trials to extract the agent's recurring action, then the infants in Experiment 2 might succeed since they were given twice as many trials to do so.

3. Experiment 2

3.1. Method

3.1.1. Participants

Participants were 14 healthy term infants, 6 male and 8 female ($M = 9$ months, 11 days, range = 9 months, 0 day to 9 months, 28 days). Half of the infants saw the short-frame event, and half saw the long-frame event. Another four infants were tested but eliminated because they were fussy (3) or distracted (1).

3.1.2. Apparatus, trials, and procedure

The apparatus, trials, and procedure used in Experiment 2 were similar to those in Experiment 1, except that the infants received a second block of familiarization trials. The object used in the fourth familiarization trial was a clear hourglass-shaped plastic toy 6.5 cm high and 5.5 cm in diameter (at its widest point), with a green top and a blue bottom; it was decorated with purple dots and filled with a small orange ball. The object used in the fifth familiarization trial was a doll's circular straw hat with a large brim; the hat was 6.5 cm high, 12 cm in diameter, and 15 cm deep. The object used in the sixth familiarization trial was a clear blue baby bottle with a tight white cap. The visible portion of the bottle beneath the cap was 9 cm high and 5.5 cm in diameter at the bottom; the cap of the bottle was 5 cm high, 4.5 cm in diameter at the bottom, and 2.75 cm in diameter at the top.

The infants were highly attentive during the 18-s pre-trial at the start of each familiarization trial and looked for 17.5 s, 16.7 s, 16.2 s, 15.7 s, 16.4 s, and 14.2 s in the first to sixth trial, respectively. During the 5-s pre-trial that preceded each of the two test trials, the infants looked for 4.4 s and 3.8 s, respectively.

Interobserver agreement during the main-trial portions of the familiarization, display, and test trials was calculated for all 14 infants and averaged 95% per trial per infant.

Preliminary analyses of the familiarization, display, and test data in Experiment 2 revealed no significant interaction involving event condition and sex, all $Fs(1,10) < 1.73$, $p > .20$; the data were therefore collapsed across sex in subsequent analyses.

3.2. Results

The looking times of the infants in Experiment 2 were compared to those of the infants in Experiment 1. The infants' looking times during the main-trial portions of the

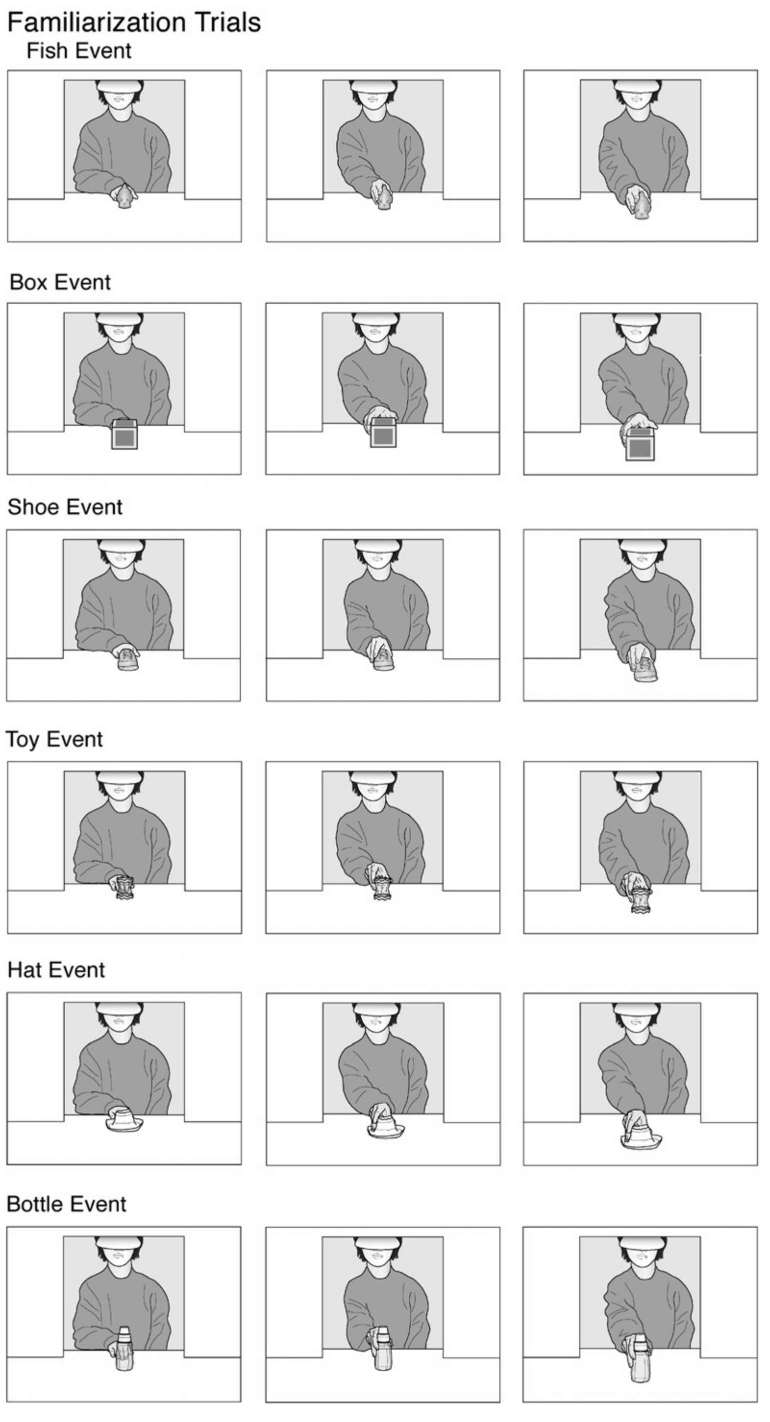

Fig. 4. Schematic drawing of the events shown during the six familiarization trials in Experiment 2. The infants saw the six events in six successive trials.

familiarization trials (all three for the infants in Experiment 1, first three for the infants in Experiment 2) were averaged and analyzed by means of a 2×2 ANOVA with Experiment (1 or 2) and event condition (short- or long-frame) as between-subjects factors. No effect was significant, all $Fs(1,22) < 2.58$, $p > .12$, suggesting that the infants in the four experimental groups tended to look equally during the familiarization trials (Experiment 1/short-frame: $M = 14.1$, SD = 7.7; Experiment 1/long-frame: $M = 13.4$, SD = 7.5; Experiment 2/short-frame: $M = 20.3$, SD = 11.2; Experiment 2/long-frame: $M = 18.9$, SD = 10.1). Analysis of the infants' looking times during the *display* trial produced similar results, all $Fs(1,22) < 1$, suggesting that the infants also looked about equally during the display trial (Experiment 1/short-frame: $M = 13.8$, SD = 6.9; Experiment 1/long-frame: $M = 12.8$, SD = 7.6; Experiment 2/short-frame: $M = 17.0$, SD = 11.7; Experiment 2/long-frame: $M = 16.0$, SD = 7.0).

The infants' looking times during the main-trial portions of the two *test* trials (see Fig. 3) were analyzed in the same manner as above. Only the interaction between Experiment and event condition was significant, $F(1,22) = 5.97$, $p < .025$. Planned comparisons revealed that, whereas in Experiment 1 the infants who saw the short- ($M = 10.1$, SD = 5.1) and long-frame ($M = 11.6$, SD = 2.8) events looked about equally, $F(1,22) < 1$, in Experiment 2 the infants who saw the short-frame event ($M = 18.2$, SD = 6.5) looked reliably longer than those who saw the long-frame event ($M = 10.1$, SD = 4.3), $F(1,22) = 9.31$, $p < .01$.[3]

Non-parametric Wilcoxon rank-sum tests confirmed the results of Experiments 1 ($W_S = 32$, $p > .20$) and 2 ($W_S = 36$, $p < .05$).

3.3. Discussion

Unlike the infants in Experiment 1, those in Experiment 2 responded differentially to the two test events: the infants who saw the short-frame event looked reliably longer than those who saw the long-frame event. This result suggests that the infants in Experiment 2 (1) interpreted the agent's actions in each familiarization trial as directed toward the goal of sliding the object used in the trial; (2) attributed to the agent, in the course of the six familiarization trials, an inclination to slide objects; (3) judged that the truck in the long frame was "slidable" and the truck in the short frame "unslidable"; and hence (4) expected the agent to reach for the truck in the long frame and were surprised when this expectation was violated. The present results thus extend those of Song et al. (2005), obtained with 13.5-month-old infants, to younger infants: when given six as opposed to three familiarization trials, even 9.5-month-old infants can attribute to an agent a disposition to perform a particular action.

The contrast between the results of Experiments 1 and 2 naturally gives rise to the following question: why did the infants in the present research succeed when given six but not

[3] As in Experiment 1, the test data were also subjected to an ANCOVA, using as covariates the infants' average looking times during the familiarization trials (all three in Experiment 1, first three in Experiment 2) and their looking times during the display trial. The results of the ANCOVA replicated those of the ANOVA: the interaction between Experiment and event condition was again significant, $F(1,20) = 8.18$, $p < .01$. Planned comparisons confirmed that, whereas in Experiment 1 the infants who saw the short- and long-frame events looked about equally, $F(1,20) < 1$, in Experiment 2 the infants who saw the short-frame event looked reliably longer than those who saw the long-frame event, $F(1,20) = 11.69$, $p < .005$.

three familiarization trials? Did the infants in Experiment 2 succeed because they saw the agent perform her sliding action *more times*? Or did they succeed because they saw the agent perform her sliding action on *more objects*?

Experiment 3 was designed to address this question. Another group of 9.5-month-old infants was tested using the same procedure as in Experiment 2, except that the infants received two identical, as opposed to two different, blocks of familiarization trials: some infants received the first block of trials used in Experiment 2 (fish, box, baby shoe) twice, whereas other infants received the second block of trials used in Experiment 2 (toy, doll's hat, baby bottle) twice.

We reasoned that if the infants in Experiment 2 succeeded because they saw the agent perform her sliding action *more times*, then the infants in Experiment 3, who saw the agent perform her sliding action the same number of times, should also succeed: the infants who saw the short-frame event should look reliably longer than those who saw the long-frame event. On the other hand, if the infants in Experiment 2 succeeded because they saw the agent slide *more objects*, then the infants in Experiment 3, who saw the agent slide fewer objects, should fail: like the infants in Experiment 1, who also saw the agent slide only three objects, they should tend to look equally at the short- and long-frame events.

Our intuition was that the second possibility was more likely to be correct, for the following reasons. To succeed at the present task, infants had to be able to accomplish three sub-tasks: first, they had to detect the goal underlying the agent's actions in each familiarization trial (e.g., sliding the fish, sliding the box, and so on); second, they had to compare the agent's goal-directed actions across trials, to extract their commonality; and third, they had to use this information to attribute to the agent a particular disposition, an inclination to slide objects. We assumed that the first sub-task was relatively easy for our infants: as we saw in the Introduction, by 9.5 months of age infants are able to attribute to agents a variety of simple goals including those of obtaining, contacting, or displacing objects (e.g., Jovanovic et al., in review; Király et al., 2003; Luo & Baillargeon, 2005a, 2005b; Luo & Johnson, 2006; Sommerville & Woodward, 2005; Song et al., in review; Woodward, 1998). We also assumed that the third sub-task was well within our infants' capacity: as we saw earlier, infants this age can attribute to agents dispositions involving objects and agents (e.g., Kuhlmeier et al., in review; Luo & Baillargeon, 2005a, 2005b; Luo & Johnson, 2006; Song et al., in review), so why not actions as well? However, we suspected that the second sub-task—comparing the agent's goal-directed actions across trials to detect what they had in common—was more difficult for our infants. Thus, we speculated that the infants in Experiment 2 were successful, not because they saw the agent perform her sliding action *more times* (they understood each individual action well enough), but rather because they saw her slide *more objects*, and hence had more unique exemplars at their disposal from which to extract the common thread linking her actions. As a rough analogy, if we want a friend to guess the concept "fruit" in a guessing game, we realize that telling her "banana, apple, orange, cherry" is likely to be more helpful than telling her "banana, apple" or "banana, apple, banana, apple": within some reasonable limits, it is obvious that the more unique exemplars one has to work with, the easier it is to generate and test hypotheses about what the exemplars might have in common. In line with this analysis, we expected that the infants in Experiment 3 would gain little from receiving two identical blocks of familiarization trials and that, like the infants in Experiment 1, they would tend to look equally at the two test events.

4. Experiment 3

4.1. Method

4.1.1. Participants

Participants were 14 healthy term infants, 7 male and 7 female ($M = 9$ months, 16 days, range = 9 months, 2 days to 10 months, 13 days). Half of the infants saw the short-frame event, and half saw the long-frame event. Another three infants were tested but eliminated because they were inattentive (2) or distracted (1).

4.1.2. Apparatus, trials, and procedure

The apparatus, trials, and procedure used in Experiment 3 were similar to those in Experiment 2, except that the infants watched the same three familiarization events twice; the three events were shown in a first block of trials and then repeated, in the same order, in a second block. Eight infants (four in the short-frame event condition and four in the long-frame event condition) saw the *first* three familiarization events shown in Experiment 2 (those involving the fish, the box, and the baby shoe) in each block of trials, and six infants (three in the short-frame event condition and three in the long-frame event condition) saw the *last* three familiarization events shown in Experiment 2 (those involving the toy, the doll's hat, and the baby bottle) in each block of trials. Following the six familiarization trials, the infants received one display and two test trials, as in Experiment 2. One infant (who saw the long-frame event) completed only one test trial, because of fussiness.

The infants were generally attentive during the 18-s pre-trial at the start of each familiarization trial and looked for 17.2 s, 16.5 s, 14.2 s, 14.3 s, 12.7 s, and 13.6 s in the first to sixth trials, respectively. During the 5-s pre-trial that preceded each of the two test trials, the infants looked for 4.0 s and 3.9 s, respectively. Interobserver agreement was calculated for all 14 infants and averaged 92% per trial per infant.

Preliminary analyses of the familiarization, display, and test data in Experiment 3 revealed no significant interaction involving event condition and either sex or familiarization objects (fish, box, baby shoe versus toy, doll's hat, baby bottle), all Fs$(1,10) < 1.76$, $p > .20$; the data were therefore collapsed across these two factors in subsequent analyses.

4.2. Results

The looking times of the infants in Experiment 3 were compared to those of the infants in Experiment 2. The infants' looking times during the main-trial portions of the *familiarization* trials were averaged within each block of three trials and were analyzed by means of a $2 \times 2 \times 2$ ANOVA with Experiment (2 or 3) and event condition (short- or long-frame) as between-subjects factors and with block (first or second) as a within-subject factor. The only significant effect was that of block, $F(1,24) = 15.38$, $p < .001$, indicating that the infants looked reliably less in the second ($M = 11.6$, SD = 7.8) than in the first ($M = 17.8$, SD = 9.0) block of trials. Planned comparisons indicated that the infants in Experiments 2 and 3 did not differ reliably in their mean looking times during the first block (Experiment 2: $M = 19.6$, SD = 10.3, Experiment 3: $M = 15.9$, SD = 7.5, $F(1,24) = 2.70$, $p > .11$), or the second block (Experiment 2: $M = 11.4$, SD = 8.1, Experiment 3: $M = 11.8$, SD = 7.7, $F(1,24) < 1$). Thus, although the infants in Experiment 2 saw different familiarization events in each block of trials, and those in Experiment 3 saw the same events, the infants in the two experiments tended to look equally overall during the two blocks of trials.

The infants' looking times during the *display* trial were compared by means of a 2×2 ANOVA with Experiment (2 or 3) and event condition (short- or long-frame) as between-subjects factors. The main effect of Experiment was marginally significant, $F(1, 24) = 3.39$, $p = .078$, suggesting that the infants in Experiment 2 tended to look longer during the display trial ($M = 16.5$, $SD = 9.2$) than did those in Experiment 3 ($M = 10.6$, $SD = 6.9$). The main effect of event condition was not significant, nor was the interaction between Experiment and event condition, both $Fs(1, 24) < 1$, suggesting that this same pattern held for both event conditions (Experiment 2/short-frame: $M = 17.0$, $SD = 11.7$; Experiment 2/long-frame: $M = 16.0$, $SD = 7.0$; Experiment 3/short-frame: $M = 9.3$, $SD = 5.1$; Experiment 3/long-frame: $M = 11.9$, $SD = 8.6$). One possible interpretation of these findings is that because the infants in Experiment 2 attributed to the agent a disposition to slide objects during the familiarization trials (as evidenced by their responses during the test trials), they closely inspected the trucks in the short and long frames during the display trial to determine whether they were "slidable". In contrast, the infants in Experiment 3, like those in Experiment 1, failed to attribute to the agent a disposition to slide objects during the familiarization trials (see below), and as a result showed only a mild interest in the two trucks in the display trial.[4]

The infants' looking times during the main-trial portions of the two *test* trials (see Fig. 3) were analyzed in the same manner as the display trial. The analysis yielded a significant main effect of Experiment, $F(1, 24) = 6.69$, $p < .025$, a marginally significant effect of event condition, $F(1,24) = 4.01$, $p = .057$, and a marginally significant interaction between Experiment and event condition, $F(1,24) = 3.87$, $p = .061$. Planned comparisons revealed that, whereas in Experiment 2 the infants who saw the short-frame event ($M = 18.2$, $SD = 6.5$) looked reliably longer than those who saw the long-frame event ($M = 10.1$, $SD = 4.3$), $F(1,24) = 7.88$, $p < .01$, the infants in Experiment 3 who saw the short- ($M = 9.0$, $SD = 6.0$) and long-frame ($M = 8.9$, $SD = 4.2$) events looked about equally, $F(1, 24) < 1$.[5]

Non-parametric Wilcoxon rank-sum tests confirmed the results of Experiments 2 ($W_S = 36$, $p < .05$) and 3 ($W_S = 50$, $p > .20$).

[4] In line with this analysis, we performed a contrast focusing on the display trial and comparing the looking times of the infants in Experiment 2 ($M = 16.5$, $SD = 9.2$) to those of the infants in Experiments 1 ($M = 13.3$, $SD = 6.9$) and 3 ($M = 10.6$, $SD = 6.9$). This contrast was marginally significant, $F(1, 37) = 3.02$, $p = .090$. Because the infants in Experiment 1 received only three familiarization trials, their looking times during the display trial might have been slightly longer than they would have been had they received six familiarization trials, as in Experiments 2 and 3. Still, the fact that the contrast was marginally significant provides tentative support for the notion that the infants in Experiment 2 (1) attributed to the agent an inclination to slide objects during the familiarization trials, and hence (2) closely examined the two trucks during the display trial to determine if either was "slidable".

[5] As in Experiment 2, the test data were also subjected to an ANCOVA, using as covariates the infants' average looking times during the six familiarization trials and their looking times during the display trial. The interaction between Experiment and event condition was significant, $F(1, 22) = 7.31$, $p < .025$. Planned comparisons confirmed that, whereas in Experiment 2 the infants who saw the short-frame event looked reliably longer than those who saw the long-frame event, $F(1, 22) = 7.74$, $p < .025$, in Experiment 3 the infants who saw the short- and long-frame events looked about equally, $F(1, 22) = 1.15$, $p > .29$.

4.3. Discussion

The infants in Experiments 2 and 3 saw the agent perform her sliding action the same number of times, twice in each of six familiarization trials. However, whereas the infants in Experiment 2 saw the agent slide a different object in each trial for a total of six different objects, those in Experiment 3 saw her slide only three different objects: the same three objects (either the first three or the last three objects from Experiment 2) were used in the first and second block of trials. During test, the infants in the two experiments responded differently: whereas in Experiment 2 the infants who saw the short-frame event looked reliably longer than those who saw the long-frame event, in Experiment 3 the infants tended to look equally at the two events. This negative result is unlikely to be due to the fact that the infants in Experiment 2 were more engaged by the familiarization events they were shown: recall that no reliable difference was found between the looking times of the infants in Experiments 2 and 3 in either the first or the second block of familiarization trials.

Why did seeing the agent slide six different objects (Experiment 2), as opposed to only three different objects (Experiments 1 and 3), help the infants succeed in the present experiment? We return to this question below, in Section 5.

5. General discussion

After watching the agent slide six different objects during the familiarization trials, the 9.5-month-olds in Experiment 2 attributed to the agent an inclination to slide objects, and expected her to select the "slidable" over the "unslidable" truck in the test trial. This result confirms and extends recent findings that 13.5-month-old infants can attribute to an agent a predilection for a particular action (Song et al., 2005). By the same token, this result adds to the evidence that infants in the first year of life can attribute to others dispositions involving objects (e.g., Luo & Baillargeon, 2005a, 2005b, in review; Luo & Johnson, 2006; Song et al., in review) and agents (e.g., Kuhlmeier et al., 2003, in review), by demonstrating that they can attribute dispositions involving actions as well.

At the same time, the present research indicates that 9.5-month-olds are not as adept as 13.5-month-olds at attributing to agents dispositions involving actions. The 13.5-month-olds tested by Song et al. (2005) expected the agent to select the "slidable" truck after seeing her slide *three* different objects during familiarization. In contrast, the 9.5-month-olds in the present research gave evidence that they expected the agent to grasp the "slidable" truck only after seeing her slide *six* different objects during familiarization (Experiment 2). When these younger infants saw the agent slide only three different objects, either in one (Experiment 1) or in two (Experiment 3) blocks of trials, they gave no indication that they expected her to select the "slidable" truck.

In addition to revealing some of the limits of 9.5-month-old infants' ability to attribute dispositions to others (we return to these limits in the next section), the negative results of Experiments 1 and 3 allowed us to eliminate possible alternative interpretations of the positive results of Experiment 2. Had the infants in Experiment 2 looked reliably longer at the short-frame event simply because they preferred seeing the actor grasp the truck in the short as opposed to the long frame, or seeing the actor grasp the truck on her left as opposed to on her right, then the infants in Experiments 1 and 3, who saw exactly the same test events, should have responded in the same manner. The fact that they tended to look equally at the short- and long-frame events thus rules out these low-level interpretations of the results of Experiment 2.

5.1. Future directions

Why did the infants in the present research succeed in attributing to the agent a disposition to slide objects when they saw her slide six (Experiment 2) but not three (Experiments 1 and 3) different objects during the familiarization trials? One possible interpretation is that, when watching the familiarization events, the infants initially tended to focus more on the *objects* used than on the *actions* performed. Across trials, as the objects changed, the infants might have attempted to determine what these objects had in common or what category they formed. With only three trials, the infants might have been unable to come to any conclusion about the objects. With six trials, however, the infants might have concluded that the objects belonged to no discernable category, and that the salient commonality across trials had to do with the actions the agent produced rather than with the objects she acted on: regardless of the object involved, she always performed the same actions.

This analysis suggests several directions for future research. First, 9.5-month-old infants might succeed in attributing a disposition to slide objects to an agent with only three familiarization trials, if they could be induced to focus on the actions the agent performs rather than on the objects she acts on. One way of inducing such a focus might be to show actions with a salient common *effects*: infants more easily attend to and interpret actions that generate salient effects (see Elsner, 2007, for a review). Thus, infants might be more likely to focus on the sliding actions used in the present research if these were accompanied by a consistent effect, regardless of the objects involved (e.g., if the objects had wheels that left clear tracks in a sandy surface). Another way of inducing infants to focus on the agent's actions might be to use a *linguistic cue*. In an ongoing experiment (Song, Baillargeon, & Fisher, in progress), infants are tested with the same procedure as in Experiment 1, except that the agent repeatedly utters the word "gorping" as she slides each object forward and backward. If by 9.5 months of age, infants recognize that words that end with "ing", or words that are not preceded by "a" or "the", may refer to actions, then hearing the word "gorping" in this context might induce them to pay closer attention to the agent's actions, and as such might help them recognize their commonality across trials. Preliminary results are consistent with this prediction: after receiving three familiarization trials in which the agent repeats the word "gorping" as she slides each object forward and backward, infants expect the agent to reach for the "slidable" as opposed to the "unslidable" truck, and are surprised when she does not.

Second, if infants naturally tend to focus on the objects an agent acts on across trials, and to look for commonalities among them, then infants might be able to detect when these objects actually belong to some category. In an ongoing experiment (Onishi, Baillargeon, & Leslie, 2007), 10.5-month-old infants first receive three familiarization trials in which an agent reaches for one of the two objects on an apparatus floor: a cup on the left or a book on the right. Crucially, different cups and books are used across trials. For half of the infants, the agent always reaches for the cup (cup condition); for the other infants, the agent always reaches for the book (book condition). In test, a novel cup and book are used, and their positions are reversed. Preliminary results suggest that infants in the cup condition look reliably longer when the agent reaches for the book than for the cup, and that infants in the book condition show the reverse looking pattern. Infants thus seem to attribute to the agent a particular disposition, a preference for one category of objects over another.

Third, another direction for research might involve varying the sliding actions performed by the agent during the familiarization trials. In the present research, the agent's actions were always exactly the same across trials, while the objects varied. If the infants had a natural tendency to attend to the objects used and/or to attend to what varied across trials, this feature of our design would have made it particularly difficult for the infants to attribute to the agent a disposition to slide objects. Therefore, what if infants were tested using the same procedure as in Experiment 1, but instead of performing the exact same sliding actions across trials, the agent spontaneously varied these actions somewhat, for example by sliding the object for a shorter or a longer distance or in slightly different directions across repetitions? Would this variation tend to draw the infants' attention to the sliding action itself, and help them detect what was common across trials: irrespective of the object involved, the agent always slid it forward and backward in some fashion? If this prediction turns out to be correct, then it would suggest that infants are more likely to attribute to an agent a disposition to slide objects if she spontaneously varies her sliding actions somewhat across trials, than if she continually repeats exactly the same action.

The preceding speculations may have implications for findings reported by Gergely, Csibra, and their colleagues (e.g., Csibra et al., 1999, Experiment 1; Gergely et al., 1995). In seminal experiments using computer-animated events, 9- and 12-month-old infants watched a habituation event in which a small circle jumped over a barrier to reach a large circle. Following habituation, the barrier was removed, and the small circle either traveled to the large circle in a straight line (expected event), or jumped as before on its way to the large circle (unexpected event). The infants looked reliably longer at the unexpected than at the expected event, suggesting that they attributed to the small circle the goal of reaching the large circle, and expected the small circle to carry out this goal in a reasonably efficient or rational manner. Infants in a control condition—the condition that concerns us here—saw the same events, except that the barrier did not stand in the path of the small circle in the habituation event: although the small circle jumped on its way to the large circle, as in the experimental condition, the barrier stood at the edge of the screen, out of the small circle's path. The infants in this condition tended to look equally at the expected and unexpected test events. In light of the present research, one might ask why the infants did not attribute to the small circle a particular disposition, a predilection for jumping. After all, the small circle jumped in each habituation trial, even though it did not have to, so why not attribute to it a disposition to jump? Had the infants attributed such a disposition to the small circle, they should have looked reliably longer at the expected event, since the small circle failed to jump on its way to the large circle.

There are several possible reasons why the 9- and 12-month-old infants in these experiments might have failed to attribute to the small circle an inclination to jump. First, infants may be able to attribute to agents dispositions to perform certain actions on objects, such as sliding, lifting, shaking, or throwing objects, but have more difficulty attributing to agents dispositions to move themselves in a certain manner, such as jumping, hopping, running, or spinning. Second, infants may be able to attribute to an agent a disposition to move in a certain manner, such as jumping, but have difficulty doing so when also reasoning about a largely unrelated goal. In the present research, and in the research described in the Introduction, the agent's disposition was typically invoked to explain the agent's goal-directed actions: for example, the agent slid the toy fish back and forth because she had an inclination to slide objects; or the agent grasped toy-A because she preferred it over toy-B (e.g., Luo & Baillargeon, 2005a, 2005b, in review; Luo & Johnson, 2006; Song et al., 2005, in progress). In the experiments above, however, the infants had to attribute to the small circle a separate goal (reaching the large circle) and disposition (a tendency to jump). Third—and this brings us back to our original point—infants may be able to attribute to an agent a disposition to move in a certain manner, even when it is unrelated to the agent's goal, only when there is sufficient spontaneous variation in the agent's movements to draw infants' attention. In the control conditions of Gergely et al. (1995) and Csibra et al. (1999; Experiment 1), the direction of the small circle's motion varied from left to right or from right to left across habituation trials. However, this change of direction may not have supplied useful variation, because it was externally caused (the locations of the large and small circles at the start of each trial determined the direction of the small circle's motion), and because the small circle—whether moving from left to right or from right to left—jumped in exactly the same manner across trials. Thus, it might be that, when watching a small circle repeat identical jumps on its way to a large circle, infants fail to also attribute to the small circle a disposition to jump. However, if the small circle spontaneously varied its jumps across trials (e.g., one large jump in one trial, two medium-sized jumps in another, one medium-sized and two small jumps in yet another, and so on), infants might then attribute to the small circle a tendency to jump on its way to the large circle (or any other destination, for that matter).

Of the three possibilities listed above, we suspect that the first is the least likely. Recent research suggests that infants readily attend to the manner in which agents move themselves (e.g., Casasola, Hohenstein, & Naigles, 2003; Pruden, Hirsh-Pasek, Maguire, & Meyer, 2004; Pulverman & Golinkoff, 2004; Pulverman, Hirsh-Pasek, Golinkoff, Pruden, & Salkind, 2006; Pulverman, Sootsman, Golinkoff, & Hirsh-Pasek, 2003). In one experiment (e.g., Pulverman & Golinkoff, 2004), for example, 7-month-old infants were habituated to a computer-animated event in which a starfish-shaped agent moved in a particular manner (e.g., spinning) along a fixed path between two locations; infants dishabituated in test when the agent changed its manner of motion (e.g., performing jumping jacks). In another experiment (Pruden et al., 2004), infants aged 7–15 months were familiarized with events in which the starfish-shaped agent moved in the same manner (e.g., spinning) along different paths. In test, the infants saw two simultaneous events in which the agent moved along a novel path either in the same manner as before (old-manner event) or in a novel manner (novel-manner event). Infants aged 13–15 months preferred the novel-manner event, suggesting that they were able to abstract the agent's common manner of motion across the different paths. If infants can attend to an agent's manner of motion, along the same or different paths, it seems plausible that they would be able to recruit this information to attribute to an agent a disposition to engage in a certain activity—just as we attributed to Cousin Hilary, who danced the night way in our family reunion example, a predilection for dancing.

Finally, yet another direction for future research might involve examining infants' responses to other kinds of actions performed by agents. So far, we have focused on various kinds of *motion actions*: actions in which agents move objects, or move themselves, either in a certain manner or along a certain path. In contrast, *relational actions* are actions in which one object is placed in a particular spatial or mechanical relation with another object (e.g., as in occlusion, containment, support, or collision events). There is evidence that infants aged 6 months and older can recognize the same relational action when performed with different objects across trials (e.g., Casasola & Cohen, 2002; Casasola, Cohen, & Chiarello, 2003; McDonough, Choi, & Mandler, 2003). For example, Casasola et al. (2003) habituated 6-month-old infants to four different containment events in which an experimenter's hand placed an object inside another object (e.g., a toy monkey inside a basket, or a small toy car inside a larger car). During test, the infants dishabituated to novel support but not containment events, suggesting that they were able to extract the action of containment from the habituation events. This research thus shows that by 6 months of age, infants can extract relational actions from events with different objects. Could infants attribute to an agent a disposition involving a relational action, such as a predilection for placing objects inside containers? We suspect that the answer to this question is yes: given that infants naturally attend to objects and their interactions, it would make sense that they would readily recruit such information to interpret others' actions.

5.2. About goals and dispositions

We began this paper by suggesting that adults not only attempt to detect the immediate goals underlying agents' actions, but often speculate about the factors that lead agents to select particular goals (see Csibra & Gergely, 2007, for a similar point of view). To this end, adults often invoke dispositions—some fleeting, others more enduring—that help make sense of agents' current actions, and also suggest how they may act in new contexts.

We then reviewed evidence that infants in the first year of life also attribute dispositions to others. Infants who saw an agent repeatedly grasp object-A as opposed to object-B during familiarization attributed to the agent a preference for object-A over object-B; had the infants only attributed to the agent the goal of grasping object-A, their test responses would have been the same when object-B was absent (or hidden from the agent) during familiarization, and this was not the case (e.g., Luo & Baillargeon, 2005a, 2005b, in review; Luo & Johnson, 2006; Song et al., in review). Similarly, infants who, during familiarization, saw actor-A repeatedly help an agent climb a hill, while actor-B provided no such assistance, inferred that the agent would be positively disposed toward actor-A but not actor-B; had the infants only attributed to the agent the goal of climbing the hill, they could have made no prediction during test as to which actor the agent was more likely to approach, and this was again not the case (e.g., Kuhlmeier et al., 2003, in review). Thus, to explain either set of findings, we must assume that the infants attributed to the agent a particular disposition—a preference for object-A over object-B, or a partiality for actor-A over actor-B.

However, it might be less clear whether the same is true in the present research. One might suggest that the results of Experiment 2 could perhaps be explained by saying that across the familiarization trials the infants came to attribute to the agent not a disposition to slide objects, but rather a general goal of sliding objects. On this view, the infants began by attributing to the agent the specific goals of sliding the toy fish, the box, the baby shoe, and so on, and eventually abstracted from these specific goals the more general goal of sliding objects. Consistent with this general goal, the infants then expected the agent to select the "slidable" rather than the "unslidable" truck in test.

We believe that this interpretation is mistaken, for the following reasons. In our framework (see also Csibra & Gergely, 2007; Csibra et al., 1999, 2003; Gergely & Csibra, 2003), a goal is a particular state of affairs that an agent wants to achieve. It can be very limited in scope (e.g., hammering in a nail) or very general in scope (e.g., building a house); either way, the agent will perform causally appropriate actions to achieve the goal. By contrast, a disposition is a trait, tendency, or state of the agent; it can be fleeting (e.g., hungry) or enduring (e.g., fond of cheesecake), and will cause the agent to choose certain goals as opposed to others. While it is easy and straightforward to explain the behavior of the agent in the present research in terms of a disposition to slide objects, it is difficult to do so in terms of a general goal: for how could sliding objects correspond to a particular state of affairs that an agent would want to achieve?

We agree that in some cases it may be difficult to determine, when observing an agent perform a series of actions, whether these actions are guided by a disposition or by a general goal. To see why, consider the following example. A young girl is shopping in a toy store and pushes a cart before her. Every now and then, she stops, selects a small item off a shelf, and adds it to her cart. Eventually, we notice that every item in the cart is bright pink in color. To explain this behavior, we might attribute to the young girl a particular disposition, a fondness for the color pink. Alternatively, we might attribute to the young girl a general goal of selecting pink toys: perhaps she is selecting gifts for a friend who loves pink, and our shopper's goal is to purchase a variety of pink toys for her friend.

In this example, something discernable is being achieved by the shopper's behavior: the purchase of a selection of pink toys. After identifying this state of affairs, we can speculate about which disposition or general goal might be driving our shopper's actions. But the situation is very different in the present research: as the agent slides object after object, it seems unlikely that any state of affairs is being achieved or strived for. Rather, it is more plausible that the agent is sliding objects because she is exercising a particular disposition, an inclination to slide objects (e.g., "Why is she sliding all these objects? I guess she likes to slide things"). To attribute to the agent a general goal of sliding objects would require understanding sliding objects as a state of affairs that the agent wants to achieve, and it is difficult even for adults to imagine how this could be the case. To put it differently: whereas the statement "the particular state of affairs the agent wants to achieve is to purchase a selection of pink toys for a friend" is well-formed, the statement "the particular state of affairs the agent wants to achieve is to slide objects" seems invalid.

Since infants as young as 5–7.5 months of age have been shown to use dispositions to make sense of others' behavior (e.g., Luo & Baillargeon, 2005a, 2005b; Luo & Johnson, 2006; Song et al., in review), and since attributing to the agent a disposition to slide objects readily makes sense of her actions, whereas attributing to her a general goal to slide objects does not, it seems likely that the infants in Experiment 2 construed the agent's actions in terms of an inclination to slide objects.

5.3. Infants' psychological-reasoning system

The present research suggests that infants as young as 9.5 months of age attribute to an agent who performs the same motion action with a variety of objects a disposition to perform that action. When the agent next faces two novel objects, one that can be used to perform the action and one that cannot, infants expect the agent to select the first object rather than the second. The present findings thus add to the growing evidence that substantial psychological reasoning takes place in the first year of life, and as such support the view that this reasoning reflects the operation of an abstract computational system that is triggered whenever infants attempt to make sense of agents' actions (e.g., Gergely & Csibra, 2003; Leslie, 1994; Luo & Baillargeon, in review; Premack & Premack, 1995; Song, Onishi, Baillargeon, & Fisher, in review).

How might this psychological-reasoning system operate? We suspect that, when watching an agent act on objects in a scene, as in the present research, infants' psychological-reasoning system builds a specialized representation of the scene, or *psychological representation*, which is used to interpret and predict the agent's actions (for further discussion, see Luo & Baillargeon, in review; Song et al., in review). This psychological representation is likely to specify at least the following components: the agent's *actions*; the physical *setting* in which the actions occur; and the agents' internal *states*. These internal states are of two kinds. On the one hand, *informational states*—such as perceptions and beliefs—specify how the physical setting is represented by the agent. On the other hand, *motivational states*—such as dispositions and goals—specify the agent's motivation in the scene. These components—together with core biases such as that agents will select actions that are not only causally appropriate to achieve their goals, but also reasonably efficient or rational (e.g., Csibra & Gergely, 2007; Csibra et al., 1999; Gergely & Csibra, 2003; Gergely et al., 1995)—provide a causal analysis of the agent's actions.

With respect to *informational* states, recent research suggests that, by about 5 or 6 months of age, infants recognize that, when the agent's representation of the physical setting is *incomplete* (e.g., because the agent cannot see one of the objects they themselves can see), it is the agent's representation that must be used to predict her actions (e.g., Luo & Baillargeon, 2005b, in review; Luo & Johnson, 2006). By about 13–15 months of age, infants also realize that, when the agent's representation of the physical setting contains *false* elements (e.g., because the agent was absent when objects were moved to new hiding locations or when new information was revealed about the objects), it is again the agent's representation that must be used to predict her actions (e.g., Onishi & Baillargeon, 2005; Scott & Baillargeon, 2006; Song, 2006; Song et al., in review; Surian, Caldi, & Sperber, in press). Finally, by about 15 months of age, infants appreciate that, when the agent's representation of the physical setting involves *pretend* elements (e.g., the agent pretends to pour liquid from an empty jug into an empty cup and then pretends to drink from the cup), it is again the agent's representation that must be used to make sense of her actions (Onishi, Baillargeon, & Leslie, 2007).

With respect to *motivational* states, research over the past 10 years suggests that infants aged 5 months and older attribute both dispositions and goals to agents (e.g., Csibra et al., 1999; Csibra et al., 2003; Gergely et al., 1995; Király et al., 2003; Kuhlmeier et al., 2003; Luo & Baillargeon, 2005a; Meltzoff, 2007; Reid et al., 2007; Shimizu & Johnson, 2004; Sommerville & Woodward, 2005; Song et al., 2005; Woodward, 1998; Woodward & Guajardo, 2002; Woodward & Sommerville, 2000). The research reported here extends these findings by showing that, by 9.5 months of age, infants can attribute to agents dispositions involving not only objects and agents, but actions as well.

Acknowledgements

This research was supported by a grant from NICHD to Renée Baillargeon (HD 21104). We thank Gergo Csibra, Cindy Fisher, and George Gergely for helpful discussions; the staff of the University of Illinois Infant Cognition Laboratory for their help with the data collection; and the parents and infants who generously participated in the research.

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