INFANTS' ABILITY TO DISTINGUISH BETWEEN PURPOSEFUL AND NON-PURPOSEFUL BEHAVIORS

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Prior studies (Gergely et al., 1995; Woodward, 1998) have found that infants focus on the goals of an action over other details. The current studies tested whether infants would distinguish between a behavior that seemed to be goal-directed and one that seemed not to be. Infants in one condition saw an actor grasp one of two toys that sat side by side on a stage. Infants in the other condition saw the actor drop her hand onto one of the toys in a manner that looked unintentional. Once infants had been habituated to these events, they were shown test events in which either the path of motion or the object that was touched had changed. Nine-month-olds differentiated between these two actions. When they saw the actor grasp the toy, they looked longer on trials with a change in goal object than on trials with a change in path. When they saw the actor drop her hand onto the toy, they looked equally at the two test events. These findings did not result from infants being more interested in grasping as compared to inert hands. In a second study, 5-month-old infants showed patterns similar to those seen in 9-month-olds. These findings have implications for theories of the development of the concept of intention. They argue against the claim that infants are innately predisposed to interpret any motion of an animate agent as intentional.

human action intention cognition habituation

In making sense of the actions of other people, the details matter. Recent studies have provided evidence that 14- to 24-month-old infants can reason about human behavior in surprisingly subtle ways. Babies at this age distinguish between behaviors that are done purposefully and those that are portrayed as accidental. Fourteen-month-olds are less likely to imitate accidental behaviors than purposeful ones (Carpenter, Akhtar, & Tomasello, 1998), 18-month-olds are able to infer the intended action of an actor who fails to

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achieve it (Meltzoff, 1995), and 24-month-olds interpret new verbs as naming purposeful behaviors, rather than accidental ones (Tomasello & Barton, 1994). These findings indicate that by the end of infancy, babies pay attention to the fine details of action, using them to inform their inferences about the actor's goals. The two studies reported here investigate the precursors to this ability in the first year of life. They test whether infants distinguish in their representations of behaviors that would be seen as purposeful versus not purposeful by an adult.

Although a decade of research has provided a wealth of information about infants' developing abilities to reason about the motions of inanimate objects, few studies have explored infants' understanding of human action. There is evidence that infants understand some of the mechanical constraints on human action, in particular, on a person's ability to move an object with his or her hand. By 6 months of age, infants expect that a hand must be in contact with an object in order to lift it (Leslie, 1984). As young as 3–4 months, infants also understand that an object is adequately supported when grasped by a hand, but not when the hand releases it (Baillargeon, 1995; Needham & Baillargeon, 1993). In addition, by 5-1/2 months, infants understand some of the constraints on an actor's ability to retrieve an object—they show surprise when an actor retrieves an object without first removing a barrier that is between her hand and the object (Baillargeon, Graber, DeVos, & Black, 1990).

Knowledge about how hands can support and retrieve objects is important, but understanding human action, in its mature form, goes beyond mechanics. Human action, unlike object motion, can be described in terms of the actor's intentions. Hands are like shelves in some ways, for example, both can support objects, but hands are unlike shelves in that, as parts of people, they move to attain goals. New evidence indicates that infants one year of age and younger have the beginnings of this distinction in that they focus on the goals of a human action over other details of the event (Gergely, Nadasdy, Csibra, & Biro, 1995; Woodward, 1998), and differentiate between people and inanimate objects in doing so (Woodward, 1998). In a recent study (Woodward, 1998), 6- and 9-month-old infants were shown an event in which an actor grasped one of two toys that sat side by side on a small stage. The actor reached in from one side, moving her arm through a distinctive path as she reached for the object. The question was how infants would construe this event. They might represent this event mainly in terms of the physical motion that took place, that is, the motion of the actor's arm through space. Alternatively, infants might focus on the relation between the actor and the object she grasped. In doing so, they, like older reasoners, would be stressing the goal related properties of this action.

This question was addressed using a habituation paradigm. Infants were habituated to one reaching event and then shown test events in which either the path of motion or the goal object had changed. To achieve this, the positions of the two toys were reversed and the actor then either moved her arm through a new path in order to grasp the same toy as in habituation, or moved her arm through the prior path in order to grasp a different toy. The results were that infants looked longer when the goal object had changed than when the path of the reach had changed, supporting the conclusion that they found the former event more novel than the latter. That is, when infants saw a person grasp an object, they focused on the relation between the person and the object. In addition, infants at both 6 and 9 months distinguished between events involving people and events involving inanimate objects. Additional groups of infants saw inanimate objects such as rods and mechanical claws that moved toward and touched or grasped the toy. These infants did not respond strongly to the change in relation between the rod or claw and the object. If anything, they showed slightly greater recovery to the change in path than to the change in object.

One possible explanation for this pattern of

findings is that the hand was more effective at drawing infants' attention to the toy than were the rod or claw. If this were the case, then the hand, but not the rod or claw, would have acted as a strong attentional "spotlight." Then, when the hand grasped a new object, babies might have looked longer because a new object was being highlighted, and infants who saw the rod or claw would not have had a new object highlighted in this way. A follow-up analysis was conducted to evaluate this possibility. If the actor's hand acted as a powerful attentional spotlight and the rod or claw did not, then this should be evident in the amount of time infants spent looking at the toy contacted by the hand versus the rod or claw. Infants' patterns of looking indicated that the hand, rod and claw did not differ in their effectiveness as spotlights: they all drew infants' attention to the object that they touched. Thus, babies allocated their visual attention in similar ways for the events involving a human hand and the rod or claw, but babies who saw the hand differed from babies who saw the rod or claw in terms of the features they weighted most heavily in their representation of the event. In particular, when infants saw a human actor grasp the toy, they weighted the goal-related properties of this event more heavily than its other properties. When they saw an inanimate object touch or grasp the toy, infants did not do this.

In sum, infants as young as 6 months of age differentiated between human and nonhuman graspers, and, critically, they construed the human grasp as goal-directed. How general is this propensity? It is possible that infants would construe any event in which a person touched an object as goal-directed. This possibility is in keeping with recent theories. For example, Premack (1990) has proposed that infants are born with a system for interpreting action as intentional that is triggered whenever they see a self-propelled motion (see also Baron-Cohen, 1997), and Gergely and his colleagues (1995) have proposed that infants interpret any motion of a trajector toward a goal as intentional, provided the path it takes is rational. Thus, infants would begin with an overly broad notion of intentional action which would extend to all motions of humans (and other self-propelled entities), or to all cases in which an object moves toward another object via a the most direct route available. On the other hand, as discussed above, recent research has shown that as early as 14 months of age, infants distinguish between different kinds of human behaviors. They see some, but not all behaviors as goal-directed. Therefore, it is possible infants distinguish between different kinds of behaviors still earlier in infancy. If so, they would construe as goal-directed only a subset of events in which people move toward and touch objects.

With these alternative possibilities in mind, the current studies investigated infants' encoding of two different events in which an actor touched a toy with her hand. In the first study, 9-month-old infants were tested. One group of infants saw events in which an actor reached in from one side of a stage to grasp a toy from above (the *grasp* condition; see Figure 1). A second group of infants saw a similar event in which an actor dropped her hand from above to land on the toy (the *back-of-hand* condition; see Figure 2). The timing of the arm's motion, the angle of the actor's arm, and the portion of the toy that was covered by the hand were similar in the two conditions. In both conditions, after making contact with the toy the actor remained still with her hand in contact with the toy until the trial ended.

Following habituation, infants in each condition saw two test events in which the positions of the toys were switched. In one of these, the actor moved her arm through the same path as during habituation, thus making contact with a new toy. In the other, the actor moved her arm through a new path, thus making contact with the same toy as in habituation. Based on previous studies (Woodward, 1998), infants were predicted to look longer at the former test event when they saw the actor grasp the toy. The question of interest was whether infants would show the same pattern when they saw the actor drop her hand onto the toy.

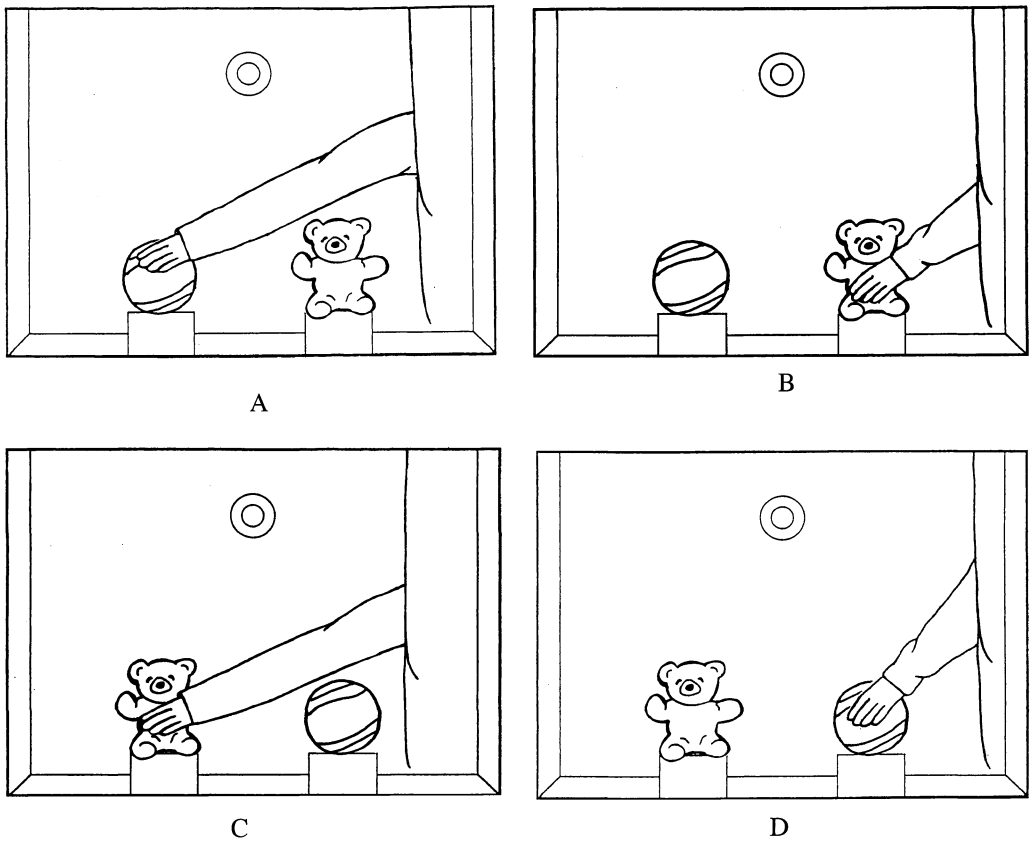

FIGURE 1
Experimental events for the grasp condition.

In sum, infants in the two conditions saw similar events, but these events differed as to whether, from an adult standpoint, the behavior was readily interpreted as purposeful. This contrast provided a good initial test of the generality of infants' understanding of goal-directed action. If infants have the propensity to interpret all human behaviors as goal-directed, they should do so for the back-of-hand events. If infants distinguish between different kinds of behaviors, we do not yet know the bases by which they do so. An event that seems unintentional to adult observers may provide the most sensitive test of these discrimination abilities. If infants discriminate between the grasp and back-of-hand events, this finding will raise the question of the means by which they did so. I will return to this question at the end of the paper.

STUDY 1

Method

Participants

Thirty-two full term infants from the city of Chicago and its suburbs participated in Study 1. They ranged in age from 8 months 7 days to 10 months 14 days (mean age = 9 months 10 days). Parents had been contacted through

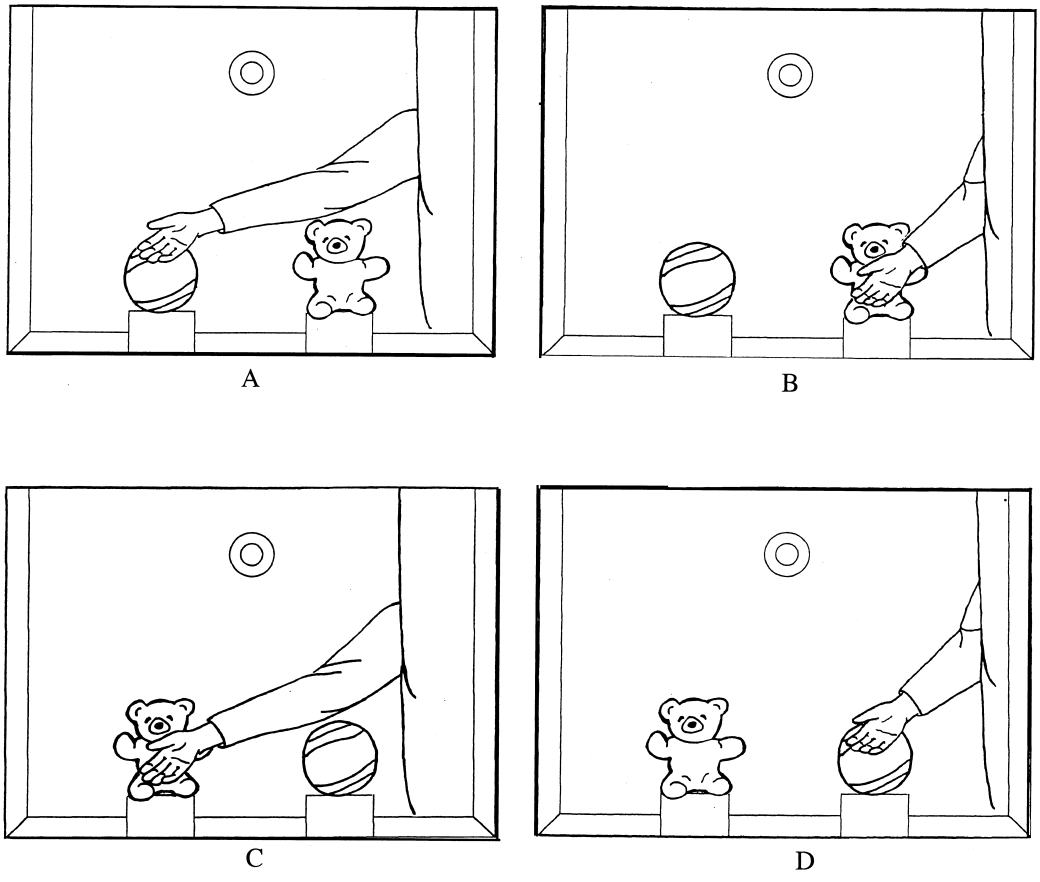

FIGURE 2
Experimental events for the back-of-hand condition.

mailings and ads in local newspapers and were offered $10.00 to reimburse their travel expenses. Eighteen additional infants visited the laboratory but were not included in the final sample because they failed to complete all trials due to distress (4), because they moved off camera during a trial (6), or because there was an error in the experimental procedure (8). In the final sample, 16 infants saw the actor reach for and grasp one of two toys (the *grasp* condition), and 16 saw the actor make contact with one of the toys with the back of her hand (the *back-of-hand* condition). There were 7 females and 9 males in the grasp condition (mean age = 9 months 13 days), and 6 females and 10 males in the back-of-hand condition (mean age = 9 months 7 days).

Procedure

Infants sat facing a stage 30 inches away on which there were two toys, a white teddy bear and a multi-colored ball. The toys stood on black pedestals 2-3/4 inches high and 10 inches apart. The three closed sides of the stage were draped in black curtains. Infants were filmed by a video camera that was mounted above and between the two toys, its lens protruding through a slit in the back curtain. Between trials, a white screen was raised from

below the stage to block the toys from view. Infants were either placed in a table-top seat or held on a parent's lap. When the infant sat in the table-top seat, the parent stood behind the infant. When the baby sat on the parent's lap, the parent was instructed to look down at the baby rather than at the experimental event.

To counterbalance the side placement of the toys and the location of the habituation reach, four infants were habituated to each of the eight events portrayed in Figures 1 and 2. At the start of each trial the screen was lowered to reveal the two toys. Before reaching into the stage, the actor waited for the observer to signal that the camera was in focus and the infant was facing forward. If the infant was not looking at the toys, the actor snapped behind the curtain to draw the infant's attention to the stage. In the grasp condition, the actor grasped the toy with her left hand. In the back-of-hand condition, the actor lowered her right hand onto the toy, letting it fall the last few inches so that it landed, palm up, on the toy. In both conditions, the actor remained still after making contact with the toy. The actor wore a magenta sweater, and her hand was bare. Only her arm was visible to the infant.

An observer coded the infant's looking on-line from a video monitor. The camera and monitor were placed so that he could not see any part of the experimental event or the toys, and he was not informed of the condition to which the infant had been assigned. The observer was trained to be able to tell, based on the direction of the infant's gaze, whether he or she was looking at the area containing the toys and the actor's arm. The observer pressed a key when the infant looked at this area, and a computer program calculated looking times and habituation criteria from this input (Pinto, 1994). The infant's looking was timed starting when the actor's hand made contact with the toy and stopped moving. To achieve this, the observer began coding as soon as the screen was lowered, and a second experimenter, standing behind the infant, began the timing process by clicking the mouse once the actor's hand had stopped moving on contact with the toy.

Trial length was infant controlled with the exception that a trial was ended after 120 seconds if the infant had not yet looked away. Otherwise, a trial was ended when the infant looked away for 2 seconds. The habituation criterion was computed using the first three trials that summed to 12 seconds or more. When the infant had 3 additional consecutive trials that summed to less than 50% of the first three trials, the habituation phase was ended. If the infant had not met the habituation criterion after 14 trials, the habituation phase was ended and test trials were begun. After habituation, the screen was raised to hide the stage from view and the positions of the toys were reversed. Then, the screen was lowered and the infant was given one familiarization trial with the toys in their new positions without the actor reaching into the stage area. After this trial, each baby saw two test events on alternating test trials for a total of three trials of each type. In the *new path* event the actor reached in and made contact with the same toy as during habituation. Since this toy was in a new position, the actor's arm moved through a new path in order to make contact with the toy. In the *new toy* event the actor moved her arm through the same path as in habituation, therefore contacting the new toy. To illustrate, a baby who was habituated to event A in Figure 1 would see events C (new toy) and D (new path) in test. Given the counterbalancing of the habituation events, each of the four possible events for each condition served as the new toy event for four babies and as the new path event for another four babies. Two babies who had been habituated to each of the events saw the new toy test event first and two saw the new path test event first. Males and females were distributed approximately evenly across these conditions.

Procedure Checks

An experimenter watched the event for each trial on-line to determine whether the actor performed the action correctly, grasping

or touching the correct object and remaining still after making contact with the toy. In addition to this on-line procedure check, two follow-up analyses were conducted. First, to determine whether the overall pacing of the events differed for the two conditions, the videotape for each infant was coded after the fact to determine the time between the lowering of the screen and the beginning of timing, that is, when the actor's hand made contact with the toy.[1] This time period included not only the reach, but also the initial check to make sure the infant was facing forward and the camera was in focus. Thus, it is not a perfect reflection of the duration of the reach. Nevertheless, differences in pacing should be evident in this measure. In the grasp condition, the time lag between the lowering of the screen and the beginning of timing was 6.0 seconds on average for events in which the actor touched the toy on the left side and 5.4 seconds for events in which she touched the toy on the right side. These latencies were 5.5 and 5.1 seconds in the back-of-hand condition. An analysis of variance with condition (grasp versus back-of-hand) as the between subjects factor and side of reach (far versus near) as the within subjects factor revealed a main effect of side of reach, $F(1,25) = 5.12$, $p < .05$, and no other reliable effects (for the main effect of grasp versus back of hand, $F(1,25) = 1.52$, $p = .23$, for the interaction, $F(1,25) < 1$). Thus, the pacing in the two conditions did not differ reliably.

A second analysis was conducted to ensure that the actor did not in any way draw the infants' attention more strongly on new-toy than on new-path test trials during the time that she was supposed to remain still (that is, while the infant's looking was measured). The on-line procedure check made this possibility very unlikely, but there was an additional source of data that could be used to confirm this. As will be described below, infants' allocation of visual attention to the toy held by the experimenter and to the other toy was coded after the fact from videotape for each test trial. If the actor influenced infants' attention in a subtle way, the only way she could do so would be by doing something to draw the infants' attention to her hand. If such cues were given and contributed to positive findings, it would be predicted that infants in the grasp condition would have their attention drawn more strongly to the actor's hand on new toy trials than on new path trials. For each infant, the percent of the trial that was spent looking at the toy touched by the actor's hand for new toy and new path trials was compared. There were reliable differences between new toy and new path trials in neither condition. Infants in the grasp condition looked at the actor's hand (and the toy it held) 44% of the time on new toy trials and 53% of the time on new path trials, $t(13) = 1.21$, $p = .25$. Infants in the back-of-hand condition looked at the actor's hand 57% of the time on new toy trials and 56% of the time on new path trials, $t(13) < 1$.

Reliability of On-Line Observing

In order to assess the reliability of the on-line observing, a second trained observer, who was unaware of condition (grasp versus back-of-hand) and test trial order (new path first versus new toy first) coded each infants' looking from videotape after the experimental session. Agreement was assessed for the six test trials for each infant. The median difference between the looking times generated by the two observers was less than 1 second per trial in each condition. As a second measure of agreement, the observers' judgments of the location of the end of each test trial were compared. The on-line and video observers were counted as agreeing if the beep signaling the end of the trial for the video observer was indistinguishable from the beep recorded on the videotape. On this measure, the two observers were in agreement on 92% of trials. Although the two observers disagreed infrequently, even a small amount of bias in one observer could systematically favor the hypothesized pattern of findings. To test for this possibility, disagreements were sorted into

TABLE 1
Mean Total Looking Time During the Last Three Habituation Trials and the Three Test Trials of Each Type for Each Condition in Studies 1 and 2 (Standard Errors of the Mean are Given in Parentheses)

	Last 3 Habituation Trials	*Test Trials*	
		New Toy	*New Path*
Study 1 (9 months)			
Grasp	13.5 (2.5)	27.2 (4.3)*	18.5 (3.9)
Back-of-hand	11.1 (1.2)	22.7 (3.0)	21.1 (3.2)
Study 2 (5 months)			
Grasp	18.7 (2.0)	34.7 (6.5)	28.1 (4.4)
Back-of-hand	23.9 (3.2)	28.5 (3.3)	33.1 (3.5)

*Greater than comparison test event, $p < .005$.

TABLE 2
Number of Infants in Each Study and Condition Who Looked Longer on New Toy Versus New Path Test Trials in Studies 1 and 2

	Test Trials	
	New Toy	*New Path*
Study 1 (9 months)		
Grasp (n = 16)	13	3
Back-of-hand (n = 16)	9	7
Study 2 (5 months)		
Grasp (n = 24)	17	7
Back-of-hand (n = 24)	9	15

two categories: (1) those that would favor the hypothesized pattern of results given that the on-line observer's data were used; and (2) those that would work against the hypothesized pattern of findings given that the on-line observer's data were used. These two kinds of disagreements were randomly distributed across the two conditions, Fisher's exact $p = .56$. Thus, there was not evidence that either of the observers was biased with respect to the predicted pattern of findings.

Results

Habituation Phase

On average, infants had 9 habituation trials in each condition. Four infants in the grasp condition and two in the back-of-hand condition reached 14 habituation trials without meeting the habituation criterion.[2] Infants in the two conditions did not differ in their levels of looking on the last three habituation trials, $t(30) < 1$ (see Table 1). Thus, babies in the grasp and back-of-hand conditions were equally attentive at the start of test trials.

Test Phase

Table 1 summarizes the main findings. The principal measure was the amount of looking on new path and new toy trials in each condition. For each infant, the total amount of looking on the three new path trials and the three new toy trials was calculated. Because a preliminary analysis revealed no effects of the initial side placement of the toys, the side of the habituation reach or the type of test trial given first, in subsequent analyses the data were collapsed across these dimensions. An analysis of variance with condition (grasp versus back-of-hand) as the between subjects factor and test trial type (new toy versus new path) as the within subjects factor revealed a Condition X Test trial type interaction, $F(1,30) = 4.33$, $p < .05$. This analysis also revealed a main effect for test trial type, $F(1,30) = 8.40$, $p < .01$, reflecting the fact that across conditions, infants tended to look longer on new toy trials. Planned comparisons indicated that in the grasp condition, infants looked longer on new toy trials than on new path trials, $t(15) = 3.98$, $p < .005$. In the back-of-hand condition, in contrast, infants looked equally on the two kinds of trials, $t(15) < 1$.

These findings were confirmed by nonparametric tests (see Table 2). In the grasp condition 13 of 16 babies had higher total looking times for new toy trials than for new path trials, $p < .05$ by sign test, whereas 9 of 16 babies in the back-of-hand condition showed this pattern, $p = .81$ by sign test. A Mann-Whitney test confirmed that infants in the

grasp condition showed a stronger preference for the new toy event than did infants in the back-of-hand condition, $z = 1.85$, $p < .05$ (one-tailed). In sum, infants in the grasp condition showed a stronger novelty response to the change in goal object than to the change in path. Infants in the back-of-hand condition, in contrast, did not differ in their responses to the two test events.

A secondary question is whether the infants in the back-of-hand condition noticed either change during test. It is possible that infants in the back-of-hand condition failed to differentiate between the test events because they were generally inattentive during the test phase. The lack of a main effect of condition in the analysis of variance reported above argues against this possibility. To explore this possibility further, infants' recovery from habituation was assessed. For each infant the total amount of looking on the last three habituation trials was compared to the totals for new toy and new path test trials. Infants in the back-of-hand condition recovered on both kinds of test trials, $t(15) = 3.60$, $p < .005$, and $t(15) = 3.46$, $p < .005$ (both one-tailed), for new toy and new path trials respectively. Thus, infants in the back-of-hand condition responded to both the change in path and the change in toy. In contrast, infants in the grasp condition showed reliable recovery on new toy trials, $t(15) = 3.11$, $p < .005$ (one-tailed), but did not recover reliably on new path trials, $t(15) = 1.07$, $p = .15$ (one-tailed). These data may be in keeping with prior findings (Woodward, 1998). However, at this time, it is not possible to know whether infants saw the new path as different from the habituation event

Analysis of Potential "Spotlighting" Effects

A follow up analysis was conducted to test one explanation for the main pattern of findings. Perhaps the differences in looking on test trials in the grasp and back-of-hand conditions derived from the effectiveness of hands in certain orientations at directing babies' attention to an object. Maybe babies are strongly attracted to hands that grasp, and this led them to look at the toy grasped by the hand for most of the trial in the grasp condition. In addition, maybe babies find inert hands to be distasteful, and thus they looked less at the hand in the back-of-hand condition. If so, then babies in the grasp condition had an effective spotlight placed on a new toy in new toy trials, whereas babies in the back-of-hand condition did not have their attention directed in this way. Thus, babies in the grasp condition may have looked longer on new toy trials than on new path trials only because their attention was drawn to a new toy on the former but not the latter trials.

If the grasping hand was an effective spotlight and contact with the back of the hand was not, then babies in the grasp condition should show a large asymmetry—looking at the toy grasped for most of the trial—and babies in the back-of-hand condition should not show a large asymmetry. To assess this possibility, observers coded the videotapes to tabulate the amount of each test trial that the baby looked at each of the toys. The observers were not informed of the condition to which each infant was assigned. Two independent observers overlapped for 7 infants. Their ratings of the overall proportion of looking to each side were strongly correlated, $r = .98$.

Figure 3 gives the percent of time infants in each condition looked at the location of the toy touched by the hand versus the location of the other toy. Since babies could look at other parts of the display, these two percentages did not always sum to 100%. To assess the relative size of the asymmetry between looking to the toy and hand versus the other toy, for each infant the difference between the amount of looking to the two locations was calculated. This difference score was reliably above 0 for infants in both conditions, $t(13) = 2.31$, $p < .05$ and $t(13) = 5.98$, $p < .0001$ for the grasp and back-of-hand conditions. The scores of infants in the two conditions did not differ, $t(26) = 1.02$, $p = .31$. Thus, infants in both

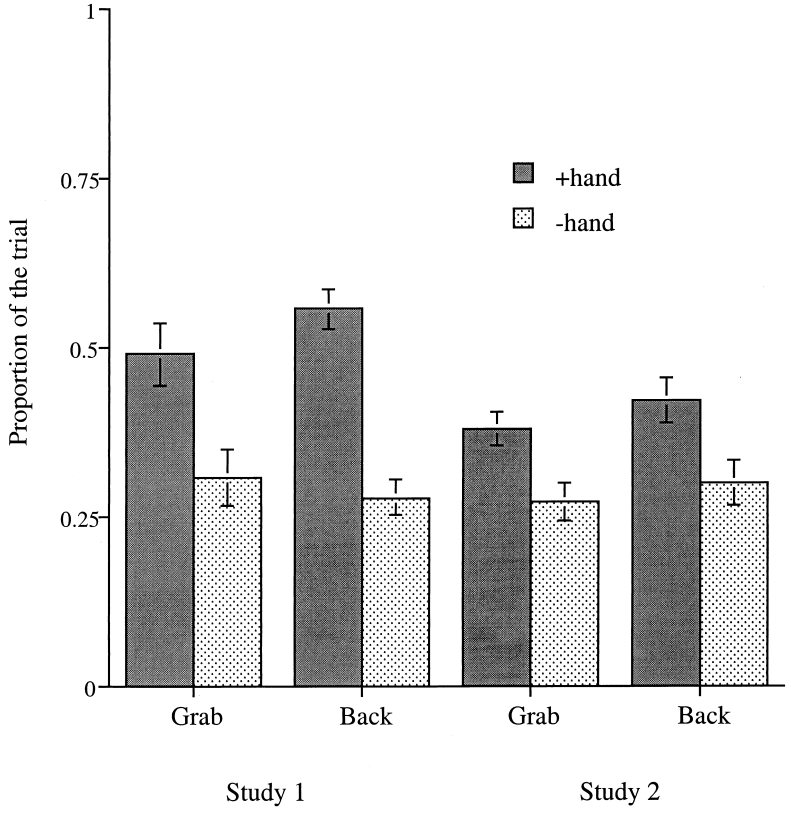

FIGURE 3
Average proportion of test trials that infants spent looking at the toy touched by the hand versus the other toy for Studies 1 and 2 (bars show standard errors).

conditions showed a strong asymmetry, looking mainly at the location of the hand. Given this result, the difference in test patterns between the two conditions cannot be explained by differential spotlighting effects of hands that grasp as compared to inert hands.

Discussion

In summary, even though they deployed visual attention similarly when watching the back-of-hand and grasp events, 9-month-old infants encoded the two events differently. When 9-month-old infants saw an actor grasp an object, they focused on the object that was grasped more than other details of the event. In contrast, infants who saw the actor drop her hand onto the toy responded equally to a change in object and a change in the path taken by the actor's arm. Because the overall levels of looking during the test phase were not different for the grasp and back-of-hand conditions, and because infants in the back-of-hand condition showed reliable recovery on both kinds of test trials, this difference seems not to be due to babies being less attentive to the back-of-hand events than to the grasp events. Moreover, since side placement of the toys and the side reached to in habituation were counterbalanced, these findings cannot be due to infants having a preference for hands that grasp bears or reaches to the far side of the

stage, and so on. These findings support conclusions from earlier work concerning infants' encoding of grasp events (Woodward, 1998). In addition, they indicate that by 9 months, babies distinguish between different kinds of behaviors. This is the first evidence to indicate that, like older children, infants under one year of age distinguish between behaviors that are goal-directed and those that are not.

In the next study, younger infants, 5-month-olds, were tested in the same procedure as in the first study. In prior work (Woodward, 1998), 4–6 months seemed to be a transitional age with respect to infants' encoding of the goal object of grasps. Six-month-olds showed differential weighting of the goal objects versus the path quite robustly, but 5-month-olds showed this pattern less strongly. Thus, testing 5-month-olds in the current procedure provided a way to investigate the development of infants' ability to distinguish between different behaviors. It is possible that infants' special weighting of goal objects for grasps begins as a general tendency to construe as goal-directed any event in which a person touches an object, and that with time and experience, infants narrow the range of behaviors that they construe as goal-directed. If so, unlike older babies, 5-month-olds might respond to the grasp and back-of-hand events in the same way.

STUDY 2

Method

Participants

Forty-eight infants, ranging in age from 4 months 0 days to 6 months 12 days (mean age = 5 months 10 days), participated in Study 2. Infants were recruited as in Study 1. An additional 27 infants began the procedure, but were dropped from the final sample because of failure to complete all trials due to distress (7) and experimental error (20).[3] In the final sample, there were 14 females and 10 males in the grasp condition (mean age = 5 months 8 days) and 17 females and 7 males in the back-of-hand condition (mean age = 5 months 12 days).

Procedure

The design and procedure were identical to those in Study 1, except that 6 infants, instead of 4, in each condition were habituated to each of the events depicted in Figures 1 and 2. Following habituation, infants were shown the two events that presented either a change in toy or a change in path during test. The test trial given first, side of habituation reach and identity of the object contacted during habituation were counterbalanced in each condition.

Procedure Checks

An experimenter watched the events for each trial on-line to monitor for presenter errors. Then, two follow-up analyses were conducted as in Study 1. First, the videotape for each infant was coded to determine whether the timing of the event differed across the two conditions.[4] In the grasp condition, the period between the lowering of the screen and the beginning of timing (when the actor's hand made contact with the toy) was 5.5 seconds for reaches to the far side of the stage and 4.5 seconds for reaches to the near side. For the back-of-hand condition these durations were 5.0 and 4.3 seconds respectively. An analysis of variance with condition (grasp versus back-of-hand) as the between subjects factor and side of reach (far versus near) as the within subjects factor revealed a main effect of side, $F(1,45) = 20.92$, $p < .0001$, and no other effects (all other F's < 1). Thus, the two conditions did not differ in the timing of the actor's arm motion. A second analysis confirmed that the actor's hand did not draw infants' attention differentially on new toy as compared to new path trials. In the grasp condition, infants looked at the actor's hand (and the toy it held) 39% of the time on new toy trials and 36% of the time on new path trials,

$t(22) < 1$. In the back-of-hand condition, infants looked at the location of the hand 42% of the time on new toy trials and 44% of the time on new path trials, $t(23) < 1$.

Reliability of On-Line Observing

Observer reliability was assessed as in Study 1. The median difference between the looking times generated by the two observers was less than 1 second per trial in each condition. The on-line and video observers agreed on the end points of 86% of trials. The disagreements between the observers were randomly distributed with respect to the direction of disagreement and condition, Fisher's exact $p = .75$. Thus, there was no indication that either of the observers was biased toward the hypothesized pattern of findings.

Results

Habituation Phase

Infants in the grasp condition had 8 habituation trials on average, and infants in the back-of-hand condition had 9. One infant in the grasp condition and two in the back-of-hand condition reached 14 habituation trials without meeting the habituation criterion. Infants in the back-of-hand condition looked somewhat longer on the final three habituation trials than did infants in the grasp condition, but this difference was not reliable $t(45) = 1.38$, $p = .17$.[5]

Test Phase

As in Study 1, for each infant, the total amount of looking on the three new path trials and the three new toy trials was calculated (see Table 1). Preliminary analyses revealed that the side of the habituation reach, identity of the object touched, and type of test trial given first did not affect infants' looking on the two kinds of test trials. Therefore, the data were collapsed across these dimensions in further analyses. Although the patterns observed at 9 months were evident in the mean scores at 5 months, parametric analyses did not reveal reliable effects. An analysis of variance with condition (grasp versus back-of-hand) and trial type (new toy versus new path) as factors revealed a marginal Condition X Trial type interaction, $F(1, 46) = 3.09$, $p = .09$, and no other effects. Planned comparisons revealed that the tendency for infants in the grasp condition to look longer on new toy trials was not reliable, $t(23) = 1.38$, $p = .18$, and that the tendency for infants in the back-of-hand condition to look longer on new path trials was also not reliable, $t(23) = -1.09$, $p = .29$.

Differences between the two conditions emerged more clearly when individual patterns of responding were examined. Infants were categorized based on whether they had longer looking times scores overall on new toy or new path trials (see Table 2). Seventeen of 24 babies in the grasp condition looked longer on the new toy trials than on new path trials, $p < .05$ by sign test, whereas only 9 of 24 babies did so in the back-of-hand condition, $p = .92$ by sign test. The difference between conditions in the distribution of infants into these two categories was reliable, $\chi^2(\text{df} = 1) = 5.37$, $p < .025$, and a Mann-Whitney test confirmed that infants in the grasp condition showed a larger preference for the new toy event than did infants in the back-of-hand condition, $z = 1.72$, $p < .05$ (one-tailed).

Next, as in Study 1, infants' looking on the last three habituation trials was compared to their looking during new toy and new path test trials. Infants in the grasp condition showed reliable recovery on both new toy trials, $t(23) = 2.49$, $p < .025$ (one-tailed), and new path trials, $t(23) = 1.88$, $p < .05$ (one-tailed). Thus, infants in the grasp condition were attentive to the changes on test trials, but, in contrast to the 9-month-olds in Study 1, they recovered reliably on new path as well as new toy trials. In the back-of-hand condition, infants showed a different pattern. They recovered reliably on new path trials, $t(22) = 2.00$,

$p < .05$ (one-tailed), but did not recover reliably on new toy trials, $t(22) < 1$ (see footnote 5). Thus, although different from the pattern at 9 months, this analysis provides further evidence that 5-month-olds encoded the grasp and back-of-hand events differently.

Analysis of Potential "Spotlighting" Effects

As in Study 1, infants' looking to each of the two toys during test trials was coded in order to evaluate the extent to which grasping hands versus inert hands drew babies' attention to the toys. Two independent coders overlapped for 7 of the infants. Their judgments on the total proportion of looking to each toy were strongly correlated, $r = .94$.

Figure 3 summarizes the results of this coding. For each infant, the difference in the proportion of looking to the location of the hand and toy versus the other toy was calculated. This difference was reliably above 0 for infants in the back-of-hand condition, $t(23) = 2.44$, $p < .05$, and for infants in the grasp condition, $t(22) = 2.74$, $p < .05$. In the back-of-hand condition, 18 of 24 infants looked for longer on average at the toy that was touched by the hand, $p < .05$ by sign test. In the grasp condition, 16 of the 23 infants who could be coded showed this pattern, $p = .09$ by sign test. Thus, if anything, contact with the back of the hand was a slightly more effective spotlight of attention than was the grasp. However, the difference score did not differ reliably between the two groups, $t(45) < 1$. As in Study 1, then, the patterns seen in test cannot be accounted for by spotlighting effects.

Discussion

The findings for 5-month-olds were less clear than those for 9-month-olds. In the grasp condition, the magnitude of infants' preference for the new toy event was not large in comparison to the variability in their looking times. Nevertheless, nonparametric analyses provided evidence that 5-month-old infants responded more strongly to the change in goal object than to the change in path for grasps: in the grasp condition, more babies looked longer overall at the new toy event than would be predicted by chance. In contrast, babies in the back-of-hand condition were randomly distributed with respect to their overall preferences. Where there was evidence for infants' construing grasps as goal-directed, therefore, there was also evidence for their discriminating between the grasp and back-of-hand events. As for 9-month-olds, this pattern was not readily accounted for by spotlighting effects. These results do not indicate an initial general propensity to construe all events in which a person touches an object as goal-directed. Instead, infants seem to distinguish between different behaviors from the beginning.

GENERAL DISCUSSION

A central aspect of reasoning about human action is distinguishing between different kinds of behaviors. The findings of these two studies suggest that by 9 months, and possibly 5 months, babies have the beginnings of this ability. Nine-month-old infants selectively weighted the goal-related properties of an event in which an actor grasped a toy. This finding confirms earlier results (Woodward, 1998) in indicating that by this age, infants understand some actions as goal-directed. In contrast, 9-month-olds did not selectively weight the goal-related properties for a similar event in which the actor contacted the toy with the back of her hand. These are the first findings to indicate that infants under one year of age distinguish between purposeful and apparently non-purposeful behaviors.

Five-month-olds were tested in the second study because prior findings suggested that infants begin to construe grasping as goal-directed at this age. Thus, if infants begin with very general notions of goal-directed action, this should be evident at this age. The findings

for 5-month-olds reflected a similar, though weaker, pattern to that seen at 9 months. Nonparametric analyses indicated that like 9-month-olds, 5-month-olds showed selective weighting of the change in goal object for grasping events. These analyses also indicated that 5-month-olds differentiated between events in which the actor grasped the object and events in which she touched the object with the back of her hand.

At both ages, infants' patterns of looking during the test phase did not result from their attending less to events in which the actor contacted the toy with the back of her hand. Infants watched the events in this condition for the same length of time, on average, as did infants in the grasp condition, and infants showed reliable recovery from habituation for one or both of the test events in each condition. Moreover, analyses of infants' patterns of looking during the test phase confirmed that these effects did not result from the grasping hand being a more effective attentional spotlight than contact with the back of the hand. Although babies attended to the grasp and back-of-hand events in similar ways, they responded differently to changes in the goal related and path related properties of these two kinds of events.

These findings are impressive given the similarity between the grasp and back-of-hand events. In both conditions, babies saw an actor reach in through a side curtain and move her hand to make contact with a toy. The motion of the arm took the same amount of time in each condition, and the final angle of the arm was the same in each condition. Whether the toy was grasped or touched by the back of the hand, the actor's hand hid a similar portion of the toy from view. Despite these similarities, babies encoded the two events differently.

These findings raise several questions about the basis by which infants distinguished between the grasp and back-of-hand events. First, consider why adults would see reaching toward and grasping an object as goal-directed. For one, this action is very familiar to adults, so much so that grasping is used metaphorically to describe goals (e.g., "If I could just get my hands on that"; "It was just beyond my grasp"). Moreover, adults understand that reaching and grasping often play a role in longer sequences of intentional action, for example, obtaining a toy to play with. This knowledge about specific actions aside, reaching and grasping have several features, such as smooth coordinated action, muscle tension, and palm orientation toward an object, that may signal purposefulness for adults. To illustrate, a completely novel action done with smooth coordinated movements might invite the inference that the action was purposeful, even if adult observers were uncertain about the actor's specific goal. Any of these sources of information could have contributed to infants' interpreting the grasp event as goal-directed and might also explain why infants did not interpret the back-of-hand event in this way.

One possibility is that infants' ability to determine whether behaviors are goal-directed rests on their familiarity with particular actions. Grasping is a very common event in infants' environments and is also an action they can themselves perform. Based on these experiences, infants may have learned that grasping is goal-directed. Unlike adults, infants may be limited to understanding as goal-directed only those actions with which they are familiar. In this case, the details of the back-of-hand event could have varied greatly and it would not have mattered for the current findings, since babies would fail to see as goal-directed any actions with which they lack experience. More research is needed to determine the range of actions that infants under one year of age construe as goal-directed. One intriguing possibility is that infants initially do this only for the set of actions that they themselves can perform. This possibility fits with the observation that it is at around 5-6 months that infants begin to construe grasping events as goal-directed.

Another possibility is that infants, like adults, have learned about features of behavior such as muscle tension and palm orientation

that could serve as cues to whether or not an action is goal-directed. These features differed between the grasp and back-of-hand events. In the grasp events the actor moved her hand to articulate on the object, palm down, whereas in the back-of-hand condition she dropped her limp hand onto the toy palm up. If infants used these behavioral cues, then they might also use other behavioral cues to inform their reasoning about action, for example, jerkiness or smoothness of motion, vocal expressions of dismay or success, or the presence or absence of coordinated gaze. Studies with toddlers indicate that by 14 months, infants use such cues to interpret novel actions. For example, in the Carpenter et al. (1998) study, to convey that a behavior was accidental, the actor jerked back slightly after performing it, made a startled facial expression and said "Oops!" Toddlers responded to this cluster of cues appropriately, in that they avoided imitating the apparently accidental behavior. In contrast, when they saw the same novel behavior performed with cues indicating the actor had acted on purpose, for example, with coordinated gaze, smooth motion and vocal expressions of success, toddlers interpreted the behavior as being purposeful (Carpenter et al., 1998; see also Meltzoff, 1995; Tomasello & Barton, 1994).

In its mature form reasoning about the actions of others is not limited to a set of canonical actions or even by a set of behavioral cues. Adults can freely interpret novel actions based on the context. They can draw on other behavioral evidence to interpret novel actions, for example, the other actions that accompany the action or repetition of the same action, to infer that it is goal-directed. To illustrate, if an adult saw someone drop his hand palm up on a teddy bear repeatedly, she might take this repetition as evidence that the action was intentional. If this action were a part of a sequence of actions with a clear goal (for example, wiping a stain from the actor's hand) the interpretation of the action as intentional would be strengthened. We do not know when and whether infants draw on this kind of information in interpreting action. Infants in the current studies seemed not to draw on the cue of repetition: babies saw the back-of-hand event between 6 and 14 times before the test trials began, and yet they did not interpret this event as goal-directed. Further research is needed to test whether additional contextual cues would influence infants' interpretations of novel actions.

The current findings make clear the need for further evidence on infants' understanding of human action. These open questions aside, these findings constrain developmental theories. In recent years, it has been proposed that a core notion of intentionality is present innately, and is "triggered" by certain patterns of motion, for example, self-propelled motion, biological motion or motion with respect to a potential goal (Baron-Cohen, 1997; Gergely et al., 1995; Premack, 1990). According to these accounts, infants would interpret as intentional any motion of this kind. The fact that infants distinguish in their encoding of different kinds of events in which people touch objects argues against these theories. In both the grasp and back-of-hand events, infants saw a person touch an object, and she did so via self-propelled, biological motion directed toward the goal object. Nevertheless, infants distinguished between the grasp and back-of-hand events, construing the former but not the latter as goal-directed. These results suggest that infants draw on knowledge about the specific features of a behavior in determining whether it is goal-directed. The findings of Study 2 suggest that this may be the case from the beginning of infants' ability to construe action as goal-directed.

Thus, infants may begin by acquiring knowledge about specific goal-directed actions via their observations of others, their own actions on objects and their interactions with social partners. This conclusion is consistent with proposals made by several theorists who argue that toddlers' understanding of certain intentional actions, for example pointing, word use, and looking, grows out of the experience of interacting with social partners (Baldwin & Moses, 1996; Butterworth, 1995;

Corkum & Moore, 1998; Moore & Corkum, 1994). The current findings lend support to the conclusion that initial understandings of intentional action are grounded in knowledge about the particulars of action, rather than being general and abstract.

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NOTES

1. The videotapes from four infants, two in the grasp condition and two in the back-of-hand condition, were lost and therefore could not be included in this analysis or in the video codings reported below.
2. In this and the second study, when infants who did not meet the habituation criterion were excluded from the main analyses, the interpretation of the results was unchanged.
3. Ten of these errors involved blocking one of the toys from view during events in which the actor reached to the far side of the stage. This occurred frequently in Study 2 because of a new presenter who had trouble with this event. This error occurred only once in Study 1.
4. The videotape from one infant in the grasp condition was lost and thus could not be included in this analysis or in the video codings reported below.
5. One outlier that was nearly 4 standard deviations from the mean in the back-of-hand condition was removed for this analysis and from subsequent analyses of infants' looking during the habituation phase.

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