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The Animate-Inanimate Distinction in Infancy: Developing Sensitivity to Constraints on Human Actions

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Infants aged 4 and 6 months were presented with events in which a person acted so as to set another person, or an inanimate object, in motion. In one condition, the actor spoke to the person (natural) or inanimate object (unnatural); in the other condition, the actor grasped and manipulated the person (unnatural) or object (natural). Six-month-old infants looked reliably longer at the natural actions than at the unnatural actions. A follow-up experiment revealed that their preference depended on the naturalness of the human actions themselves, not on the features or motions of the person or object that was acted upon. Looking preferences at 4 months were equivocal, consistent with the thesis that sensitivity to the natural actions develops over the first 6 months of age. We discuss these findings in relation to the development of social understanding, social gaze, and visual exploration.

A growing body of research provides evidence that infants become sensitive to distinctions between inanimate objects and persons within the first 6 months of life (for reviews see Johnson, 2000; Poulin-Dubois, 1999; and Spelke, Phillips, & Woodward, 1995). In studies using preferential looking methods, for example, 6-month-old infants apparently represent the successive motions of two inanimate objects as causally related only if the objects come into contact (Ball, 1973; Leslie,

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1988; Oakes & Cohen, 1995), whereas they represent similar motions of two animate agents as causally related without contact (Csibra, Gergely, Biro, Koos, & Brockbank, 1999; Gergely, Nadasdy, Csibra, & Biro, 1995; Woodward, Phillips, & Spelke, 1993). Five-month-old infants also react to changes in the goal of a human reach, whereas they show no such reaction to the motions of inanimate objects (Woodward, 1998, 1999; Woodward, Sommerville, & Guajardo, 2001). When infants observe people and inanimate objects, therefore, they appear to have somewhat different expectations about how the two types of entities should behave.

In addition, young infants have been reported to interact differently with persons and inanimate objects, in ways that are appropriate to the different properties of those entities. For example, infants as young as 2 months tend to greet a person with eye contact, vocalizations, and social gestures, whereas they tend to greet an inanimate object with incipient manipulatory actions such as extending the arm and opening the fingers (Brazelton, Koslowski, & Main, 1974; Ellsworth, Muir, & Hains, 1993; Legerstee, Corter, & Kineapple, 1990; Trevarthen, 1977; but see Frye, Rawling, Moore, & Myers, 1983, and Sylvester-Bradley, 1985, for evidence that these differences are not robust in young infants). Even newborn infants move their hands and fingers differently in response to people versus objects (Ronnqvist & von Hofsten, 1994). These and other findings (e.g., Legerstee, 1992; Stern, 1999) suggest that young infants quickly become sensitive to some differences between persons and inanimate objects when they interact directly with those entities, and that this sensitivity guides appropriately differentiated actions on the two kinds of entities.

This research investigates whether young infants are able to put these two abilities together and make appropriate inferences about the manner in which a person should interact either with another person or with an inanimate object. When infants observe the actions of another person, do they appreciate, on any level, that a person should influence the behavior of inanimate objects through direct manipulation, whereas he or she should interact with other people through social gestures such as smiling and talking? Like the studies described in the first paragraph, the experiments reported here used a preferential looking method. Like the studies described in the second paragraph, the experiments focused on infants' sensitivity to appropriate ways of acting on people versus inanimate objects. In the present studies, however, we do not investigate infants' sensitivity during direct social interaction or object manipulation but their ability to make appropriate inferences about the observed interactions of an adult with another person or object.

We chose first to investigate 6-month-old infants' knowledge of interactions between two humans and between humans and inanimate objects because infants this age are themselves reasonably adept both at interacting socially with other people and at reaching for and manipulating inanimate objects. In these experiments, infants were presented with videotaped events in which an actor turned to face either a person or an inanimate object of similar size and position. In one condition, the actor smiled and talked to the person (natural) or to the inanimate object (unnatural) and then the person–object responded by moving spontaneously back and forth. In the other condition, the actor reached for, grasped, and manipulated the person (unnatural) or inanimate object (natural), which underwent a passive back and forth motion. Looking times to these events were observed and compared to determine whether infants reacted differently to the natural and unnatural actions. We assumed initially that infants would look longer at the unnatural actions if they were sensitive to their unnaturalness. Contrary to this assumption, we found in the first experiment that 6-month-old infants looked reliably longer at the *natural* actions. A subsequent experiment revealed that this preference was indeed a reaction to the naturalness of the interaction, rather than to other properties of the motions or features of the person or object that the actor acted upon. A further experiment provided no evidence for this sensitivity to natural actions at 4 months, when infants' own ability to manipulate objects is less extensive. After presenting these findings, we return to the question of how infants' sensitivity to human actions develops and how it is manifest in their visual exploration.

EXPERIMENT 1

Infants were presented with a series of videotaped events involving a human actor, a second person, and a large ball on a dowel (see Figure 1). First, infants were familiarized on two trials with the person and ball on which the actor would later act: They viewed the stationary person and ball side by side, wearing identical triangular hats decorated with bells. Then infants were habituated to an event in which the actor engaged in one of two actions on an entity that was entirely occluded except for its triangular hat. In one condition (talk), the actor turned to the occluded entity, smiled, and spoke to the entity, whereupon the hat on the occluded entity began to move, causing its bells to bounce and ring. In the other condition (touch), the actor turned to the occluded entity, grasped the hat, and moved the hat back and forth on approximately the same trajectory as in the talk condition, causing a similar bouncing and ringing of the bells. The presence of the hats thus allowed infants clearly to see both the actor's physical contact or lack thereof with the occluded entity and also the entity's response to the actor's behavior without revealing to the infant the identity of the acted upon entity. We reasoned that, having seen during familiarization that the occluded entity could be either a ball or a person, infants might infer the identity of the entity during the habituation sequence.

Following habituation, infants were presented with two test events. In both, the occluder was removed and the person and ball again were fully visible, now standing immediately to the right of the actor. The actor turned to the per-

FIGURE 1 Display showing actor (left), person (center), and ball (right) as they appear on video displays in Experiments 1 through 3.

son–ball immediately to her right and engaged in the same action as before, either smiling and talking or grasping and manipulating the hat. In one test event, the actor directed her behavior to the person, who stood between the actor and the ball and moved in response to the actor's action. In the other test event, the actions were directed to the ball, which stood between the actor and the person and moved (manipulated by an experimenter, off-screen, in the talk condition) in response to the actor's action.

Method

Participants

Thirty-two infants (18 boys and 14 girls) ranging in age from 5 months 12 days to 6 months 12 days (*M* age = 5 months, 26 days) participated. All participants were born of full-term pregnancies, had no known health problems, and lived in or near Ithaca, New York. An additional 9 infants failed to complete the experiment or were eliminated from the sample because of excessive fussiness (6) or errors in the experimental procedure (3).

Displays and Apparatus

Infants sat on a parent's lap, about 70 cm from a 54 × 40 cm video monitor that was surrounded by a curtain extending from floor to ceiling. Additional curtains to either side formed a small room measuring approximately 1.5 m square. These curtains blocked the infant's view of the experimenter and the audio-visual equipment in the larger room. Infants were videotaped throughout the study by a video camera mounted above the monitor and aimed through a hole in the curtain. Looking times were coded live from this video record by two observers who watched the infant over a separate monitor in a different, sound-isolated room. Observers were not informed of the condition or the order of test events for any infant and so were blind to the particular displays at which the infant was looking on each trial. A computer in the same room with the infant, receiving remote input from the observers via push-button connections, signaled the onset and offset of each infant's looking to the experimenter who operated the video display system.

The videotaped displays presented an actor, a second person (hereafter, the person), and an inanimate object (see Figure 1). The actor was a young woman with long brown hair and fair skin, dressed in a dark green shirt. She was filmed from about the waist upward, and her image measured about 30 × 18 cm on the screen. The person was a young woman with short black hair and fair skin, dressed in a light orange shirt. Her image on the screen measured 30 × 16 cm. The inanimate object was a 7 cm blue ball covered with multicolored polka dots mounted on a dowel. The ball was designed to be a clearly inanimate object but also to be visually comparable to the person's face with respect to overall size, shape, and featural complexity in order to reduce the possibility of baseline preferences between it and the person. The image of the ball and dowel on the screen measured 30 × 7 cm. On the heads of the actor and person and on top of the ball were identical cone-shaped hats (colored pink and green with a yellow brim and decorated with polka dots and jingle bells). The hats were tied on with matching blue scarves.

Familiarization displays. Two videotaped familiarization displays presented only the person and the ball in the two locations they would occupy during the test trials, standing fully visible side by side at the center and on the right side of the image without motion. In one display, the person was at the center position and the ball was on the right. In the other display, these two positions were reversed.

Habituation displays—Talk condition. Two videotaped displays presented the actor standing on the left side of the display. The displays differed only in that in one display the ball stood at the center and the person to the right and in the other the person stood at the center and the ball to the right. During habituation, however, only the actor and the hats on the person and ball were visible. The person and the ball were otherwise fully occluded by a 37.5 × 21.7 cm screen positioned in front

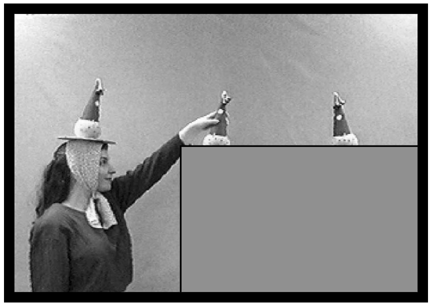
of the video monitor. In both displays, the actor first faced forward, then turned toward the occluded entities, smiled, and spoke to the entity in the center position. The actor spoke for 5.3 sec at about normal speaking volume, saying, "Hello, how are you? What a lovely hat you have. Can you move your hat?" As soon as she stopped speaking, the center entity began to move such that its hat traversed a 7 cm arc, moving left and right at the rate of about 40 cycles/min and jingling the bells on top of the hat. When the person moved, she tilted her head from side to side. When the ball moved, it was tilted back and forth by an off-screen assistant. For these occluded displays, adult observers were unable to determine whether the person or the ball was in motion.

Habituation displays—Touch condition. The two videotaped displays for the touch condition (see Figure 2) were similar to those for the talk condition, with the following exception. In both displays, the actor first faced forward, then turned toward the occluded entities, raised her left arm, and grasped the hat on top of the central entity. This action took 3.4 sec. As soon as it was complete, the actor began to move the hat back and forth such that it traversed a 7 cm arc, moving left and right at the rate of 40 cycles/min and ringing its bells as in the talk condition. In one display, the person was at the center position and her head moved passively from side to side as her hat was moved by the actor. In the other display, the ball was at the center position and it moved passively from side to side as the hat was moved. As in the talk displays, adult observers could not distinguish whether the actor was manipulating the ball's or the person's hat.

Test displays. The two test displays for each condition consisted of the two habituation displays for that condition presented with no occluder, so that the actor, the ball, and the person were fully visible (see Figure 2).

Design

Half the infants were tested in the talk condition and half were tested in the touch condition. All infants first viewed the two familiarization displays for 10 sec each. During habituation, infants were presented in alternation with the action performed on the occluded person or the occluded ball, with half the infants in each condition viewing the action on the occluded person first. Although these events were indistinguishable to adults, each infant was nonetheless exposed to both displays during habituation in order to control for any irrelevant, unintended perceptual differences between them. Following habituation, all infants were tested with the two fully visible and audible test events in which the actor conducted the same action viewed during habituation on the person or the ball. Both gender and test event order were counterbalanced across the two conditions.



Habituation display

Test display: Person

Test display: Ball

FIGURE 2 Habituation and test displays presented to infants in the touch condition in Experiments 1 and 3 (experimental condition). The talk condition sequence was identical except that the actor spoke to the entity rather than manipulating it.

Procedure

Each infant was brought into the laboratory with a parent and was seated in front of the display on the parent's lap. The experimenter tapped on the four corners of the unilluminated video monitor to calibrate the infant's direction of gaze to the display for the online observers. She then withdrew behind the curtains to operate the audio-visual equipment and run the experiment. One stationary familiarization display of the person and ball was presented to the infant until the recording of looking time by the primary observer indicated that the infant had looked at the display for 10 sec. The second stationary familiarization display of the person and ball was presented next, again until the infant had looked for 10 sec. The experimenter then reappeared, positioned the occluder in front of the video display covering the region of the screen where the person and ball had appeared, and withdrew to begin the habituation sequence.

On each habituation trial, the actor appeared on the video monitor to the left of the occluder. She spoke to or manipulated the hat of the central occluded entity and the hat moved back and forth. The experimenter pressed a key to activate the recording of looking time as soon as the person's action was complete. The trial continued, with the hat in motion, for as long as the primary observer judged that the infant was looking at the screen, or for a maximum of 120 sec. When the infant was judged to have looked away for 2 consecutive sec after looking at the monitor for at least 1 sec, the computer signaled with a beep that the trial should end, and the experimenter turned off the video display. About 15 sec later, the experimenter presented the next display, beginning the next trial. Habituation trials continued until the infant's looking time on three successive trials had declined to a criterion of habituation or until 14 trials were presented. The habituation criterion—a decline of 50% in looking time over three consecutive trials, relative to the looking time on the first three consecutive trials for which looking equaled or exceeded 12 sec—was calculated by the computer and signaled by a second beep.

When the habituation criterion was met, the experimenter appeared before the infant, removed the occluder, and disappeared behind the curtain to present the test trials. Infants were presented with two events involving the same action that they had seen throughout habituation. In one event, the actor spoke to or manipulated the hat of the person; in the other event, the actor spoke to or manipulated the hat on the ball. Infants viewed the two events in alternation, for a total of four test trials.[1] Except for the absence of the occluder, the procedure for the test trials was the same as for the habituation trials.

[1]All but one infant in fact completed six test trials. However, the trained observers, who were blind to each infant's condition and test trial order felt that many infants became exceedingly fussy by the last two trials of the relatively lengthy procedure. These infants nonetheless continued to look at the displays as though they found it difficult to disengage visually from the brightly illuminated video monitor. On the basis of the blind observers' comments, the decision was made to discard the last two trials for all infants.

Measures and analyses. Looking times during the habituation and test displays were measured, based on the recordings by the primary observer, beginning at the end of the actor's action (smiling and speaking or reaching and grasping) and continuing until the trial ended. Agreement between the primary and secondary observers, calculated for all 32 infants as the proportion of time the two observers indicated that the infant was or was not looking at the monitor, was high, averaging .95.

On most trials, infants were found to look at the motions attentively for durations varying from about 5 sec to about 60 sec and then to look away. On 10 of the 128 trials, however, infants appeared to become mesmerized by the event and looked with glazed eyes throughout all or most of the 120-sec period. To minimize the effect of these periods of apparently passive looking, all test trials with looking times in excess of 60 sec were truncated, so that only the first 60 sec of looking time was measured.[2]

Habituation data were analyzed through a 2 (condition: talk vs. touch) × 2 (block: first three trials vs. last three trials) mixed design analysis of variance (ANOVA) with the last factor within subjects. In the principal analysis, infants' total looking times to each test event were analyzed by nonparametric statistics to determine whether infants within each condition looked longer at one test event or the other. In addition, we calculated the overall proportion of looking to the actor–person test event for infants in each condition. For this measure, equal looking at the two test displays is represented by a proportion of .5, preferences for the actor–person event are represented by proportions greater than .5, and preferences for the actor–ball test event are represented by proportions less than .5. These proportions were compared across the two conditions through a Wilcoxon-Mann-Whitney z test to determine whether looking patterns differed across the two conditions. Trial-by-trial looking times were analyzed by a 2 (condition: talk vs. touch) × 2 (trial pair: first vs. second presentation of the two test displays) × 2 (test display: person or ball acted upon) mixed design ANOVA with the last two factors within subjects, to determine whether any of these factors influenced the findings revealed by the nonparametric analysis.

Results

Figure 3 (left side and center) presents the mean looking times on the first three and last three habituation trials and on the four test trials, for the infants in each condi-

[2]Like the decision to discard data from the last two test trials, the decision to truncate trials at 60 sec was made in response to the judgments of the blind observers that some infants appeared to become dazed and fixated on the video monitor as if unable to look away. This criterion was then applied across the board for all trials. In fact, 7 of the 10 trials (out of 128 possible) that were truncated occurred on trial types that supported the final outcome of the study. Statistical analyses indicate that looking distributions for all trials were highly skewed, and that truncation at 60 sec reduced skewness measures by approximately 50%. In fact, truncation had little effect on the outcome of the study or on the comparison between Experiments 1 and 2, simply producing a more consistent correspondence between the nonparametric and the parametric analyses.

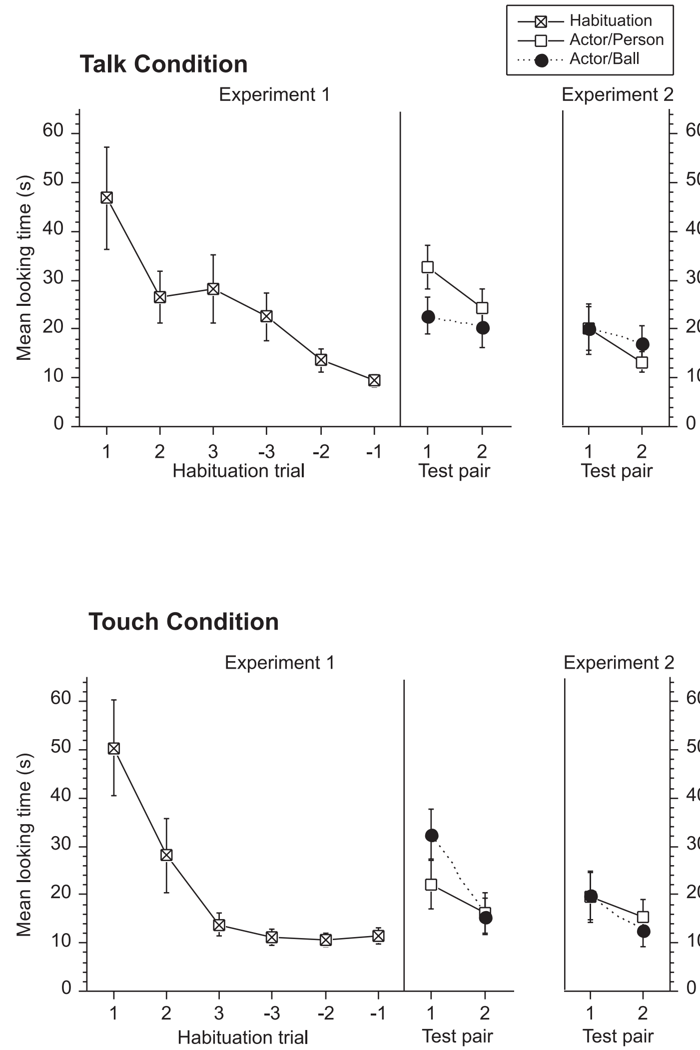


FIGURE 3 Six-month-old infants' mean looking times (s) in the talk and touch conditions on the criterion habituation and test trials in Experiment 1 (left side and center) and test trials in Experiment 2 (right side). Bars indicate standard errors.

tion. As expected, infants' looking time declined over the habituation sequence in both conditions, $F(1, 30) = 30.3$, $p < .0001$. Importantly, neither overall looking nor decrease in looking across trial blocks differed as a function of infants' habituation condition, both Fs < 1, *ns*.

During the test, infants in the talk condition looked longer overall at the event in which the actor talked to the person ($M = 56.88$ sec, $SE = 6.62$) than at the event in which the actor talked to the ball ($M = 43.15$ sec, $SE = 6.58$), Wilcoxon $z = 1.96$, $p < .05$. Infants in the touch condition showed the opposite preference, looking longer at the event in which the actor manipulated the ball ($M = 47.92$ sec, $SE = 7.33$) than at the event in which she manipulated the person ($M = 38.47$ sec, $SE = 7.68$), Wilcoxon $z = 2.27$, $p < .05$ (see Figure 3). Eleven of the 16 infants in the talk condition preferred the actor–person test event, while only three infants in the touch condition demonstrated this preference. A Wilcoxon-Mann-Whitney test comparing the total proportion of looking during test at the actor–person test event revealed that infants in the talk condition spent a greater proportion of time looking at this display than those in the touch condition, Wilcoxon-Mann-Whitney $z = 3.09$, $p = .002$ (Figure 4, far left).

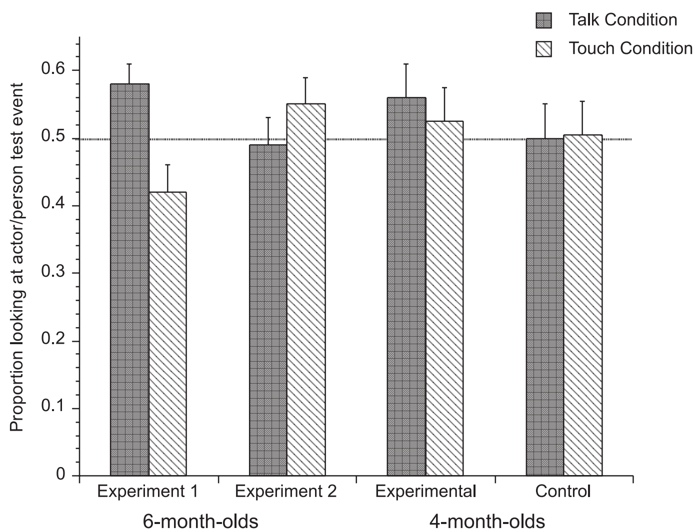


FIGURE 4 Proportion of total looking devoted to the actor/person test display for infants in the talk and touch conditions for all three experiments. Equal looking at the two displays is indicated by a proportion of .5. Bars indicate standard errors.

The ANOVA further confirmed that looking patterns differed in the two conditions, revealing a significant interaction of Condition (talk vs. touch) by Display (action on person vs. action on ball), $F(1, 30) = 5.99$, $p = .02$. Planned comparisons revealed that infants in the talk condition preferred the actor–person display, $t(15) = 2.22$, $p < .05$, whereas infants in the touch condition demonstrated a nonsignificant preference in the opposite direction, $t(15) = -1.32$, $p = .21$ (see Figure 3). The ANOVA also revealed a main effect of trial pair, $F(1, 30) = 8.76$, $p < .01$, indicating that infants' looking times declined from the first to the second test pair.

Discussion

Infants looked longer at a human actor smiling and talking to a person than the same actor interacting in the same fashion with an inanimate object. In contrast, they looked longer at a human actor reaching out and physically manipulating an inanimate object than the same actor interacting in the same fashion with another person. In one respect, these findings confirm the initial hypothesis that infants would be sensitive to the naturalness or unnaturalness of these interactions. In another respect, however, the findings were unexpected. Following the familiarization with the two entities that occupied the area behind the occluding screen, the opportunity existed for infants to infer the entity with which the actor was interacting during the habituation sequence. We thus anticipated that infants, having become habituated to this natural albeit partially occluded event, would then react to the novelty of the unnatural event during test (e.g., Bornstein, 1985; Spelke, 1985; see Baillargeon, 1993, for a review of studies using this method to investigate infants' reasoning about the behavior of inanimate objects). Instead, infants showed the opposite looking preference, focusing their visual attention on the natural actions in which the actor talked to a person or manipulated the ball. What accounts for this finding? At least two potential explanations seem plausible.

First, a review of the research on infants' perception of natural speech as well as social interaction suggests that across the 1st year of life, infants often prefer natural or familiar human verbal and social behavior. For example, 18-month-old infants in English-speaking homes show a reliable preference for grammatical over ungrammatical English (Santelmann & Jusczyk, 1998). Two-month-old infants prefer their native language to a passage in a different language (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988). Finally, 9-month-old infants prefer sentences containing natural phrasal pauses over sentences in which these pauses have been artificially relocated to fall within phrases (Jusczyk, Hirsh-Pasek, Kemler-Nelson, & Kennedy, 1992; see Jusczyk, 1997, for a review). Likewise, infants prefer human social behavior that is appropriately versus inappropriately responsive to the infant (Ellsworth et al., 1993; Murray & Trevarthen, 1985; Nadel, Carchon, Kervella, Marcelli, & Réserbat-Plantey, 1999). Although the nature and timeframe of emergence of this sensitivity is currently a matter of some debate (e.g., Hains & Muir, 1996; Rochat, Neisser, & Marian, 1998; Rochat, Striano, & Blatt, 2002; see Muir & Hains, 1999; Nadel & Tremblay-Leveau, 1999; and Rochat & Striano, 1999, for reviews), it appears to be in place by the age of 4 to 6 months. Both 9- and 12-month-olds sometimes show negative affect when an entity that behaves like a person has the features of an inanimate object (a robot; Poulin-DuBois, LePage, & Ferland, 1996). In all these cases, infants seem to orient primarily to human behavior that is natural, expected, or familiar. These findings raise the possibility that infants will also orient primarily to a human interaction that is natural, expected, or familiar.

A second possibility is that infants' direction of preference was at least in part a function of the complexity of the task or the stimuli, or both. A number of researchers (e.g., Cohen & Marks, 2002; Hunter, Ames, & Koopman, 1983; Hunter, Ross, & Ames, 1982; Roder, Bushnell, & Sasseville, 2000; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982; Schilling, 2000; see Hunter & Ames, 1988, for a review) have demonstrated that when infants have had insufficient opportunity to encode the information available in the experimental stimuli, they prefer these familiar stimuli during test. Likewise, infants are more likely to prefer familiar stimuli when the stimuli or the task are complex (Hunter, Ames, & Koopman, 1983). These findings seem especially applicable to Experiment 1. First, social stimuli are inherently quite complex. As most social stimuli do, the displays in Experiment 1 presented both a complex array of perceptual features (multiple sounds, colors, objects, and patterns of motion) and also a rich array of communicative information conveyed in the actor's gestures, gaze, tone of voice, and facial expression. Second, because an essential portion of the display (the identity of the actor's communicative partner) was occluded during habituation, infants were prevented from processing information contained within that area. Infants' familiarity preference may thus have reflected their desire to continue processing information concerning a familiar but not yet fully encoded complex display. Indeed, such considerations may at least partially explain infants' more general tendency to demonstrate familiarity preferences to social or communicative stimuli, or both, in the research described earlier.

Taken together, these findings cast doubt on our initial assumption that infants would react with longer looking at unnatural or unfamiliar human actions and they accord with our finding that infants show the reverse preference. But were the infants in Experiment 1 really responding to the naturalness or familiarity of the actions they witnessed, or did they respond to other features of the displays?

Because of the design of Experiment 1, many potential alternative sources of infants' looking preferences can be eliminated. First, the findings cannot be explained by a general preference for certain actions over others (e.g., smiling over reaching), or by a general preference for interactions with certain entities over other entities (e.g., interactions with people over balls). In Experiment 1, infants showed no general preference for either action or entity, but rather an interaction

between these factors: They preferred to watch the actor smile and talk to a person, or reach for and manipulate a ball. Second, the findings cannot be explained by a preference for certain kinds of motions or visual configurations, because these were equated across the four test events. All the test events presented the same three agents, with the person or ball in the center undergoing the same patterns of motion. Infants' looking time depended, therefore, on the nature of the actor's action in relation to the nature of the entity she acted on. Finally, because all the infants in each condition actually viewed *both* test displays presented behind the occluding screen during habituation, the findings cannot be explained by unintended (and, to adults, imperceptible) differences between the motion of the actor, the motion of the hats, or the sound of the habituation displays and the subsequently preferred test displays.

One possible influence on infants' looking patterns that we cannot entirely rule out is that of potential baseline preferences for one or two of the test displays. For example, infants may have begun the study with a preference for the "hat-on-person-wiggling" display (i.e., the actor–person display) based solely on the perceptual features of the display. In this case, infants' preference for this display in the Talk condition would simply reflect a baseline preference and only the preference for the "hat-on-ball-wiggling" display (i.e., the actor–ball display) in the Touch condition would represent a conceptual preference for human interaction with inanimate objects through direct contact. If baseline preferences are influencing infants' looking durations, then the obtained looking patterns may only reflect conceptual understanding of one type of interaction (or possibly neither, in the worst case scenario that preferences in both conditions actually reflect baseline preferences for these two specific test displays). We consider this possibility, however, to be unlikely. The test displays were deliberately designed to be as visually similar as possible across conditions. Indeed, the four displays differed exclusively with respect to whether the actor caused the outcome motion by speaking or by manipulating and whether the person or the ball (designed to be as visually interesting and complex as the person) was the recipient of the actor's attention. Because infants' looking during habituation did not differ across conditions, infants apparently had no preference for the behavior of speaking to or manipulation of the hat on the part of the actor. To preview the results of Experiment 2, this study demonstrates that infants also showed no preference for the motion of the person or the ball in either condition. Therefore, any purely perceptually driven baseline preference would have to result from a complex interaction between the actor's behavior, the motion of the recipient, and the identity of the recipient. Although conceivable, it is difficult to identify specific perceptual features of the displays that might give rise to such a preference.

There is, however, one potential alternative interpretation of the present findings that cannot be ruled out through the data available in Experiment 1. Although all four test displays were designed to involve the same motions of the same entities filmed in the same positions, we cannot exclude the possibility that the portion of the events that infants viewed for the first time during test differed in some subtle fashion that influenced infants' looking. It is possible, for example, that movement of the person was different when she turned her head actively versus passively or that the manner in which the actor moved the ball differed from that of the unseen assistant. If these differences influenced infants' looking time, then they may have produced the apparent preference for natural actions observed in Experiment 1. Experiment 2 tested this possibility.

EXPERIMENT 2

The 6-month-old infants in Experiment 2 were presented with the same test events as in Experiment 1, except in one respect: Both the actor and the hats on the person and ball were occluded throughout the test event, and infants were presented only with the portion of the event that occurred after the actor had interacted with the person or ball—that is, the portion during which looking was recorded in Experiment 1 (see Figure 5). Therefore, from an adult point of view, neither display depicted any natural or unnatural interaction. On each test trial, infants watched the person and the ball moving and listened to the jingling bells, as in the test events from Experiment 1, in both the talk condition and the touch condition. If the looking patterns in Experiment 1 were caused by subtle differences in the appearance or the motion of the person and ball, then the same looking patterns should have been obtained in Experiment 2. In contrast, if the looking patterns in Experiment 1 reflected a preference for natural human actions over unnatural ones, then no such preference should have been observed in Experiment 2, because the relevant actions were not presented to the infants.

Method

The method was the same as that of Experiment 1, except as noted here.

Participants

Sixteen infants (10 boys, 6 girls) ranging in age from 5 months 18 days to 6 months 17 days (*M* age = 5 months, 28 days) participated in the study.[3] An additional 9 infants were eliminated from the study because of fussiness (3) or experimenter error (6)

[3]The decision to reduce the number of infants was based on the fact that because the procedure was much shorter with no habituation, presentation of all four test displays would in fact equate the total duration of the study as well as providing an efficient use of our limited participant pool in upstate New York. Because each infant viewed all four displays, statistical power was lost only in the ANOVA. All other analyses were conducted on each condition separately.

Displays

The experiment employed the same familiarization displays as Experiment 1. It also employed the same test displays as Experiment 1, presented with a new occluder covering the left side and the top of the screen (Figure 5). With this occluder in position, the infants were able to see both the person and the ball but not the actor or the two hats. Each test event began when the person or ball at the center began to move, at the end of the actor's action.

Design

Each infant was presented with all four test events from Experiment 1. Half the infants first saw the events in which the unseen actor talked to the person and to the ball on four alternating trials, and then saw the events in which the unseen actor grasped and manipulated the unseen hat of the person and the ball on four alternating trials. The remaining infants saw the two types of events in the reverse order. Gender and order of test displays (action on the person first vs. on the ball first) were counterbalanced across conditions.

Procedure. The procedure was identical to that of Experiment 1, except that infants were not presented with the habituation sequence and each infant saw a total of eight rather than four test trials.

Measures and analyses. Interobserver agreement, calculated as in Experiment 1, averaged .94. On 6 of the 128 trials, infants looked for most or all of the 120 sec. To be consistent with Experiment 1, therefore, the decision was made to truncate all trials across the board at 60 sec. The principal nonparametric analyses were identical to that of Experiment 1. The data were further analyzed by a 2 (condition: talk vs. touch) × 2 (trial pair: first vs. second presentation of the two test events) × 2 (test display: person vs. ball acted upon) ANOVA with all 3 factors within subjects. Further nonparametric analyses compared looking preferences as indicated by proportion of looking at the actor–person test display in Experiment 2 to those obtained in Experiment 1.

Results

Figure 3 (right side) presents the mean looking times in Experiment 2. In the talk condition, infants looked slightly longer when the ball moved spontaneously (M = 36.93 sec, SE = 6.83) than when the person moved spontaneously (M = 33.24 sec, SE = 5.36) but this difference was not significant, Wilcoxon $z < 1$. In the touch condition, infants looked slightly longer when the person moved passively (M = 35.05 sec, SE = 6.70) than when the ball moved passively (M = 32.31 sec, SE = 7.55) but this difference also was not significant, Wilcoxon $z < 1$. Six infants in the talk

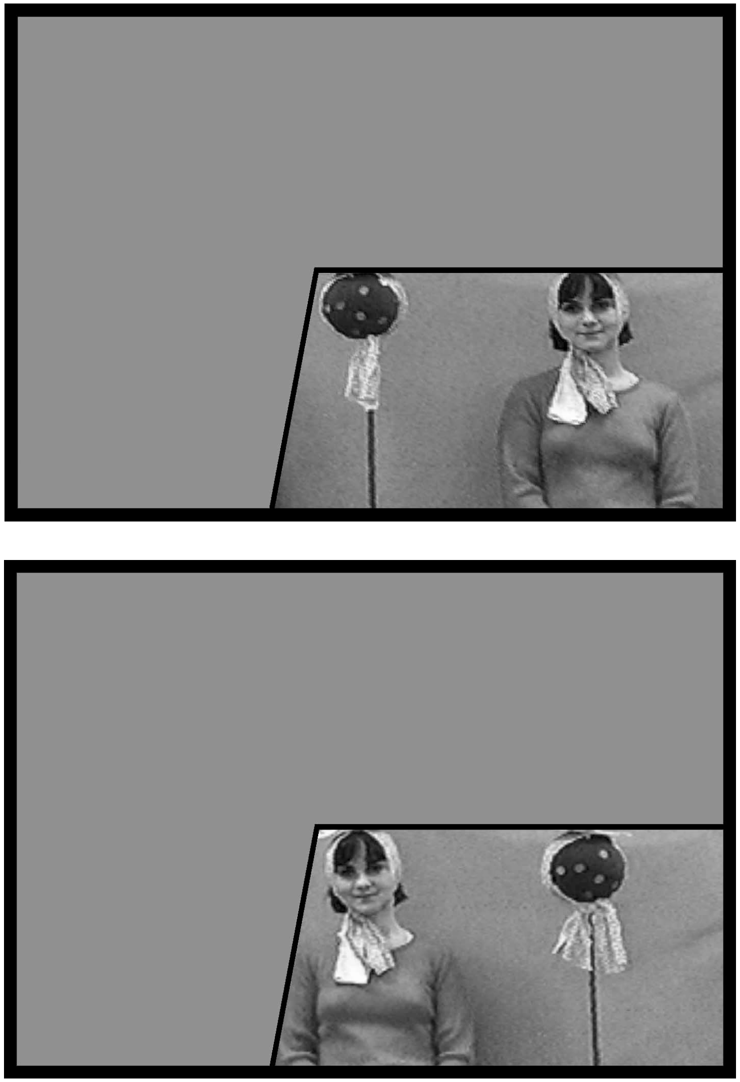


FIGURE 5 Test displays presented to infants in the talk condition in Experiments 2 and 3 (control condition).

condition and 10 infants in the touch condition preferred the test display in which the person moved. Overall, infants across the two conditions did not differ in the proportion of time they spent looking at the actor–person display, Wilcoxon z =1.34, $p > .15$ (see Figure 4). The ANOVA confirmed these findings, revealing only a significant effect of trial pair, $F(1, 15) = 4.97$, $p < .05$, reflecting a decline in looking time across the two pairs for each test sequence. There was no effect of condition and, in particular, no Condition × Test display interaction (all Fs < 1).

Further analyses compared infants' proportion of looking at the actor–person display in the two test conditions of Experiment 2 to those in Experiment 1 (see Figure 4, left side). In the talk condition, the infants in Experiment 1 looked longer when the actor talked to the person, whereas those in Experiment 2 showed a nonsignificant preference in the opposite direction. A Wilcoxon-Mann-Whitney test conducted on the proportion of time infants looked at the actor–person interaction revealed that this difference in looking was significant (Wilcoxon-Mann-Whitney $z = 1.96$, $p = .05$). In the touch condition, infants in Experiment 1 looked longer when the actor manipulated the ball, whereas those in Experiment 2 showed a nonsignificant preference in the opposite direction. This difference too was significant, as revealed by a Wilcoxon-Mann-Whitney test on proportion of looking at the actor–person interaction ($z = 2.49$, $p < .02$). Combining across the two conditions, the proportion of looking at the natural interaction was reliably greater in Experiment 1 ($M = .58$, $SE = .02$) than in Experiment 2 ($M = .47$, $SE = .03$), Wilcoxon-Mann-Whitney $z = 3.13$, $p = .002$.

Discussion

Infants showed no tendency to look longer at the displays in which the person moved actively and the ball moved passively than at the other displays in which the person moved passively and the ball moved actively. Comparing the looking patterns in Experiment 2 to those in Experiment 1 revealed a reliable difference between these experiments. Although infants showed no preferences between the test displays when the actor was occluded and her initial actions were not presented, they showed reliable preferences for the natural events when the entire interaction was visible and audible.

These findings provide evidence against the alternative interpretation offered for Experiment 1. The infants in Experiment 1 evidently did not look longer at the natural actions in Experiment 1 because of subtle, and unintended, differences in the lighting, objects, or motions presented in the portion of the displays that was newly visible to the infants during the test sequence. In Experiment 2, infants saw exactly the same displays as in Experiment 1, minus only the critical actions of the actor and the hats (differences in these were controlled through presentation of both displays during the habituation sequence of Experiment 1), and so any subtle differences in the newly visible portion of the displays should have had the same effect in the two experiments. The reliable differences between the looking preferences in the two experiments, therefore, provide evidence that the infants in Experiment 1 responded to the interactions between the actor and the ball versus the person. Infants looked longer when an actor engaged in the natural actions of talking to a person or manipulating an inanimate object than when she engaged in the unnatural actions of talking to an inanimate object or manipulating a person.

In the next experiments, we attempted to investigate the earlier development of sensitivity to the naturalness of human interactions with other people and with inanimate objects. We turned to studies of younger infants because 6-month-old infants are fairly adept at smiling to people and at reaching for and manipulating objects. It is possible, therefore, that infants of this age have become sensitive to the different constraints on actions on people versus inanimate objects from their own experiences interacting with these entities. Consistent with this hypothesis, Woodward and her colleagues (Sommerville & Woodward, in press; Woodward & Guajardo, 2002) have demonstrated that infants' understanding of the relation between pointing and object pointed at as well as their understanding of the relation between means-end sequences and the goals of those sequences are related to infants' own production of these behaviors. At 4 months, infants are adept at smiling to people but they are just beginning to reach for and manipulate objects effectively. If sensitivity to the appropriate actions of others develops through experience with one's own actions, then 4 months may be a transitional age for this development.

EXPERIMENT 3

Experiment 3 replicated Experiments 1 and 2 with 4-month-old infants.

Method

The method was the same as Experiments 1 and 2, except as follows.

Participants

Thirty-two infants (16 boys, 16 girls) ranging in age from 3 months 19 days to 4 months 16 days (*M* age = 3 months, 27 days) participated in the experimental condition. Twenty-eight of the infants lived in the environs of Ithaca, New York; the remaining infants lived in the vicinity of Boston, Massachusetts. An additional 15 infants were eliminated from the sample because of fussiness (11) or experimenter error (4). Participants in the control condition were 24 infants (8 boys, 16 girls) ranging in age from 3 months 15 days to 4 months 19 days (*M* age = 3 months, 26 days), from the Ithaca, New York, area (12) and the greater Boston, Massachusetts, area (12). Twenty additional infants were eliminated from the control condition because of fussiness (13) or experimenter error (7).

Displays and Apparatus

These were the same as in Experiments 1 and 2.

Design and Procedure

Infants were randomly assigned to either the experimental or the control condition. The design and procedure were identical to those of Experiment 1 for the experimental condition except that only four test trials were presented. For the control condition, eight infants were tested in both conditions (four in each order) for a total of four trials per condition. Because many of the infants became fussy at some point during the second set of four test trials, an additional eight infants were tested in the talk condition only and eight were tested in the touch condition only.

Measures and Analyses

Interobserver agreement, calculated as in Experiment 1, averaged .95 in the experimental condition and .96 in the control condition. Inspection of the data and videotapes indicated that looking times were longer, on average, at 4 months of age than at 6 months of age. Although infants looked longer than 60 sec on a large number of trials ($n = 37$), most did not appear to involve glazed or "blank" looking according to the observers who coded looking and who were blind to the infants' condition. Consequently, looking times were not truncated at this age and so varied from 1 sec to 120 sec per trial.[4]

The analyses for Experiment 3 were identical to those for Experiments 1 and 2. In addition, we compared looking preferences between the older infants in Experiment 1 and the younger infants in Experiment 2 through Wilcoxon-Mann-Whitney z tests on the proportion of time infants in each experimental condition spent looking at the actor–person test display.

Results

Figure 6 (left side and center) presents the mean looking times on the first three and the last three habituation trials and on the test trials of Experiment 3 for the infants in the experimental condition. As expected, infants' looking time declined over the habituation sequence, $F(1, 30) = 46.4$, $p < .0001$. Neither overall looking nor decrease in looking across trial blocks differed as a function of habituation condition, both Fs < 1, *ns*. During test, the infants in the talk condition looked somewhat lon-

[4]In fact, it made no difference to the results whether the trials were truncated or not.

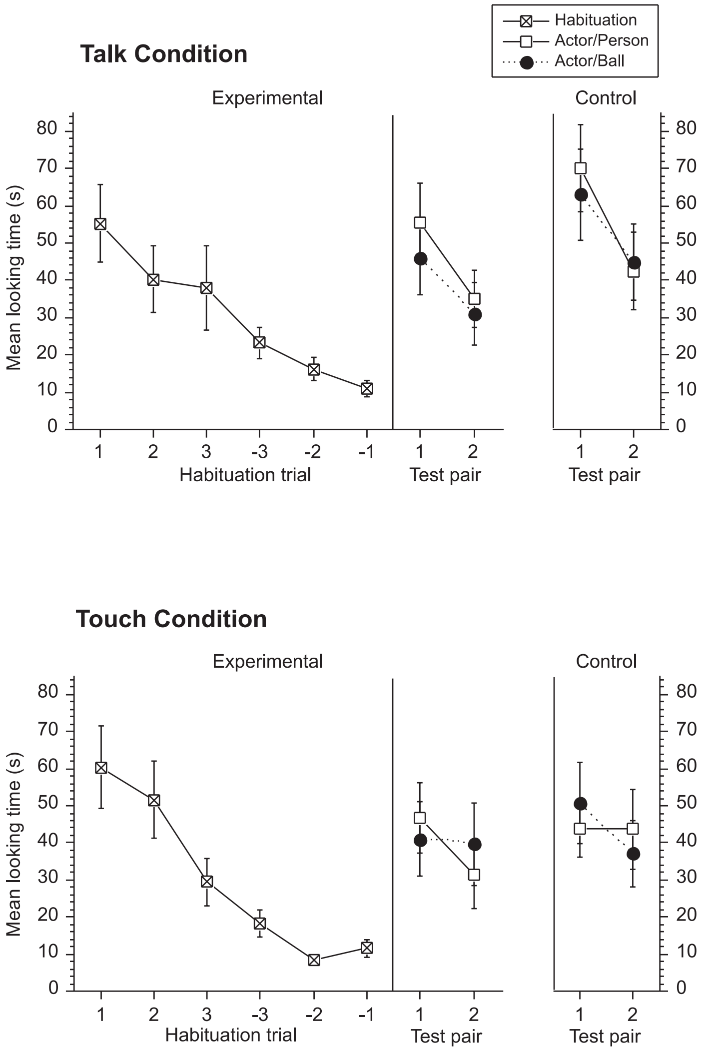


FIGURE 6 Four-month-old infants' mean looking times (sec) in the talk and touch conditions on the criterion habituation and test trials in Experiment 3 in the experimental condition (left side and center) and control condition (right side). Bars indicate standard errors.

ger when the actor smiled and talked to a person ($M = 90.70$ sec, $SE = 12.25$) than when she smiled and talked to a ball ($M = 77.19$ sec, $SE = 14.13$) but this tendency was not significant, Wilcoxon $z = 1.24$, $p > .10$. The infants in the touch condition showed inconsistent looking preferences (Wilcoxon $z < 1$), with longer looking when the actor manipulated the person on the first pair of trials and longer looking when she manipulated the ball on the second pair of trials (see Figure 6). Nine infants in the talk condition and eight infants in the touch condition preferred the actor–person test event. Overall, infants showed no tendency to look longer at the natural event, Wilcoxon $z < 1$. The ANOVA revealed only a main effect of trial pair, $F(1, 30) = 5.20$, $p < .05$: Looking time declined from the first to the second test pair. Infants showed no differential preference for the test displays as a function of experimental condition, $F < 1$, *ns*.

Figure 6 (right side) presents the mean test trial looking times for the infants in the control condition. Infants showed no preference between the events in which the person versus the ball moved, either in the talk condition (Wilcoxon $z < 1$) or in the touch condition (Wilcoxon $z < 1$). Eight infants in the talk control and six infants in the touch control preferred the display in which the person was seen moving. The ANOVA revealed only a marginally significant effect of trial pair, $F(1, 30) = 3.84$, $p < .06$, reflecting the decline in looking time over the test sequence. Comparisons of the test trial looking preferences in the experimental versus control conditions revealed no differences in proportion of time looking at the actor–person display either for the talk events or for the touch events, each Wilcoxon-Mann-Whitney $z < 1$ (see Figure 4, right side).

Further analyses compared the looking preferences of the 4-month-old infants in the experimental conditions to those of the 6-month-old infants in Experiment 1 (see Figure 4). In the talk condition, infants at both ages preferred the event in which the actor smiled and talked to the person and the proportion of looking at this event did not differ across the two ages, Wilcoxon-Mann-Whitney $z < 1$. In the touch condition, although the older infants appeared to spend a smaller proportion of time looking at the actor–person test display while the younger infants showed no preferences between these two events, these looking patterns did not differ reliably, Wilcoxon-Mann-Whitney $z = 1.62$, $p = .11$. Combining across conditions, the proportion of time infants at the two ages spent looking at the natural event (4 months $M = .52$, $SE = .03$; 6 months $M = .58$, $SE = .02$) did not differ, Wilcoxon-Mann-Whitney $z = 1.21$, $p > .2$.

Discussion

When 4-month-old infants watched an actor smile and talk, they looked no longer when the object of these actions was a person (natural) than when it was an inanimate object (unnatural). When the infants watched an actor reach, grasp, and manipulate something, moreover, they looked no longer when the object of these actions was an inanimate object (natural) than when it was a person (unnatural). These findings provide no evidence that infants at this age are sensitive to the naturalness or unnaturalness of the interaction between the actor and the person or ball.

The findings of Experiment 3 are consistent with the hypothesis that infants' developing sensitivity to the appropriateness of human interactions with other persons versus objects depends on their own experiences interacting with persons and objects (Sommerville & Woodward, in press; Woodward & Guajardo, 2002). At 4 months, infants have little experience reaching for, grasping, and manipulating objects, and they showed little preference for a natural event in which those actions are performed by another person. In contrast, 4-month-old infants have more experience interacting with people and they showed a trend (albeit insignificant) to preferring the natural actor–person interaction.

The younger infants may, however, have failed to demonstrate clear sensitivity to the naturalness of the displays for other reasons. Our efforts to equate the visual interest of the displays by employing identical hats and a round ball with spots that might resemble eyes may have made it more difficult for younger infants to identify the person as animate and/or the ball as inanimate. The younger infants may also have been overwhelmed by the novelty of a fully visible screen for both test displays, thus obscuring clear preferences for the familiar displays. Whatever the ultimate explanation of infants' failure in Experiment 3, the present findings support no strong developmental conclusions, because the looking preferences of the 4-month-old infants did not differ reliably either from chance or from the looking preferences of the 6-month-old infants. We cannot say, therefore, whether their responses were qualitatively different from, or simply more variable than, those of the older infants. These contrasting possibilities invite further research probing developmental changes in reactions to natural and unnatural human actions.

GENERAL DISCUSSION

These experiments provide evidence that 6-month-old infants are sensitive to the naturalness of certain kinds of human interactions with animate and inanimate objects: They appreciate, on some level, that smiling and talking are more naturally directed to another person, whereas grasping and manipulating are more naturally directed to an inanimate object. In one sense, these findings are not surprising in light of the findings of previous research. Previous studies, reviewed in the introduction, already provided evidence that young infants themselves are more apt to smile and coo at a person and to grasp and manipulate an inanimate object. Moreover, previous studies provided evidence that 6-month-old infants distinguish animate from inanimate objects, applying a notion of contact to inanimate object motions and applying a notion of goal-directedness to animate motions. These studies

indicate that infants can put these abilities together and make sense of the actions of people whom they observe without social interaction.

These findings allow us to go beyond the conclusions afforded by previous studies in a further respect. In previous studies of infants' differential actions on animate versus inanimate objects, a major outstanding question concerned infants' understanding of their own actions and of the objects on which they acted (see Rochat, 1999, and Spelke et al., 1995, for discussion). Young infants may smile preferentially at other people, for example, because they conceptualize those people as animate, socially responsive objects, and they understand that their own action of smiling will be an effective elicitor of a social response. Alternatively, it is possible that young infants' smiling to people is a more reflexive action, triggered by faces or other social stimuli, and guided by no such understanding (see Rochat, 1999, for different views of infants' social-cognitive abilities).

Accounts of infants' own social behavior in terms of a set of reflex-like responses to triggering social stimuli are not, in themselves, implausible. Even if young infants lacked any understanding of other people as animate beings and social partners, it is likely that they will have evolved tendencies to act in ways that will attract their caregivers and ensure proper care. Actions such as smiling in the presence of a face stimulus could well be of adaptive significance to an infant and therefore could have evolved in the absence of any understanding of the person to whom the smile is directed.

In these studies, however, we focused not on infants' own actions toward other people and objects but on infants' reactions to the actions of another person. We found that 6-month-old infants react differently to an actor's natural interactions in which they themselves would be inclined to engage (smiling at a person, manipulating an inanimate object) than to an actor's unnatural actions in which they would not tend to engage (smiling at an inanimate object, manipulating a person). This finding suggests, in turn, that the knowledge that guides infants' own actions is also accessible to guide their interpretation of the actions of others, at least by 6 months of age. These studies therefore bring us a step closer to the conclusion that 6-month-old infants make meaningful distinctions between animate and inanimate objects, and that these distinctions guide their evaluations of the interactions that are appropriate for entities in each category. Indeed, this sensitivity to the naturalness of human interaction with other humans and with inanimate objects may provide part of the foundation on which joint attention skills and other social-cognitive skills are beginning to develop between 6 and 12 months (e.g., Butterworth & Grover, 1988; Phillips, Wellman, & Spelke, 2002; Scaife & Bruner, 1975).

These findings also shed light on infants' understanding of the animate-inanimate distinction in a different way. Although a growing body of research using preferential looking methods now provides evidence that infants respond differently to animate versus inanimate entities, a major outstanding question concerns the basis of these different responses (see Poulin-Dubois, 1999; Rakison &

Poulin-Dubois, 2001; Spelke et al., 1995, for discussion). On one interpretation, infants conceptualize objects as animate versus inanimate, and they reason differently about the behavior of objects in the two categories. In particular, infants may view animate objects as generating their own motion in accord with internally derived goals and free from the constraints of contact mechanics. In contrast, infants may view inanimate objects as lacking any capacity for self-generated, goal-directed action and as determined in their motions by contact relations to other objects.

Existing preferential looking studies do not, however, demand these interpretations. In particular, infants may lack any conceptualization of the animate–inanimate distinction, and their expectations about the behavior of animate and inanimate objects may depend only on certain learned correlations between different object features (see Jones & Smith, 1993, for general discussion). For example, infants may learn that one local feature of certain objects (e.g., "has eyes") tends to accompany other local features (e.g., "makes noise," "moves around spontaneously") (see Rakison & Poulin-Dubois, 2002, for evidence that, by 14 months but not by 10 months, infants can construct such associations). Such local cue learning could account for infants' appropriate responses to goal-directed actions of a hand (see Woodward, 1998) and to causal relations among inanimate or animate objects (see Oakes & Cohen, 1995; Spelke et al., 1995).

Although it is very difficult to decide conclusively between conceptual interpretations and perceptual-cue learning interpretations of infants' reactions to animate and inanimate objects, the present experiments increase the plausibility of the conceptual interpretation, at least for 6-month-old infants. In contrast to previous research, the present studies did not focus directly on infants' expectations about the motions of animate or inanimate objects. Rather, they focused on infants' expectations about the actions that a third party—the actor in the videotaped events—should perform on an animate or inanimate object. First-order associative learning about the different cues that co-occur within a particular object is not sufficient to account for such expectations. Either infants' reactions depend on a conceptual distinction between animate or inanimate objects, or they depend on more elaborated, higher order associations that capture the relations between the features that identify entities as human, the features that identify entities as inanimate, and the features of appropriate interactions among these entities. Those theorists who would root our conceptual understanding in associative learning would argue, however, that such higher order associations are the essence of human understanding (see, e. g., Smith, 1999). On either the associative or the conceptual view, therefore, the present findings bring us a step closer to the conclusion that 6-month-old infants share part of the adult's conceptual distinction between persons, on one hand, and inanimate objects, on the other.

Unfortunately, these findings support no conclusions about the earlier development of the animate–inanimate distinction. It is possible that a conceptual distinction between persons and inanimate objects develops around 6 months of age, perhaps as a result of infants' experiences manipulating objects, interacting with people, and observing the actions of others. Alternatively, it is possible that this distinction develops earlier but is not manifest in studies using the present displays or methods. As we noted, infants younger than 4 months may fail to perceive people and their actions appropriately in videotaped displays, they may fail to exhibit any looking preference for natural human actions, or they may exhibit this preference with high variability. Further research with different displays or a different method is needed to test these possibilities and chart the development of infants' understanding of the appropriateness of different actions on persons and inanimate objects.

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