Social Cognition and Social Responsiveness in 10-month-old Infants

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In this study, we investigated relations between infants' understanding of intentional actions and measures of social responsiveness during a transitional period, 9- to 11-months. Infants ($N = 52$) were tested in visual habituation paradigms tapping their understanding of the relation between a person and the object of her attention. Measures of social responsiveness included orienting to the target of another's attention, point production, and supported joint attention in parent–child play. Infants' responses to the habituation events were related to their social responsiveness. Distinct factors for understanding actions and social responsiveness as relational were revealed. Infants who produced object-directed points were more likely to understand pointing as relational, and infants who engaged in high amounts of shared attention were more likely to understand gaze. Infants' tendency to orient in response to an adult's gaze shifts and points was unrelated to their understanding of gaze and pointing. These findings elucidate the ways in which social cognition and social responsiveness, although distinct, are related in development.

Between 9 and 12 months of age, infants begin to participate in increasingly rich triadic interactions. During this period, the shift in complexity of infants' social behavior is so dramatic that Tomasello (1995) dubbed it the "social-cognitive revolution". This term implies that changes in infants' social responsiveness are accompanied by changes in their understanding of others' actions. Although this assumption provides the foundation for many theories of social-cognitive development, until now it has not been empirically tested. Tomasello and colleagues (Tomasello, Carpenter, Call, Behne, & Moll, 2005, pp. 689) highlighted the need

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for this research when they recently wrote, "There has been almost no research— not even training studies or correlational studies—that establishes a solid relationship between any kind of particular social experience infants might have and individual differences in the unfolding of [intentional action knowledge]." We began to fill this gap by seeking clearer evidence concerning the relation between social responsiveness and intentional action knowledge during infancy.

By social responsiveness, we mean the initiation of behaviors that are shaped in response to the actions of another person and fulfill a social function. Similar behaviors might be a demonstration of social responsiveness in one context and not in another, depending on the functions they serve. To illustrate, consider two examples of gaze behavior, gazing at a social partner's face to establish joint attention and gazing at a passerby on the street. The first is socially responsive behavior, whereas the second may not be.

Human infants are socially responsive from early infancy in their dyadic interactions with caretakers (Hains & Muir, 1996; Jaffe, Beatrice, Stanley, Crown, & Jasnow, 2001; Tronick, 1989). For example, in the first few months of life, infants' rate of smiling declines when their mothers look away from them (Hains & Muir). Toward the end of the first year of life, infants begin to incorporate outside entities, such as objects or events, in their interactions with others. These triadic interactions (i.e., between infant, other, object) often involve sharing attention on objects during play (Bakeman & Adamson, 1984). During these interactions, infants follow adults' gaze (Butterworth & Grover, 1990; Carpenter, Nagell, & Tomasello, 1998; Moore & Corkum, 1998; Scaife & Bruner, 1975), spend increasingly long bouts engaged in shared attention with adults (Bakeman & Adamson), and produce communicative gestures, such as showing or pointing, which may function to direct adults' attention (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Carpenter et al., 1998; Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004) or to elicit responses from adults (see Corkum & Moore, 1995).

The marked developments in triadic behaviors between 9 and 12 months have been used to support the argument that intentional understanding first appears during this time period. In fact, infants' emerging social responsiveness in triadic interactions provides a foundation for several current theories of social-cognitive development. To start, these behaviors have been taken as evidence that infants understand others' intentions (Bretherton, 1991; Carpenter et al., 1998; Tomasello, 1999). For example, Tomasello (1999) proposed that "different joint attentional behaviors in which infants follow, direct, or share adult attention and behavior are not separate activities or cognitive domains; they are simply different behavioral manifestations of this same underlying understanding of other persons as intentional agents" (p. 64). This assumption stems from rich interpretations of the social function of behaviors, for example, assuming that infants alternate gaze to assess the adult's focus of attention (for alternative interpretations, see Baldwin & Moses, 1996; Corkum & Moore, 1995).

Furthermore, infants' engagement in triadic interactions has been hypothesized to play a formative role in the development of intentional understanding. For example, Moore and colleagues (Barresi & Moore, 1996; Corkum & Moore, 1995, 1998; Moore & Corkum, 1994) suggested that infants' social responsiveness sets the conditions for the discovery of others' intentions. Through engagement in joint attention episodes, they proposed, infants align their own states of attention with the observable actions of others, thereby coming to understand others' inner states. Infants initially create merged representations of their own and others' intentional states during triadic interactions, and, in later development, they come to differentiate their own intentions from those of others (for similar proposals, see Carpendale & Lewis, 2004; Tomasello, 1999).

These accounts are noteworthy because they take seriously the role of environmental structure and conceptual learning in infant social cognition, thereby offering an alternative to strongly nativist accounts. However, empirical investigation of these proposals has been restricted by a reliance on infants' social responsiveness as the chief source of evidence for their underlying social cognition. When infants follow others' gaze shifts, point to objects, and engage in shared attention, the argument goes, their actions directly reflect underlying conceptions of others' intentions and attention. However, these behaviors are open to more than one interpretation, and their status as evidence of underlying social cognition has been hotly debated. To illustrate, Moore and his colleagues (Barresi & Moore; Corkum & Moore, 1996) suggested that infants' propensity to follow gaze could be the result of low-level orienting responses or perhaps operant reinforcement, and, therefore, may not reflect knowledge about others' attention. Similarly, Baldwin and Moses (1996) suggested that infants' tendency to look toward a parent's face when confronted with an ambiguous situation might reflect comfort seeking, rather than attempts to monitor the parent's focus of attention.

Infants' overt attempts to direct others' attention via pointing and other communicative gestures seem to provide clearer evidence that infants understand others' states of attention (Liszkowski et al., 2004). These behaviors have also been subject to lean as well as rich interpretations. Infants begin to produce points directed at objects as early as 9 months of age in some cases (Bates et al., 1979; Bates, Camaioni, & Volterra, 1975; Carpenter et al., 1998; Trevarthen, 1977). However, the function of these early points may be to mark infants' own focus of attention (Kaye, 1982; Werner & Kaplan, 1963), rather than to direct another person's attention. After 12 months of age, infants accompany points with gaze alternation between the onlooker and the object (Bates et al., 1979; Carpenter et al., 1998). Moreover, infants initiate shared attention by alternating their gaze between a person and an object (i.e., engaging in coordinated joint attention) beginning at around 12 months of age (Bakeman & Adamson, 1984; Carpenter et al., 1998). Although these more complex actions are often taken as evidence for infants' understanding of others' attention, several researchers have argued that they may reflect

something less sophisticated. For example, Moore (Moore & Corkum, 1994; Moore & D'Entremont, 2001) suggested that infants turn to the adult after pointing because they anticipate the adult's response, rather than out of a desire to monitor the adult's attention (but see Liszkowski et al., 2004).

Research with other populations highlights the problems of inferring social cognition from well-organized social responses. For instance, similar debates have arisen in the domain of animal cognition. Although some nonhuman primates follow gaze and anticipate others' actions, it is not clear that they possess rich or abstract conceptions of intention or attention (Call, Hare, Carpenter, & Tomasello, 2004; Povinelli, 2001; Povinelli & Eddy, 1996; Tomasello, Call, & Hare, 2003; Whiten, 1994). In some human populations, the relation between social responses and social cognition is also unclear. For example, individuals with autism, characterized by deficits in social responsiveness, can learn to produce social responses to particular cues (Klin, Schultz, & Cohen, 2000). Unfortunately, this learning does not generalize well to an understanding of others' behavior in novel situations (Klin et al., 2000). The cooccurrence of deficits in social behavior and social understanding in autism may be unique (e.g., Mundy, 2003; Travis, Sigman, & Ruskin, 2001). However, even typical adults' social responses, like gaze following, do not always reflect underlying attributions of attention or intention (Driver et al., 1999; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002).

A second problem is that reliance on social responsiveness as evidence for social cognition contributes to a circular argument in which researchers have proposed that social responsiveness is both an effect of social cognition and a cause of this effect (Barresi & Moore, 1996; Carpenter et al., 1998; Tomasello, 1999). For example, one could argue that infants who produce robust orienting responses may be more likely to "catch" the target of another's attention. Consequently, robust orienters learn to form a relation between a person and the object of her attention, which in turn causes them to orient to the targets more. Although this argument and others like it might be true, they are impossible to test without an independent source of evidence about infants' underlying knowledge of attentional relations. These considerations indicate the need for alternative sources of evidence about infants' social cognition.

Recent studies point to the kind of evidence that could address these problems. Several studies have used visual habituation measures to investigate infants' understanding of intentional action, and, in particular, their appreciation of the invisible relation between a person and the object of his or her attention (Phillips, Wellman, & Spelke, 2002; Sodian & Thoermer, 2004; Woodward, 2003; Woodward & Guajardo, 2002). To illustrate, in one study (Woodward, 2003), infants viewed events like the ones depicted in Figure 1. Infants were habituated to an actor turning to look at one of two toys, a teddy bear and a ball. After infants habituated to this event, the positions of the toys were reversed. Infants then saw alternating trials in which (a) the relation between the actor and the object changed (new
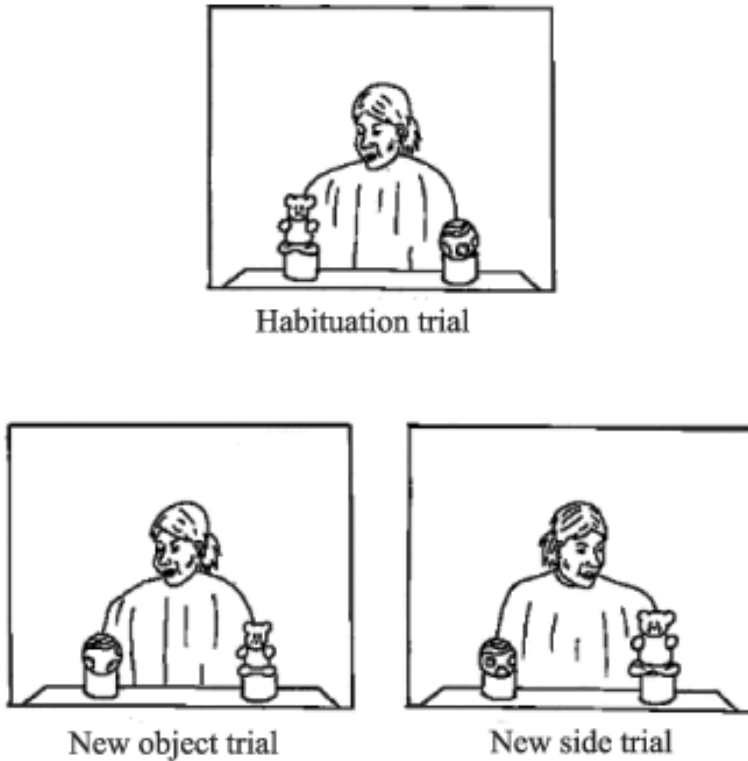
FIGURE 1   Diagram of sample habituation and test trials in Woodward (2003).

object trials) or (b) the actor's direction of motion changed, but her relation to the object did not (new side trials). If infants represented the relation between the actor and the object of her attention during habituation, then they were predicted to look longer at the new object trials than the new side trials because the actor-object relation was disrupted. Infants at 12 months of age, but not 7 or 9 months of age, looked significantly longer at the new object trials than the new side trials, which suggests that they responded to the change in the actor-object relation. Other studies have converged in indicating a transition in infants' understanding of attentional relations between 9 and 12 months of age (Phillips et al., 2002; Sodian & Thoermer, 2004; Woodward & Guajardo, 2002).

In these studies, the behavior that indexes social cognition is not a social response. Looking times in habituation procedures are generally assumed to index information processing and novelty detection. Studies that have employed this method to assess infants' understanding of intentional action report similar

patterns of habituation and dishabituation to those involving inanimate events. Moreover, although the context of the study might be seen as social in some respects because the infant views a person, longer looking times on some test trials versus others serve no obvious social function.

Further evidence that looking times in this kind of habituation procedure are distinct from social responses comes from an analysis of a social response in the context of these studies. In the Woodward (2003) study, infants followed the experimenter's gaze. This social response was distinct from infants' overall looking times on the experimental test events. Infants at each age (7, 9, and 12 months) spent more time looking at the target of the actor's gaze than the other toy, regardless of whether they viewed new object or new side trials. For the younger infants, there was a disassociation between their understanding of the looking relation and their gaze following; they did not encode gaze as relational, yet they followed the actor's gaze. Woodward and Guajardo (2002) reported similar findings for infants' understanding of and responses to pointing events.

These findings suggest that the visual-habituation paradigm can provide an independent measure of infants' understanding of intentional action, thus providing a way to investigate relations between social responsiveness and social cognition. Indeed, an initial investigation has suggested that informative relations exist between infants' social responsiveness and their social cognition. Woodward and Guajardo (2002) found that between 9 and 12 months of age, infants' understanding of pointing as relational (as assessed in the habituation paradigm) was correlated with their own ability to produce object-directed points. Infants who produced object-directed points encoded pointing as relational, but infants who did not yet produce points did not do so. Because the infants who pointed did not differ in age from those who did not yet point, the relation between point production and point comprehension was not accounted for by age.

In this study, we investigated the potential relations between infants' emerging social responsiveness and their emerging social cognition between 9 and 12 months of age. We tested 10-month-old infants to investigate whether and how measures of social responsiveness and social cognition are related during a transitional period, when both social responsiveness and social cognition are undergoing development. Social responsiveness was assessed using four measures: gaze and point following in a naturalistic paradigm, orienting to the target of an actor's attention in the visual-habituation paradigm, parent report and observation of object-directed pointing, and shared attention in parent–child play. Social cognition was assessed using the difference in infants' looking time to the test events in the visual-habituation paradigm as indicative of understanding attentional relations. Infants participated in two visual-habituation sessions to index their understanding of two canonical expressions of attention, looking and pointing. By exploring the concurrent relations across these tasks, our goal was to take an initial step toward discovering developmental relations between social responsiveness and social cognition in infancy.

Testing the same infants in two different habituation paradigms also allowed us to investigate a second issue: the extent to which infants' understanding of attentional relations is uniform across different kinds of actions. Comparing across infants (Sodian, Schoeppner, & Metz, 2004) and across studies (Moore, 1999; Woodward, 2003; Woodward & Guajardo, 2002), we know that infants typically begin to understand both gaze and pointing as relational between 9 and 13 months of age. However, whether understanding one action is associated with understanding the other is currently unknown. We addressed this question by investigating correlations in infants' responses in the gaze and point habituation procedures, as well as by assessing whether responses in these two procedures correlate with the same aspects of social responsiveness.

METHOD

Participants

Fifty-two full-term infants from the Chicago area participated in this study. Participants were recruited from mailings and advertisements. Their parents were offered $10 to reimburse their travel expenses. Infants between 9 and 11 months of age were recruited with a mean age across visits of 10 months 3 days (range 9 months 2 days to 11 months 3 days). On average, visits were 1 week apart ($M = 7.7$ days, range 3 to 14 days). There were 28 boys and 24 girls. Parents identified their infants as White (52%), African-American (15%), Hispanic (19%), Asian (2%), and other (12%). An additional 20 infants began the study but were not included in the final sample because they only participated in one visit ($n = 10$), did not complete a habituation task due to distress ($n = 4$), or because of an experimental error in the procedure ($n = 6$).

Procedure and Measures

Infants visited the lab for two sessions. On each visit, following informed consent procedures, the experimenter interviewed the parent about the infants' point production. Next, infants participated in a series of interactive tasks. We focus on two: parent–child play (Visit 1) and attention following (Visit 2). Then, infants participated in a visual-habituation procedure. Two infants participated in the visual- habituation procedure before the other tasks because of scheduling conflicts. The data for these infants did not differ from the rest of the sample, so they were included in the analyses. The interactive tasks took place in a playroom separate from the habituation procedure.

Coders were unaware of an infant's pattern of responses during the habituation procedure. For all tasks, interobserver reliability was calculated by having a second observer code all infants or a randomly selected group.

Measures of Social Cognition: Understanding Attentional Relations.
Two visual-habituation procedures were used to index infants' comprehension of
the attentional relations of looking and pointing. Infants saw gaze events and point-
ing events on alternate visits. For gaze understanding, infants viewed events in
which a presenter looked at one of two toys (Figure 2). For point understanding, in-
fants viewed a very similar event, in which the presenter both looked at and pointed
to one of the toys (Figure 2). Infants saw the same presenter on each visit. The ha-
bituation procedures were modeled after Woodward (2003) and Woodward and
Guajardo (2002). Each infant was randomly assigned to a condition that included
three factors: (a) visit, which type of events they saw on their first visit (those con-
taining gaze alone or those containing gaze and pointing), (b) type, which type of
event they saw on the first test trial (new object or new side), and (c) goal, which
toy was the target of the actor's action in habituation (ball or teddy bear). In all,
eight conditions were approximately evenly distributed across the sample.

Apparatus.   In the habituation procedure, the infant sat on his or her parent's
lap inside a black curtained booth facing a puppet stage about 24 in. away. The par-
ent was instructed to look down at the infant, rather than at the experimental events,
and not to talk or direct the infant's attention in any way once the screen was low-
ered. The stage floor was a narrow table covered with black cloth. It held two black
3-in. pedestals spaced 13 in. apart, equidistant from the center. A toy was affixed to
the top of each pedestal. On the pedestal to the infant's right sat a white teddy bear
wearing a maroon sweater. The pedestal to the infant's left held a multi-colored
ball. The actor sat behind the stage, so that only her upper body and face were seen;
the lower part of her arms and hands remained on her lap, except during the point-
ing events. She wore a red long-sleeved shirt. A camera protruded from a small
hole in the wall behind the actor to record the infant's patterns of looking. A second
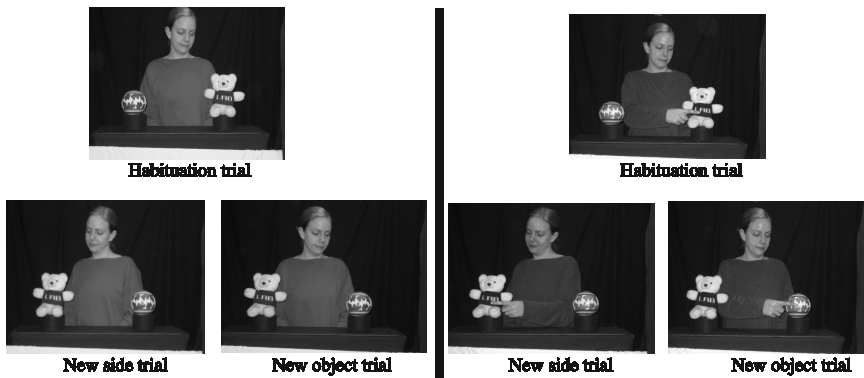

FIGURE 2   Sample habituation and test events.

video camera captured the infant's view of the events. A white muslin screen was raised to hide the stage from the infant's view between trials.

Procedure.   At the start of each trial, the screen was lowered and then the actor made eye contact with the infant and said "Hi". Next, she said, "Look," and turned to look at one of the two toys. For the pointing events, she pointed to the toy, contacting it with her index finger, while she turned to look at it. The actor remained still in this position (i.e., looking at, pointing to the toy) until the end of the trial. The infant's attention to the display was coded once the actor was in this final static pose. The trial ended when the infant looked away from the display for 2 consecutive sec. The habituation criterion was a 50% decrement in attention, on the basis of the sum of the first three habituation trials. When the infant looked less than half of this sum over three consecutive trials, he or she met the criterion. Therefore, every infant saw at least 6 trials. If an infant failed to meet this criterion after 14 trials, the habituation phase was ended, and the infant then continued in the procedure.

Following habituation, one additional trial of the habituation event was presented. This baseline trial provided an unbiased estimate of attention at the end of habituation. Then, before beginning the test trials, the actor reversed the location of the toys while the screen hid the stage from the infant's view. The test events were the exactly the same as those seen in habituation, except that the location of the objects and target object of the actor varied. There were 3 pairs of alternating trials. On new side trials, the actor looked (or looked and pointed) at the same toy as during habituation, turning to a new location to do so. On new object trials, the actor looked (or looked and pointed) toward the other toy, which sat on the same side of the stage that she had previously turned toward.

A trained observer coded the infant's looking behavior on-line via a monitor. An infant was classified as looking at the events when his or her gaze fell within a triangle defined by endpoints at the top of the actor's head and the outer edge of each of the toys. The observer could not see the experimental events and was unaware of the condition assignment of the infant. She used a custom software package (Pinto, 1994) that recorded infant's looking with the press of a button.

Reliability.   Every infant was coded from video by a second observer, who was unaware of the condition assignment. Observers were coded as agreeing if they identified the same look away from the display as ending the trial. The primary and secondary observers agreed on the endings of 95% (range 75–100%) of the test trials for the gaze events, and they agreed on 92% (range 75–100%) for pointing events. Although there were few disagreements, it was possible that the disagreements favored the hypothesis that infants would look longer on new object trials. To test for this possibility, disagreements were categorized as favoring the hypothesis (i.e., beeping late on new object trials, beeping early on new side trials)

or going against the hypothesis. Disagreements did not favor the hypothesis for either the gaze events, $X^2(1, n = 15) = .80$, $p = .37$, or the pointing events, $X^2(1, n = 22) = 1.00$, $p = .99$.[1]

Measures of Social Responsiveness

Point production.   To determine whether an infant produced object-directed points, the experimenter administered a brief interview at each visit. She asked the parent whether the infant produced a well-formed point gesture (index finger extended, other fingers curled back), and if so whether the infant directed this gesture at objects. If the parent answered both questions affirmatively, then the infant was categorized as a pointer. In addition, as in the Woodward and Guajardo (2002) study, if an infant produced a well-formed point that was clearly directed at a distant object during the visit, he or she was categorized as a pointer.

Parent–child play.   To obtain a measure of shared attention, the parent was asked to play with his or her infant, as if they were playing at home, for 10 min, following the procedure developed by Bakeman and Adamson (1984). For all infants, the parent in the play session was the primary caregiver, whether that parent was the mother ($n = 50$) or the father ($n = 2$). The parent and infant were brought into a room containing a basket of toys which were chosen to encourage interaction between them. The dyad sat in the center of the room on the floor near the basket of toys. An experimenter stood silently behind a video camera placed in the corner of the room and observed the session through the viewfinder to ensure that the interaction was captured on film.

Videotapes of the session were digitized and coded with inGest (Aronson, 1999), using coding categories based on those of Bakeman and Adamson (Adamson, Bakeman, Russel, & Deckner, 1998). Two states from the Bakeman and Adamson coding regime were of focal importance to our research questions: supported joint attention and coordinated joint attention. In each of these, the infant and parent actively shared attention on an object. Supported joint attention meant that the infant and parent were jointly engaged, but the work at sustaining this shared attention seemed to be done by the parent. The infant did not acknowledge the parent's attention to the toy. Coordinated joint attention was defined as supported joint attention accompanied by the infant's alternating gaze between the parent and the toy(s), thus suggesting that the infant contributed to sustaining

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[1]To control for the possibility that the actor performed differently across trials, a coder, who was unaware of which condition infants were assigned to, guessed the test trial order by watching a videotape of the actor. A sample of about 20% ($n = 10$) of the sessions for both event types was coded. The coder was correct on 40% and 53% of the pairs for gaze and pointing events, respectively; for the first pair, she was correct 50% and 60%. The coder's accuracy did not differ significantly from chance, $t(9) = -1.20$, $p = .26$, and, $t(9) = .25$, $p = .81$, respectively; first pair, $t(9) = 0$, $p = .99$ and $t(9) = .61$, $p = .56$.

shared attention. Because the goal of the coding scheme is to capture the infants' sustained states of attention, each state was coded only for bouts that lasted 3 sec or more.

Two measures were derived from this coding. The first, a dichotomous measure, was whether or not infants engaged in coordinated joint attention. The second, a continuous measure, was the proportion of time which the infant spent in either supported or coordinated joint attention. These two categories were combined (henceforth, called shared attention) because each reflected a time when the infant and parent shared a common focus of attention and because, given the age of the participants, coordinated joint attention was infrequent. Most infants ($n = 38$) did not meet the criteria for coordinated joint attention, and those who did spent an average of only 2% ($SD = 0.5\%$) of the session in this state. In contrast, all infants engaged in supported joint attention and, on average, spent 24% ($SD = 11\%$) of the time in this state.

A second trained observer repeated the coding procedure for approximately 20% of the sessions ($n = 9$). Agreement on the dichotomous measure was 100%. Agreement on the continuous measures, using Cohen's kappa, was .70 (range 0.61-0.84); Fleiss (1981) characterized kappas between .60 and .75 as "good" and above .75 as "excellent".

Attention following.   To assess infants' orienting in a relatively naturalistic interaction, we used the attention-following task developed by Carpenter et al. (1998). The infant sat on his or her parent's lap in a chair across the table from the experimenter. Four targets were positioned in the playroom (see Figure 3). Two targets were pink paper lanterns, which differed in shape, hanging from the ceiling. The remaining two targets were stuffed animals (Bugs Bunny™ and Bob the Builder™), positioned on a chair and tripod, respectively.

The experimenter drew the infant's attention to center by saying, "Hi," and/or the infant's name. Then, while saying, "Look," she turned her head to look toward a target. After 1 sec, she gazed back to the infant, exclaimed, "Wow," or "Neat," and alternated her gaze between the target and the infant once more. After receiving two trials like this, the infant saw the experimenter point to the target (across her body). Each infant received a total of four trials with unique targets: two gaze trials, followed by two pointing trials.

The session was videotaped using a digital camera mounted to a tripod, placed in the back corner of the room. A trained observer watched the videotape of the session and coded whether or not the infant turned to look at the correct target. The observer used the vocal cue of the experimenter (i.e., completion of the word "Look") to determine when each trial began. Infants received a score for the number of targets they followed, 0 to 4. A second coder watched the videotape and coded the task the same way. Thirty-six infants (75% of the sample) were coded for reliability. Average agreement was 85% (range 50–100%).
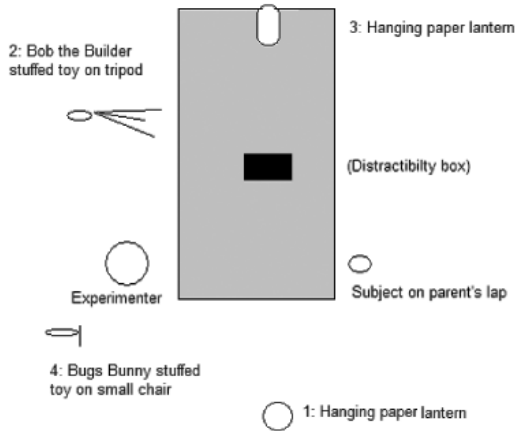
FIGURE 3   Diagram of the order and location of the targets in the attention following task.

Orienting.   As another measure of orienting, the amount of time an infant spent attending to the same target as the actor during the visual-habituation paradigm was coded, as was done in the Woodward (2003) and Woodward and Guajardo (2002) studies. To assess each infant's orienting response to the actor's attention, coders watched the videotape for each session in real time and coded the duration of infants' attention to each toy during the test trials. From this coding, the proportion of time that the infant looked at the same toy as the actor versus the other toy was calculated. A second pair of observers repeated the procedure for about 20% ($n = 10$) of the infants. Reliability between the pairs of coders was 92% (range 80–97%) for the gaze events and 90% (range 71–98%) for the pointing events.

RESULTS AND DISCUSSION

Descriptive statistics for each measure are presented in Table 1. The data were analyzed in two steps. First, we analyzed infants' responses in the visual-habituation procedures and derived scores to index their understanding of attentional relations for the gaze and pointing events. Second, we examined potential relations between action understanding and social responsiveness.

Habituation Responses: Understanding Attentional Relations

Infants met the habituation criterion for both the gaze and pointing events in an average of eight trials. One infant did not meet the habituation criterion for the gaze events, and 4 infants did not meet it for the pointing events. When these infants

TABLE 1
Overview of Measures and Descriptive Statistics

Measure	n^a	Whole Sample			Pointers		Non-pointers	
		M	SD	Range	M	SD	M	SD
Action understanding								
Gaze understanding	52	0.49	0.24	0.05–0.89	0.48	.27	0.49	0.22
Point understanding	52	0.54	0.18	0.10–0.90	0 .59[*]	.15	0.51	0.20
Social orienting								
Orienting in habituation (mean)	51	0.26	0.12	0.03–0.53	0.29	.11	0.25	0.12
Gaze habituation	51	0.18	0.13	0–0.53	0.18	.12	0.18	0.13
Point habituation	48	0.36	0.16	0.06–0.67	0.42	.15	0.32	0.16
Attention following	51	1.57	1.03	0–4	1.95	.83	1.32	1.08
Shared attention	52	0.26	0.12	0.05–0.63	0.25	.12	0.26	0.13

[a]Number of children out of 52 in study who had complete data for measure.
[*]$p < .05$, two-tailed t test compared to chance (.50).

were excluded from the analyses, the patterns of findings did not change. Therefore, the following analyses included data from all 52 infants.

Infants' attention during habituation did not differ significantly for the gaze and pointing events. A repeated measures Analysis of Variance (ANOVA) on total looking time during the habituation trials of each session with action (gaze or pointing) as the within-subjects factor revealed no main effect, $F(1, 51) = 1.55, p = .22$. Following habituation, infants responded to the change in the events during the new object and new side trials for both the gaze and the pointing events. Paired comparisons of infants' looking time during the baseline trial and the first new object and new side trials revealed reliable recovery in all cases, all ps $< .0003$. During the test trials, infants' attention to the events did not vary by action. A repeated measures ANOVA on total looking time during the test trials of each session with action (gaze or pointing) as the within-subjects factor revealed no main effect, $F(1, 51) = 1.45, p = .23$.

For the focal data analyses, we derived a single measure for each of the habituation tasks. These measures, gaze understanding and point understanding, were proportional scores calculated by dividing the time looking to the new object event by the total time looking to the new side event and the new object event. These scores were selected because they capture the primary measure of interest, infants' selective attention to a change in the object of the agent's attention, a measure that has been found to be related to a social response (pointing) in earlier studies (Woodward & Guajardo, 2002), and because they are not conflated with other measures such as overall levels of attention.[2] However, preliminary analyses re-

[2]Secondary analyses revealed no significant correlations between the measures of habituation (i.e., number of test trials to habituate, total habituation time, proportion decrement in looking across trials) and the measures of action understanding or the measures of social responsiveness.

vealed infants' attention tapered off across trials. Means (with standard deviations in parentheses) for the average looking time for the first and third pairs of the gaze events were 7.46 (4.28) and 5.83 (7.53), respectively, and for the pointing events were 10.65 (5.91) and 4.81 (2.45), respectively. Therefore, gaze understanding and point understanding scores were calculated using the first test trial pair. These scores could be interpreted as an infant's preference for the events that contained a change in the actor-object relation. A score greater than .50 indicated that an infant showed a preference for the new object event over the new side event, and this was taken as evidence of understanding the attentional relation implied by the action.

The action understanding scores did not vary reliably as a function of the type of action infants viewed, the order in which infants received the gaze and point proce-dures, or the particular experimental configuration to which they had been assigned. An ANOVA with action (gaze vs. pointing) as the within-subjects factor, visit (gaze or pointing events on the first visit), goal (ball or teddy bear in habituation), and type (or new side test event given first) as between-subjects factors, revealed no signifi-cant main effects or interactions. There was a positive, but nonsignificant, correla-tion between gaze understanding and point understanding, $r = .24$, $p = .09$.

For neither the gaze nor the pointing events did infants show a reliable prefer-ence as a group for the new object trial over the new side trial. That is, their action understanding scores did not significantly differ from chance (.50) for gaze, $t(51) = -.39$, $p = .70$, or for pointing, $t(51) = 1.50$, $p = .14$. These findings were consistent with prior studies of infants at this age (Phillips, Wellman, & Spelke, 2002; Sodian & Thoermer, 2004; Woodward, 2003; Woodward & Guajardo, 2002). Recall that this variability in action understanding was precisely what we wanted to explore.

Relations between Action Understanding and Social Responsiveness

The central analyses investigated relations between the two measures of action un-derstanding and infants' social responsiveness, including point production, atten-tion following, and participation in shared attention with caretakers.

One approach to this issue is to ask whether those infants who attained the highest possible scores on the measures of social responsiveness (i.e., are those who pointed engaged in coordinated joint attention, and who reliably followed attention) were more likely to respond systematically in the habituation procedures. However, given the age of our participants, few infants achieved top marks on the measures of social responsiveness. Only 1 infant reached the top of the scale on all three measures, and only 10 of the 52 infants achieved top scores on two of the three measures. Thus, clas-sifying infants on the basis of a composite, categorical measure seemed likely to miss important variation in our sample. Therefore, we considered each measure of social responsiveness separately in the analyses. In the case of point production, we had a dichotomous measure (infants either had begun to produce object-directed points or had not). The measures of attention following and shared attention provided graded

information. Therefore, we pursued analysis strategies that were appropriate for the data, evaluating categorical differences for the pointing data, and correlational patterns for the measures of attention following and shared attention.

Action Understanding and Point Production

Twenty infants, 12 girls and 8 boys, were identified as pointers by parent report (n = 9), observation in the laboratory (n = 3), or both (n = 8). We predicted that infants who produced object-directed points would be more likely to understand pointing as relational than nonpointers based on Woodward and Guajardo (2002). An open question was whether pointers would also understand gaze as relational.

Table 1 shows the descriptive statistics for the 20 pointers and 32 nonpointers. In contrast to Woodward and Guajardo (2002), pointers were significantly older than nonpointers, $t(50) = 3.59$, $p < .001$. On average, pointers were 10 months 13 days, although nonpointers were 9 months 27 days. However, age was not significantly correlated with gaze or point understanding, $r = -.11$, $p = .45$, and $r = .07$, $p = .61$, respectively. There was no difference between pointers' and nonpointers' habituation patterns. To test whether infants' understanding of pointing as relational was related to their own production of object-directed points, we conducted an ANOVA with point understanding as the dependent variable, pointing status (producing or not producing object-directed points), type (new object or new side test event given first), and goal (ball or teddy bear in habituation) as independent variables, and age as a covariate.[3] There was a significant interaction between pointing status and goal, $F(1, 52) = 4.56$, $p = .04$, and no other reliable effects.

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[3]To rule out age as an explanation for the effect of point production on point understanding, we conducted an alternative analysis after reducing the sample's age range. This eliminated 15 younger infants (14 nonpointers, 1 pointer), and 1 older pointer. The remaining 19 girls and 17 boys had an average age of 10;11. Pointers' ($n = 18$) age ($M = 10;13$, range 9;2–10;29) did not differ from nonpointers' ($n = 18$) age ($M = 10;8$, 9;27 - 10;29), $t(34) = -1.55$, $p = .13$. Point understanding scores were significantly above chance for the pointers, $t(17) = 3.47$, $p < .005$, but not for the nonpointers, $t(17) = -.57$, $p = .58$. Gaze understanding scores did not differ significantly from chance for either group ($ts < 1.00$). Pointers' scores were significantly greater than nonpointers' for point understanding, $t(34) = 2.51$, $p < .05$, but not for gaze understanding, $t(34) = .30$, $p = .76$.

To explore this interaction, we conducted post hoc ANOVAs separately on the pointer and nonpointer groups. Point understanding was entered as the dependent variable, with goal (ball or teddy bear in habituation) as the dependent variable, and age as a covariate. For the pointers, there was no significant main effect of goal. For the nonpointers, there was a significant effect of goal, $F(1, 32) = 4.78$, $p = .04$. Post hoc comparisons of pairs revealed a mean difference of .15 ($SE = 0.07$), $p = .04$; nonpointers who saw the teddy bear in habituation had higher point understanding scores than nonpointers who saw the ball in habituation, 0.57 ($SD = 0.18$) and 0.42 ($SD = 0.20$), respectively. Planned comparisons against chance (.50) revealed that pointers looked reliably longer on new object compared to new side trials, $t(19) = 2.56$, $p = 0.02$. Nonpointers did not differ from chance as a group, $t(31) = 0.21$, $p = 0.83$, or when divided into the groups that saw the teddy bear versus the ball as the goal object, $t(18) = 1.70$, $p = 0.11$ and $t(12) = -1.55$, $p = 0.15$, respectively.

A parallel set of analyses was carried out with gaze understanding as the dependent variable. An ANOVA with pointing status, type (new object or new side test event given first), and goal (ball or teddy bear in habituation) as independent variables, and age as a covariate, revealed no significant main effects or interactions. Neither pointers nor nonpointers differed from chance in their responding on new object versus new side trials for the gaze events.

These results replicated the findings of Woodward and Guajardo (2002) in finding that infants who produced object-directed points were more likely than nonpointers to represent observed points in terms of the relation between the agent and the object. Notably, this effect was limited to point understanding; pointers did not differ from nonpointers on the gaze understanding measure. Given that pointers did not demonstrate an understanding of gaze, their performance on point understanding cannot be attributed to more sophisticated responses overall on the visual-habituation tasks. Instead, pointers' performance on the point-understanding task seems to reflect knowledge that is specific to pointing.

Action Understanding, Shared Attention and Attention Following

We next considered relations between action understanding and the continuous measures tapping attention following and shared attention with caretakers by entering these measures into an exploratory factor analysis. Because our sample size was relatively small for this type of analysis, we kept the number of factors to a minimum. We separately entered the gaze-understanding and point-understanding scores from the habituation procedures. For the measures of social responsiveness, we entered the attention following, orienting (to the actor's gaze, point during the habituation procedure), and shared attention (degree of engagement in shared attention with the caretaker during parent–child play).[4] We also included age (infants' average age across visits) to determine whether it explained significant variance in these measures. Therefore, in total, we entered six factors for 52 participants and had a subjects-to-variable ratio of 8.5, which is above the minimum rule of 5 (Bryant & Yarnold, 1995) but below the ideal of 10:1 (Nunnally, 1978). We did not include point production in this analysis because it was operationalized as a dichotomous variable.

Factor analysis provided a way to test whether correlations between different measures of social responsiveness and social cognition reflected a general pattern, or instead distinct factors. By including both measures of action understanding, we

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[4]Orienting was an average of gaze orienting and point orienting because they were positively related, $r_s = 0.26$, $p = .08$, after removing two outliers who were greater than 2 standard deviations above the mean for gaze orienting; when separate analyses were conducted with gaze orienting and point orienting the results did not change.

TABLE 2
Correlations Among the Measures

Measure	1	2	3	4	5	6
1. Age		−.11	.07	.22	.20	.12
2. Gaze understanding			.24	.04	−.15	.37*
3. Point understanding				.14	.12	−.10
4. Orienting in habituation					.37*	−.06
5. Attention following						−.19
6. Shared attention						

Note. For correlations including attention following and orienting in habituation, $n = 51$. For the correlation between attention following and orienting in habituation, $n = 50$.

$N = 52$.

*$p < .01$.

could see whether they shared the same patterns of relations with the measures of social responsiveness, or whether the patterns seemed to be action specific. In contrast to regression, factor analysis did not require us to specify an outcome variable. Therefore, this relation could be explored without presupposing the developmental sequence of these behaviors.

For each measure, scores were standardized with respect to the mean of the sample.[5] Correlations among the measures are presented in Table 2. The measures were entered into a factor analysis (principal components) with Varimax rotation. The analysis yielded three factors that accounted for 69% of the variance in the model (Table 3). The measures that reflected infants' social orienting (orienting, attention following) loaded positively on a single factor (Factor 1) with age (.70) that accounted for 26% of the variance. The measures that represented infants' action understanding (gaze understanding, point understanding) loaded positively on a separate factor (Factor 3) that accounted for 21% of the variance. The other factor (Factor 2) included measures from both components, shared attention and gaze understanding, which both loaded positively and accounted for 22% of the variance.

The solution with three factors was produced on the basis of the amount of variance accounted for in the data by statistically independent factors. Therefore, we can interpret these factors as unique contributors to infants' performance across tasks. It is interesting to note that these independent factors accounted for similar

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[5]Mean substitutions were used to replace missing data points for two infants (one for attention following, the other for orienting in habituation). When these infants were excluded from the analysis instead, the pattern of findings did not change. One infant was excluded from the analysis because the amount of time he spent in shared attention was greater than 3 standard deviations above the mean. This inflated the relation between shared attention and the other variables within the factors. When he was excluded, the overall pattern of findings (i.e., factor structure, variance) did not change.

TABLE 3
Factor Analysis of the Measures

	Factor Loading		
Measure	Factor 1	Factor 2	Factor 3
Age	0.70		
Gaze understanding		0.52	0.70
Point understanding			0.80
Orienting in habituation	0.72		
Attention following	0.71		
Shared attention		0.90	
Factor statistics			
Eigenvalue	1.56	1.32	1.24
Variance explained (%)	26	22	21

Note.   The three factor solution was selected on the basis of a cutoff criterion of eigenvalues greater than or equal to 1. Factor loadings under .40 were suppressed.

amounts of variance in the data, which suggests that they weighed relatively equally into infants' performance.

Factor 1, which we refer to as "Social Orienting", did not include either measure of social cognition. This factor confirmed that our two measures of social orienting, one taken from infants' propensity to follow the habituation actor's attention, the other from a more naturalistic procedure, each tapped the same underlying ability. Further, our findings suggest that this ability is independent of infants' understanding of gaze and pointing as object-directed actions. Follow-up analyses confirmed this finding, even when infants' responses were considered within an action: There were no reliable correlations between gaze orienting and the gaze-understanding task, $r_s = 0.07$, $p = .64$, and point orienting and the point-understanding task, $r_s = 0.12$, $p = .42$. Thus, in keeping with prior findings (Woodward, 2003; Woodward & Guajardo, 2002), these findings suggest that gaze and point following are not correlated with action understanding at this age. The emergence of social orienting and action understanding as independent factors argues against the assumption that gaze and point following are direct indexes of action understanding.

Factor 3, which we refer to as "Action Understanding," did not include any measure of social responsiveness, but it did include the two measures of action understanding. This factor provides stronger evidence for the relation between gaze and point understanding than was evident in the correlational analysis. To take a closer look at this relation, we classified infants into groups, on the basis of whether their preference for the new object trial fell above or below chance (.50) for each action (Table 4). The chi-square distribution of infants' proportion scores approached significance, $\chi^2 (1, N = 52) = 3.07$, $p = .08$. There was a trend for more infants to un-

TABLE 4
Distribution of Infants' Action Understanding Scores

Point Habituation	Gaze habituation		
	< .50	> .50	Total
< .50	14	7	21
> .50	13	18	31
Total	27	25	52

derstand pointing than gaze as relational. These results suggest that infants may have more readily noted the relation between agent and object for the pointing events than for the gaze events. Given that the pointing events contained two cues, gaze and pointing, as well as a concrete connection between the actor and the object, more infants may have interpreted the pointing events as relational because they contained richer information.

Furthermore, there was an asymmetry in the relation between these scores, which suggests that point understanding may be a facilitator of understanding gaze. Of the 31 infants who performed above chance on the point-understanding task, 18 of them performed above chance on the gaze-understanding task, $p = .48$. In contrast, of the 25 infants who performed above chance on the gaze-understanding task, 18 of them performed above chance on the point-understanding task, $p < .05$.

The remaining factor, Factor 2, produced a novel finding, documenting a relation between a particular measure of social responsiveness, Shared Attention, and a particular measure of social cognition, Gaze Understanding. To investigate this relation further, we considered infants in the upper and lower third of the distribution in shared attention. The group in the upper third spent between 30 and 63% of their time in shared attention, and the group in the lower third spent between 5 and 19% of their time in this state. On average, the 18 infants in the upper third group, 8 girls and 10 boys, spent 39% ($SD = 9\%$) of the time in shared attention. The infants in the lower third group, 7 girls and 10 boys, spent 13% ($SD = 5\%$) of their time on average in this state. The two groups did not differ significantly in age, $t(33) = 0.48$, $p = 0.64$.

Compared to the lower third group, infants in the upper third group scored significantly higher on gaze understanding, 0.41 ($SD = 0.21$) and 0.58 ($SD = 0.22$), respectively, $t(33) = 2.26$, $p = .03$. This effect did not carry over to point understanding, $t(33) = 0.77$, $p = .45$, indicating that shared attention systematically related to infants' understanding of the actor-object relation of the gaze events, but not to the pointing events (Figure 4). However, infants in the upper third group were not above chance on the gaze-understanding score, $t(17) = 1.49$, $p = .15$. The mean for infants in the lower third group fell below chance, but it did not differ reliably from
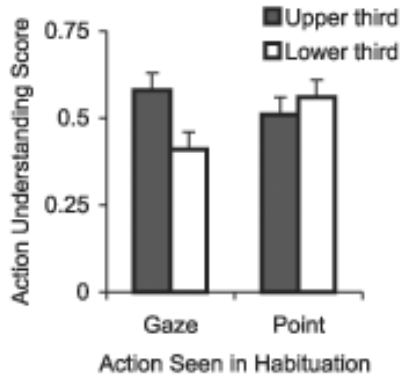
FIGURE 4   Comparison of infants' performance on the action-understanding tasks split by their amount of shared attention in parent–child play.

chance $t(16) = -1.71, p = .11$. It seems likely that if we had tested slightly older infants, who would have had higher levels of shared attention, then those at the upper end of the distribution would have responded more systematically to the habituation events. Further research is needed to test this possibility.

GENERAL DISCUSSION

Two assumptions have been prevalent in the recent study of infant social cognition: first, that infants' social responsiveness directly reflects their social understanding, and second, that emerging conceptions of intentional action are monolithic. This study is the first we know of to directly test these assumptions by independently investigating infants' understanding of intentional relations and their social responses. Our findings provide new insights into infants' emerging ability to represent intentional relations and the relation between this ability and developments in social behavior. They indicate that emerging social cognition correlates with some, but not all, socially functional behaviors. They further suggest that relations between action knowledge and social responsiveness may, at least initially, be local and circumscribed.

An initial question was whether infants would be equally sensitive to the intentional structure of two different actions, looking and pointing. Prior findings indicate that between 9 and 12 months of age infants begin to understand each of these actions as implying a relation between an agent and the object of her attention (Phillips et al., 2002; Sodian & Thoermer, 2004; Woodward, 2003; Woodward & Guajardo, 2002), but no study had directly compared understanding of these two actions within the same infant. Our findings were consistent with prior

research in that, as a group, the 10-month old infants we tested did not respond systematically to the gaze or pointing events in the habituation procedure. There was a marginal positive correlation between infants' responses in the two procedures, although this relation was more evident in the factor analysis. Categorical analyses suggested that infants' point understanding may be a prerequisite for gaze understanding. Of those infants who responded above chance for the gaze events, most responded in the same way for pointing, but those who responded systematically for pointing were evenly divided in their responses to gaze. Thus, our findings suggest that infants' understanding of gaze and pointing are related in development. Even so, our subsequent analyses revealed that these two aspects of action knowledge are also related to distinct aspects of social responsiveness.

For both the gaze and pointing events, one goal of this research was to determine whether infants' understanding of actions as relational could be distinguished from their propensity to orient in response to viewing these actions. Infants' gaze and point following is often assumed to reflect an understanding of the intentional relations at hand. Our findings suggest otherwise. Infants did shift their own attention in response to others' actions, both while viewing the habituation events and in the more naturalistic assessment of gaze and point following. However, these orienting responses were unrelated to infants' sensitivity to the intentional structure of the habituation events.

Despite the lack of correlation with infants' habituation responses, the measures of orienting were related to one another. There was a significant correlation between infants' orienting to the actor in habituation and their orienting to the experimenter in the more naturalistic task. These two measures of orienting positively contributed to the same factor in the factor analysis. This suggests that both measures of social orienting accurately reflected infants' propensity to respond to the attention of another. Neither measure loaded on the same factor as infants' action understanding in the factor analysis. Collectively, these findings strengthen the evidence against the assumption that the traditional estimates of infants' action understanding, gaze and point following, reflect understanding the attentional relations of actions.

It is possible that the infants' orienting responses become more closely linked with their analysis of intentional relations at later points in development. For example, older infants are able to modify their orienting responses when an adult's gaze is blocked by a blindfold or barrier (Brooks & Meltzoff, 2002; Butler, Caron, & Brooks, 2000; Caron, Butler, & Brooks, 2002). These findings suggest that infants intend to see what the experimenter is seeing, and therefore have some knowledge about the relational nature of gaze events. These more intelligent gaze following responses support arguments outlined by Moore and colleagues (Barresi & Moore, 1996; Corkum & Moore, 1998; Moore & Corkum, 1994) that social responses become infused with social cognition early in development.

Although infants' action understanding was not related to their propensity to follow gaze or points, it was related to other aspects of social responsiveness. Our analyses revealed independent clusters of relations with point understanding and gaze understanding. These clusters suggest that acquisition of knowledge about pointing and gaze events may follow different trajectories and relate to different kinds of social experiences. In particular, we found two specific links between infants' social cognition and social responsiveness. The first was a relation between point production and point understanding, and the second was a relation between shared attention and gaze understanding. In each case, an aspect of social responsiveness was related to one kind of action knowledge, but not to the other. Following, we review these links and discuss possible explanations for them. Because we are working with concurrent data, we cannot be certain about the direction of causation that may account for the correlations we observed. Indeed, we think it is very likely that relations between social cognition and social responsiveness are bidirectional. Even so, our findings shed new light on these relations and highlight a number of questions for further study.

Infants who pointed were more likely to interpret pointing as relational than infants who did not yet point. This relation was not accounted for by age. This aspect of our findings replicates a prior study (Woodward & Guajardo, 2002). Our findings provide new insight into this relation because they indicate it is action specific at this point in development. Pointers were no more able than nonpointers to recover the relational structure of the gaze events.

There are several possible explanations for the positive relation between point production and point understanding. One possibility is that infants learn the function of pointing by observing others' pointing and are then motivated to begin pointing themselves. Another possibility, and one that we think is more likely to be true, is that infants begin to point for other reasons, and through pointing themselves, become aware of the attentional relation this action implies in others. Some researchers have suggested that infants initially point as an expression of their own attention, rather than as a symbol for others (Bates et al., 1979; Desrochers et al., 1995; Schaffer, 1984; Werner & Kaplan, 1963). If this is the case, then the point gesture might function as an overt signal of an attentional relation that could enable infants to interpret other people's point gestures. These possibilities emphasize the causal role of observing or producing a specific action, pointing, in acquiring action knowledge. Further, they are consistent with the proposal that the root of intentional understanding comes from aligning self and other (Meltzoff & Gopnik, 1993; Tomasello, 1999). Because we do not know whether infants begin pointing first or understand pointing as relational first, we can only speculate about these possibilities. Longitudinal studies are needed to address this issue.

The second correlation among social cognition and social responsiveness concerned the relation between shared attention and gaze understanding. These measures were positively correlated, and this relation accounted for a significant

amount of variance in the infants' performance. Shared attention could contribute to infants' understanding of gaze by providing them with increased opportunities to observe and participate in triadic interactions. This idea is consistent with the theory put forth by Moore and others (Corkum & Moore, 1995) that joint engagement leads to discovery of others' intentions. Conversely, infants' increase in shared attention could result from their understanding of gaze. For example, perhaps infants who understood gaze drew their parents to play with them by looking to them more or by using the parents' gaze to locate a common object of interest. Given the existence of this concurrent relationship, future studies can investigate these relations over time and thereby begin to isolate the causal relations involved.

To summarize, we found different patterns of correlations with social responsiveness for point and gaze understanding. These findings indicate that infants' pockets of knowledge about actions may be related to different aspects of experience. These findings raise the possibility that concepts of intention, although unified at some point in life, do not begin that way. If we had found that infants' understanding of gaze and point were significantly correlated and that this unified action knowledge was related to some aspect of social responsiveness, we might argue that infants' initial concepts of intention are inclusive of different attentional relations. However, the action-specific relations we found better support the idea that infants' understanding of referential actions starts out as piecemeal.

If this suggestion is correct, then it raises the question of how and when infants' action knowledge becomes integrated. One possibility is that understanding one action facilitates understanding the other. For example, infants might first understand pointing as relational, and this knowledge could support later learning about gaze. The findings that point and gaze understanding were moderately correlated in our sample and that point understanding seemed to predict gaze understanding are consistent with this possibility. If point understanding supports infants' growing sensitivity to the relational nature of gaze, we might expect that seeing pointing events first in our procedure would have led to more systematic responses to the gaze events. We did not find evidence for this kind of facilitation. Infants' responses to the gaze and pointing habituation events did not vary as a function of the order in which they received them. However, facilitation might be evident in the course of development over longer time scales.

By incorporating measures of social cognition into studies of infants' social responsiveness, the bidirectional influence of infants' achievements during this transitional period can be investigated. Examining infants' abilities on these skills during this transitional period of development has provided a starting point for investigating the relation between social cognition and social responsiveness in development and highlighted the need to do so. Accounts of social development should take seriously the distinction and developmental relations between social cognition and social responsiveness.

ACKNOWLEDGMENTS

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