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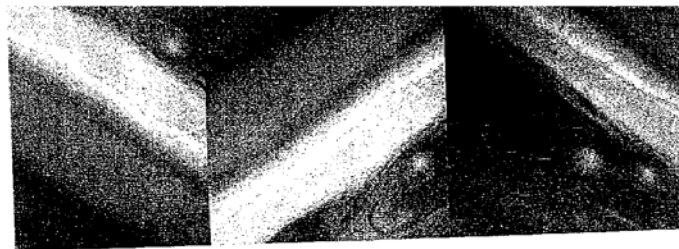
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Teresa McCormack, and Johannes Roessler

## Infants' Understanding of the Actions Involved in Joint Attention

Amanda L. Woodward

Joint attention plays a pivotal role in many aspects of development. This is because episodes of joint attention provide children with a great deal of information. To illustrate, imagine a mother and her young son at a family reunion. The mother turns to look at a newcomer to the party, smiles, points at her, and exclaims, "There's Aunt Grace." The child in this situation could infer from these actions that Aunt Grace is the name of the indicated person. He might further infer that his mother likes Aunt Grace and is likely to seek contact with her. That is, joint attention behaviors provide information not only about the objects at which they are directed, but also about the dispositions and mental states of the person who performs them.

The child's ability to extract this information rests on his understanding of attentional behaviors such as looking and pointing. It is possible to respond to the attentional behaviors of another person apparently appropriately, yet not understand the meaning of these behaviors for the person who performs them. To illustrate, the child in the above example might shift his attention to Aunt Grace in response to his mother's gaze and pointing, without yet understanding that his mother is attending to Aunt Grace. In this case, the significance of these behaviors would be largely lost on the child. He would have no basis for making inferences about his mother's utterances, epistemic states, emotional reactions, or likely next behaviors.

In investigating the development of joint attention, therefore, it is critical to distinguish between children's orienting responses to gaze and pointing and their understanding of these behaviors as involving attention on the part of the person who performs them. There is now a wealth of evidence concerning the first of these abilities. As George Butterworth's work elegantly documented, by 6 months of age, infants respond to shifts in gaze by shifting their own gaze at least in some situations, and by 18 months of age, infants are skilled at following both gaze and points with precision (Butterworth, 1995; Butterworth and Cochran, 1980; Butterworth and Groer, 1988; Butterworth and Jarrett, 1991). These findings

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indicate that gaze and pointing direct infants' attention from early in life. However, there is as yet little evidence concerning infants' understanding that these behaviors involve an attentional connection between a person and an object.

Adults understand many aspects of attentional behaviors. For example, we understand the likely phenomenological experience of a person who looks at something—we can imagine what he or she sees. We can also predict the effects that this experience will have on his or her epistemic states, emotional reactions, and other mental processes. We know that when someone points to an object, she is aware of it, and she likely wishes to make someone else aware of it as well. Finally, we also understand the implications of looking and pointing for a person's subsequent behavior. For example, people tend to move toward and act on the objects of their gaze. Underlying all of this knowledge is the fundamental insight that there is a connection between a person and the object of her gaze and pointing. That is, like many other intentional actions, gaze and pointing are object-directed. If infants lacked an understanding of gaze and pointing as object-directed, it would be impossible for them to interpret these behaviors as anything more than a series of motions, like sneezing or jumping, or as signals to orient in a particular direction.

The work I describe below investigates this most basic insight about joint attention behaviors. This approach provides a new view of infants' comprehension of points and gaze. Until now, researchers have generally used orienting responses as measures of infants' comprehension of points or gaze. The assumption has been that infants' propensity to orient in response to another person's gaze or point is an indicator of their underlying understanding of these actions as implying a psychological relation between the person and the object. As one illustration, in a recent review chapter, Bruner concluded that in order to understand gaze-following in young infants, "All that is needed... beyond a shared knowledge of space... is knowing that another is looking and experiencing something in the visual world" (Bruner, 1995, p. 7). The work described below will suggest that this assumption is not always correct.

### INFANTS' APPRECIATION OF ACTOR-OBJECT RELATIONS

Many actions that adults understand as intentional instantiate a relation between an actor and some object; that is, they are object-directed. This is true for attentional actions such as gaze and pointing, as well as for physical actions such as grasping. In mature systems of knowledge, many aspects of the relation between actor and object are represented. As discussed above, adults understand the specific psychological and behavioral implications of gaze and pointing, and they also understand these aspects of grasping and other physical actions (e.g. adults understand that an actor who grasps a toy probably wants it, is likely to bring it closer to herself, etc.). In order to develop this rich understanding of intentional

actions, children must at least understand the object-directed nature of these actions. Prior work from my laboratory has shown that by 6 months of age, infants understand at least one intentional action as involving a link between actor and object (Woodward, 1998, 1999). These studies focused on grasping, an action that is commonly performed both by the agents whom infants observe and, after 4–5 months, by infants themselves. Because these studies provide a model for our later work on gaze and pointing as well as an informative point of comparison, I will review them here.

When infants see a person reach for and grasp an object, there are many ways in which they could represent this event. They might focus on the 'surface' of the event, encoding the path of motion taken by the actor's arm, the angle at which the arm is extended, the position of the object relative to the person and other objects in the scene, etc. On the other hand, infants might represent this event primarily in terms of the relation between the person and the object which she grasps. This would be like adults' construal of such events as object-directed ('She grasps the bear' or, perhaps, 'She wants the bear').

The visual habituation paradigm provides a way to test which of these two construals infants apply. In a series of studies completed in my laboratory (Woodward, 1998), infants were first shown an event in which a person reached for and grasped one of two toys which sat side by side on a small stage (see Fig. 6.1). To habituate infants to this event, it was repeated on subsequent trials

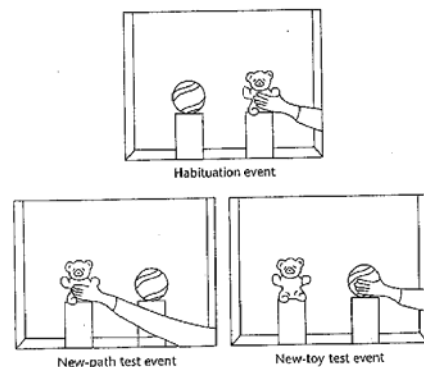


FIGURE 6.1. Sample events for the studies of grasping (based on Woodward, 1998).

until the infant's attention to it declined to half its initial level. Then, the positions of the toys were reversed, and infants saw two test events in alternation. In one (the new-toy event), the actor reached to the same location as during the habituation phase, this time grasping a different toy. In the other (the new-path event), the actor reached to the other location, grasping the same toy as during the habituation phase. Following habituation, infants will look longer at stimuli which are less similar to the habituation stimuli, and less long at those which are more similar to the habituation stimuli. Therefore, infants' level of looking on the two kinds of test trials provides evidence as to how they represented the habituation event. If infants represented the habituation event mainly in terms of the physical properties of the reach, then they would be expected to look longer on new-path trials. Alternatively, if infants represented the habituation event mainly in terms of the relation between actor and object, then they would be expected to look longer on new-toy trials. The results were that 6- and 9-month-olds looked longer on new-toy trials than on new-path trials, suggesting that at these ages, infants understand the human grasp as an object-directed action.

Additional findings indicated that young infants' propensity to construe actions as object-directed is specific to human actors and, initially, specific to the act of grasping. First, when infants observed a mechanical claw move toward and grasp a toy, they looked equally at new-toy and new-path test events, suggesting that they did not construe this event in terms of the relation between the claw and the toy (Woodward, 1998). Second, when infants observed an actor contact the toy with the back of her hand, they did not construe this action as object-directed (Woodward, 1999).

Before accepting this evidence as strong support for infants' understanding the object-directed nature of human grasps, however, it was critical to rule out an alternative explanation for the findings. It was possible that infants' responses to the new-toy and new-path test events derived from the spotlighting effects of hands that grasp. Perhaps infants have a bias to orient attention to hands that grasp and the objects they hold, but lack such a bias for claws and inert hands. If this were the case, infants' patterns of response to the grasping events could be driven by the fact that a new object is being spotlighted on new-toy trials but not on new-path trials. To explore this possibility, we coded the videotapes of each infant's test trials frame by frame to determine how long they looked at the toy that was the target of the action versus the other toy. This coding revealed that the grasping hand, claw, and inert hand were equally effective at drawing infants' attention. Regardless of which of these contacted the toy, infants spent more time staring at the toy that was contacted than at the other toy.

This result is important for two reasons. First, it rules out one possible explanation for the findings of the habituation experiments. Because the grasping hand, claw, and inert hand were equally effective at directing infants' attention, spotlighting cannot account for infants' differential responses to these three

actions. Second, it indicates that infants' encoding of actor-object relations can be distinguished from their propensity to orient in response to actions. It is possible to draw infants' attention to an object in many ways, including grasping it with one's hand, grasping it with a mechanical claw, and laying one's hand on top of it. Only for human grasps, however, do young infants represent the action in terms of the relation between actor and object.

The findings from these studies suggest a strategy for investigating the distinction between infants' orienting responses to pointing and gaze and their understanding of these actions as object-directed. Specifically, infants' novelty responses to changes in the relation between actor and object can serve as a measure of their understanding of the object-directed nature of an action, and infants' attention to the individual objects in the events can serve as an index of their propensity to orient in response to the action. The studies I describe below pursued this strategy.

#### INFANTS' DEVELOPING UNDERSTANDING OF GAZE AS AN OBJECT-DIRECTED ACTION

Like grasping, gaze is ubiquitous in infants' environments. Moreover, young infants are sensitive to eyes and eye direction from the first few months of life. Infants as young as 2 to 6 months show preferential attention to eyes over other aspects of the face (Caron *et al.*, 1973; Haith, Bergman, and Moore, 1977; Maurer and Salapatek, 1976). Young infants respond to shifts in gaze direction (Hains and Muir, 1996; Symons, Hains, and Muir, 1998; Vecera and Johnson, 1995), and direct their own attention based on another person's gaze by 6 months or perhaps even younger (Butterworth and Jarrett, 1991; D'Entremont, Hains, and Muir, 1997; Hood, Willen, and Driver, 1998; Scaife and Bruner, 1975).

Given that gaze serves as an attentional spotlight for young infants, do infants also understand gaze as an action that links a person to some object? In a recent series of studies (Woodward, 2003), I used the habituation paradigm described above to ask this question. The first experiment tested twenty infants at each of two ages, 7 and 9 months. Infants saw events in which an actor turned to look at one of two toys (see Fig. 6.2). At the start of each trial the experimenter made eye contact with the infant, said "Hi. Look!" as she turned to look at one of the toys. She then held still until the infant looked away for 2 seconds to end the trial. Infants saw the same event on subsequent trials until they had habituated to it. Then, the positions of the toys were reversed, and infants saw two kinds of test events. On new-toy trials, the actor turned to the same side as during habituation, this time looking at a new toy. On new-side trials, the actor turned to the opposite side as during habituation, to look at the same toy as during habituation. If infants attend to the relation between a person and the object of her gaze, then they would be expected to look longer on new-toy trials, in which this relation is altered.

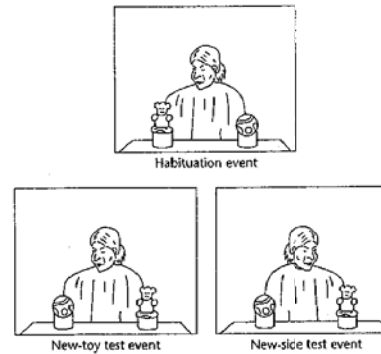


FIGURE 6.2. Sample events for the studies of looking (based on Woodward, 2003).

If infants respond instead to surface features of the event, such as the physical motion of the actor, they might look longer on new-side trials.

A preliminary question was whether infants oriented in response to the actor's gaze. If they did not, then they would have had no chance to note the relation between actor and object. Given the findings from studies of gaze-following described earlier, it was predicted that the infants in this experiment would follow the actor's gaze to the toy, and they did. As in the earlier studies of grasping, we coded the test trials for the amount of time infants spent looking at the same toy as the actor versus the other toy: 81 percent of the 7-month-olds and 94 percent of the 9-month-olds spent more time looking at the same toy as the actor than at the other toy.

The question of interest was whether infants at either age responded to the change in relation between the actor and the object, as evidenced by longer looking on new-toy trials than on new-side trials. In spite of the fact that they responded systematically to the actor's shift in gaze by orienting to the same toy, infants at neither age responded to the change in the relation between actor and object. Both 7- and 9-month-olds looked equally on new-toy and new-side test trials. In fact, infants at both ages failed to show a reliable increase in looking from the end of habituation on either kind of test trial. It is as if 7- and 9-month-olds identified the visible objects (the bear, the ball, and the actor) as being the same as during habituation, without considering the relations between them.

One concern about these findings is that the method may have been insensitive to infants' representations of object-directed action. Although we had used this

paradigm successfully with 6- and 9-month-old infants, in our prior work the actor's face was never visible. Since the measure was looking time, anything that might contribute to longer or shorter looking times overall could add noise to the data. The addition of a human face, known to be a highly attractive stimulus for infants, could have had such an effect. To investigate this possibility, a second group of infants at each age was shown events that were identical to those in the first experiment, with one exception—as she turned to look at the toy, the actor also grasped it. Thus, in this study infants saw an action that they understand as object-directed—namely, grasping—in the presence of a potentially distracting human face. Given prior findings, if the current paradigm was sensitive to infants' representations of action, we would expect infants at both ages to look longer on new-toy trials than on new-side trials. This is precisely what was found. Infants at both ages looked longer on new-toy trials than on new-side trials, and infants at both ages recovered from habituation on new-toy but not new-side trials. Taken together, the findings indicate that 7- and 9-month-olds understand grasping, but not looking, as an object-directed action.

A final question is the age at which infants begin to represent the relation between looker and object. A third experiment addressed this question by testing 12-month-old infants using the events from the first study, in which the actor looked at but did not grasp the toy. Like the younger infants, 12-month-olds responded to the actor's shift in gaze by looking at the same toy as she did: 84 percent of the babies looked longer at this toy than at the other toy. In contrast to the younger infants, 12-month-olds also showed evidence of noting the relation between actor and object. They looked reliably longer on new-toy trials than on new-side trials, and recovered from habituation on new-toy trials but not new-side trials. Therefore, the results suggest that infants begin to understand the object-directed nature of looking between 9 and 12 months of age.

To summarize, when they saw a person turn toward and look at a toy, 7- and 9-month-old infants did not organize their representations of the event around the relation between the actor and the toy. In contrast, 12-month-olds did. The failure of the younger infants to attend to the relation between actor and object is remarkable given that they systematically responded to the actor's gaze by shifting their own gaze to the object at which she looked. Thus, at one level, 7- and 9-month-olds were quite attentive to the experimental events, but at another level, they missed a critical aspect of these events. As was the case in our earlier studies of grasping by hands versus claws, therefore, there is evidence for a dissociation between infants' propensity to orient in response to an action and the representations that they derive from witnessing the action. Infants begin to orient in response to gaze shifts several months before they appreciate the relation between a person who looks and the object of her gaze.

These findings support two conclusions. First, at the earliest stages, infants' gaze-following seems not to reflect knowledge of gaze as object-directed.

Therefore, researchers should be careful in drawing conclusions about infants' understanding of seeing or attention based only on infants' propensity to follow gaze. However, this is not to say that there is never a relation between gaze-following and infants' understanding of the object-directed nature of gaze. From the end of the first year onward, infants become more skilled at following gaze and negotiating joint attention episodes. For example, infants become able to follow gaze to objects outside their own field of view and to locate the object of an adult's gaze when there are several objects in the same region (Butterworth and Jarrett, 1991). In addition, at the end of the first year, gaze-following becomes embedded in rich joint attention interactions, in which infants actively seek to manipulate the attention of others, and seem to check to see whether their efforts have been successful (Bates *et al.*, 1979; Carpenter, Nagell, and Tomasello, 1998; Schaffer, 1984). These later developments may rest on an emerging understanding of the link between a person and the object of her gaze. Additional investigations are needed to explore this possibility.

The second conclusion derives from a comparison of infants' understanding of grasping and gaze. Even though gaze, like grasping, draws young infants' attention to an object, infants do not seem to understand gaze as an object-directed behavior until several months after they begin to understand grasping as object-directed. These findings indicate that infants do not begin with a propensity to construe all human actions as object-directed. Instead, they seem to discover actor-object relations at different points in development for different kinds of actions. This finding contributes to a more general pattern emerging from the work in our laboratory (Guajardo and Woodward, *in press*; Sommerville, 2002; Woodward, 1999; Woodward, Sommerville, and Guajardo, 2001), suggesting that the earliest stages of intentional understanding are grounded in experience with particular actions and particular actors. This apparent specificity is at odds with several recent proposals that infants are endowed with relatively abstract and general notions of intentionality (Baron-Cohen, 1995; Csibra *et al.*, 1999; Premack, 1990).

#### Discovering the Link between Looker and Object

In discovering the relation between a person and the object of her gaze, there are at least two kinds of evidence on which infants might draw. First, infants might note the behavioral regularities associated with gaze—that is, the ways in which gaze is related to the other actions a person performs. For example, people tend to move toward and act on objects that are the targets of their gaze rather than objects that have not been the targets of their gaze. These behavioral regularities are a critical aspect of the adult's understanding of gaze. Because we understand these aspects of gaze, we seamlessly infer that an opponent on the soccer field will veer in the direction in which her eyes are pointed and that a curious toddler will

reach for the attractive coffee mug he has just spied. For adults, these behavioral regularities provide evidence of underlying psychological states, such as intentions, interests, or desires. Infants may understand the looker-object link at a behavioral level, without yet making inferences about the underlying psychological link between looker and object. It is also possible that behavioral evidence provides one source of infants' understanding of the psychological link between looker and object. As Whiten (1994) has proposed, a detailed behavioral understanding of human action could provide the basis for an insight about the underlying psychological causes of action.

Another route into the understanding of the link between looker and object may be provided by a second source of evidence available to infants—the evidence provided by their own eyes. Infants might reflect on their own experience of seeing, and in some way map this experience onto the gaze behavior of other people. This mapping would provide infants with information about the internal, psychological aspects of attention. This process might occur directly, based on an innate ability to link facial actions of self and other, as hypothesized by Meltzoff and Gopnik (1993). Alternatively, the experience of orienting in response to the gaze of another person could set up the conditions for associating the experience of seeing a particular object with observing the gaze of another person. This mechanism has been proposed by Moore and Corkum (1994) to contribute to the development of joint attention.

Each of these kinds of evidence likely plays a role in children's developing understanding of gaze at some point, and considering each of these kinds of evidence can help to explain the developmental lag in infants' understanding of gaze as object-directed compared to their understanding of grasping as object-directed. To start with, the behavioral information concerning the relation between actor and object may be less clear for acts of looking than for acts of grasping. Whereas grasps involve a physical connection between the actor and the object, gaze involves a relation at a distance. The demands posed by relating entities separated in space may make it more difficult for infants to learn about gaze. In addition, in everyday life, grasping is often accompanied by concrete cues to the actor's underlying intentions, and such cues may be more limited or even absent for gaze. For example, grasping often results in the object being moved closer to the actor, and this could help infants to infer that the actor had the goal of obtaining the object. In contrast, gaze itself has no effect on the object, and the consequences of gaze for the actor are not always obvious. In addition, if infants draw on their own experience of seeing, and seek to relate this to the behavior of other people, the demands of doing this may be greater for gaze than for grasps. Infants can observe their own grasps, but not their own gaze. Although there is evidence that infants can note the correspondence of oral gestures produced by themselves and others (Meltzoff and Gopnik, 1993), there is as yet no evidence as to whether they can do this for the actions of their eyes.

#### INFANTS' DEVELOPING UNDERSTANDING OF POINTING AS AN OBJECT-DIRECTED ACTION

For adults, pointing, like gaze, serves as a spotlight to direct the observer's attention, and also implies an attentional link between the actor and an object. Most of the time in natural interaction, points, like gaze, specify an object at some distance from the actor. Infants begin to orient in response to points later than they do so for gaze. At about 12 months, or perhaps even later, babies begin to follow points at a distance; before 12 months infants are likely to ignore points or look at the pointing hand itself (Butterworth and Jarrett, 1991; Desrochers, Morissette, and Ricard, 1995; Lempers, 1979; Leung and Rheingold, 1981; Murphy and Messer, 1977).

When points occur in physical contact with the referent object, or quite close to the object, they may function as spotlights of attention for younger infants. For example, some researchers report that points very near to an object lead infants as young as 9 months of age to look at the object (Lempers, 1979; Murphy and Messer, 1977; but see Butterworth and Groer, 1988; Desrochers *et al.*, 1995). This instance of spotlighting may not be specific to points, since, as our prior work has shown, contacting an object with an inert hand or mechanical claw also serves to draw young infants' attention to the object (Woodward, 1998, 1999).

Jose Guajardo and I (Woodward and Guajardo, 2002) adapted the habituation paradigm described above to investigate infants' appreciation of pointing as an object-directed action. Given the findings just summarized, we were concerned that infants under 12 months might not follow a point at a distance to the referent object. If this occurred, then infants would have no hope of noting the relation between actor and object. Therefore, in the experimental events, we had the actor touch the toy with her index finger as she pointed. We expected that contact between the actor's hand and the toy would be sufficient to direct infants' attention to the toy.

In our first experiment, we tested 9- and 12-month-old infants. There were forty infants at each age. Half the infants at each age saw events that were very similar to the grasping events, in that only the actor's arm was visible (see Fig. 6.3, panel A). The other half saw events that more closely resembled naturalistic points. The actor was fully visible from the waist up; she made eye contact with the infant and greeted him or her, and then turned to look at and point to the toy (see Fig. 6.3, panel B). We thought that these additional cues might provide further evidence that the point was directed toward the object, and therefore that infants in this condition might respond to the relation between actor and object more strongly than those who saw only the actor's arm. In each condition, infants were habituated to one pointing event. Then the positions of the toys were reversed and infants saw new-toy test events (in which the actor moved her arm in the same way to point at the other toy) and new-path test events (in which the actor moved her arm through a different path in order to point at the same toy).

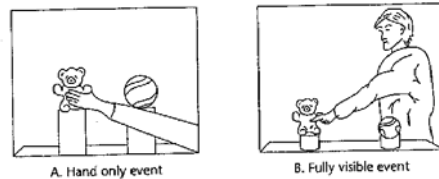


FIGURE 6.3. Sample for the studies of pointing (based on Woodward and Guajardo, 2002).

Our first question was whether we had been successful at directing infants' attention to the toy to which the actor pointed. To address this question, as in prior studies, we coded the amount of time during test trials that infants looked at the object indicated by the actor versus the other object. This coding confirmed that both 9- and 12-month-olds oriented toward the object at which the actor pointed: 92 percent of 12-month-olds and 95 percent of 9-month-olds looked for longer at the indicated object than at the other object during test trials.

The next question was whether infants at either age attended to the relation between the actor and the object of her point, as indicated by their overall levels of looking on new-toy and new-path test events. Counter to our intuitions about the additional information provided when the actor was fully visible, there were no reliable differences between the patterns shown by infants who saw the actor's face versus those who saw just the actor's arm. The main finding was that infants at the two ages responded differently to the two kinds of test events. The 12-month-olds looked longer on new-toy trials than on new-path trials, indicating that they noted the change in the relation between actor and object. In contrast, the 9-month-olds as a group looked equally at the two test events. Further analyses indicated that for 9-month-olds the results varied as a function of the test trial type given first. Infants at this age looked longer at the event they saw first, regardless of whether it was a new-toy or a new-path event. In contrast, 12-month-olds looked longer on new-toy events whether they came first or second. Thus, by 12 months, infants seem to understand pointing as an object-directed action. As is the case for gaze, therefore, infants appear to discover the object-directed nature of points between 9 and 12 months of age.

The finding that 9-month-olds did not show evidence of understanding pointing as object-directed is noteworthy in comparison to the findings from earlier studies indicating that infants 9 months of age and younger understand grasping as object-directed (Woodward, 1998, 1999; Woodward *et al.*, 2001; see also Wellman and Phillips, 2001). Pointing is similar to grasping in several respects: it is a manual action, involving motion in the direction of an object, coordinated

motions of the digits, and, in our studies, physical contact between the actor and the toy. Nevertheless, 9-month-old infants represented the grasping and pointing events differently. These findings lend further support to the conclusion that infants begin with relatively specific understandings of object-directed action, and that they enrich this understanding by discovering the link between actor and object for new actions one at a time.

#### Discovering the Link between Pointer and Object

How do infants discover the object-directed nature of pointing? One possibility is that infants discover this link based on behavioral evidence during interactions with adults who point. Murphy and Messer (1977) found that when mothers point during interactions with their infants, they almost always look at the object of their point, and the onsets of the point and glance co-occur within a very narrow time window. Infants may note this co-occurrence and infer that, like looking, pointing also relates an actor to some object. It is also possible that in parents' behavioral repertoires pointing is probabilistically linked with other behaviors such as approaching, grasping, and handling, and that infants use these behavioral linkages as further evidence about pointing.

In addition to this source of evidence, the timing of the onset of point production, as well as the nature of the first points, suggests another possible contributor to the development of the understanding of points as object-directed. Researchers report the onset of object-directed points as early as 9 months of age (Bates *et al.*, 1979; Lempers, 1979; Murphy and Messer, 1977). Index finger extensions appear much earlier (Fogel and Hannon, 1985), but it is not until about 9 months that points appear to be directed at objects. A number of observers have reported that infants' first object-directed points appear not to be communicative in nature, but rather seem to be an expression of the infant's own attention and interest (Bates *et al.*, 1979; Desrochers *et al.*, 1995; Schaffer, 1984; Werner and Kaplan, 1963).

The appearance of object-directed points beginning at about 9 months of age suggests a means by which infants might learn about the relation between pointer and object: Specifically, infants might draw on their own experience of pointing as an expression of interest to infer that the points of others reflect a similar internal state. That is, infants may seek to relate their own internal experiences and actions to the observable actions of other people, and thereby gain an understanding of the attentional link between a person who points and the object of her point. If this account is correct, then infants' first insight into the object-directed nature of points may arise outside the communicative arena. That is, infants may first understand pointing as object-directed, and only later come to use and understand the gesture in acts of communication.

One prediction of this account is that there should be a correlation between infants' use of object-directed points and their understanding of the link between another person and the object of her point. In a first exploration of this possibility, Guajardo and I (Woodward and Guajardo, 2002) tested forty-eight infants between the ages of 8.5 and 11 months in the same procedure as in the first experiment, except that all infants saw the events from the 'fully visible' condition. In addition, we gathered two kinds of data on infants' own pointing behavior. First, by means of a short questionnaire, we asked parents whether they had observed their infants pointing at objects and also whether their infant seemed to use pointing to communicate. Second, we coded the videotape from each habituation session for the incidence of object-directed pointing. Much of the time the two sources of evidence agreed, but for some infants one but not the other provided evidence of object-directed pointing. We used these two sources of evidence together to determine whether there was any evidence that an infant pointed in an object-directed manner and whether this object-directed pointing was also communicative.

There were eighteen infants for whom there was evidence of object-directed pointing (henceforth, the pointers), and thirty for whom there was no evidence of object-directed pointing (henceforth, the nonpointers). Of the eighteen pointers, eight were rated by their parents as also using points to communicate, and ten were not. Thus, like previous observers, we found evidence for the existence of early, noncommunicative, object-directed pointing. Interestingly, pointing status was not related to age in the group we studied. The pointers were 9 months, 21 days, of age on average (those who used points communicatively had an average age of 9 months, 20 days, and those who did not had an average age of 9 months, 22 days), and the nonpointers were 9 months, 18 days, on average.

Our main finding was that pointing status was related to infants' responses to the habituation events. The nonpointers looked equally on the two kinds of test trials, thus showing no evidence of having noticed the relation between the actor and the object of her point. The pointers looked significantly longer on new-toy trials than on new-path trials, indicating that they noted and responded to the change in relation between the actor and the object of her point. This was true whether or not the infant also pointed communicatively. That is, the critical aspect of pointing behavior seemed to be the production of object-directed points and not the communicative use of points. This finding was not accounted for by differences in overall levels of engagement: pointers and nonpointers did not differ in the number of trials they took to habituate, or the total amount of time they spent watching the test events. Thus between 9 and 11 months, those infants who produced object-directed points also understood points produced by others as object-directed, whereas those who did not produce object-directed points seemed not to understand points as object-directed.

Of course, the existence of a correlation does not provide evidence as to the direction of causality. Infants may begin to produce object-directed points

because they have learned about the object-directed nature of this gesture in others; or, as we hypothesize, they may discover the significance of the pointing gesture in other people based on their own use of the gesture. Until further evidence is gathered, our hypothesis remains a speculation. However, we believe some of the existing evidence supports it. Specifically, infants seem to understand the object-directed nature of points before they use or respond to them in the course of social interactions. Our findings suggest that infants become sensitive to the object-directed nature of others' points between 9 and 11 months. As reviewed above, it is not until after 12 months that infants systematically follow the points of social partners in the laboratory. This ordering of events is inconsistent with the possibility that insight into the object-directed nature of points results from observing the (socially produced) points of adults. If laboratory findings are an accurate reflection of point-following in the wild, then it is possible that infants' propensity to follow points results from their earlier discovery that pointing is an object-directed action.

Our preliminary findings indicate the need for further studies, particularly studies investigating the ontogeny of noncommunicative object-directed points. Because of a preoccupation with finding evidence for the intentional, communicative use of pointing, noncommunicative points have been neglected in the literature. In fact, some researchers report the onset of pointing as relatively late, 12 months or later, because they only count points that are accompanied by evidence of the intent to communicate such as gaze alternation (e.g. Carpenter *et al.*, 1998).

## DISCUSSION

Infants develop in a sea of human action. This sea is packed with information critical for myriad aspects of development. Simply swimming in the sea is not sufficient for infants to gain full access to this information. Beyond just soaking it in, infants must be able to derive well-structured representations of the intentional actions they observe. This is particularly true for attentional and referential actions, such as gaze and pointing. In principle, observing these actions in others could inform infants about the properties of objects (e.g. which things are dangerous, or disgusting, or pleasing), the functions of cultural artifacts, and the meanings of words, as well as information about the behavioral propensities and internal states of the person who performs them. Children's ability to extract this information is dependent, in part, on their understanding that there is an attentional relation between the person and the object of her gaze and/or point.

It has long been known that infants in the first and second year of life respond to gaze and pointing by orienting to the relevant piece of the world. But until recently, little evidence has been available concerning infants' understanding of attentional relations. The findings reviewed in this chapter provide initial insights



into this aspect of social cognition. They indicate that infants are not adrift in the sea of action, but rather, that they have begun to analyze the actions of others in terms of their intentional structure. Our findings suggest three initial conclusions, each of which motivates continued investigation.

1. *Infants discover the relational structure of different actions at different points in development.* Our findings suggest that infants become sensitive to the relational structure of different actions at different points in development. Although infants understand grasping as object-directed by 6 months of age, they do not seem to understand gaze and pointing as object-directed until near the end of the first year of life. Despite the fact that the pointing and grasping events we showed infants were in many ways similar, infants encoded them differently, suggesting that they attend to the fine details of actions. It is not the case that infants begin by encoding all human actions, or even all manual actions, as relational. Rather, infants seem to accrue knowledge about particular actions gradually during the first year of life.

These findings offer an initial foothold into infants' action knowledge, but they leave much of the terrain unexplored. There are many aspects of a mature understanding of pointing, and gaze that are not represented in the simplest construal of these actions as object-directed. The work reported here focuses on the way in which grasping, pointing, and looking are the same—they center on a relation between actor and object. In doing so, it leaves unaddressed infants' understanding of the ways these actions differ from one another, including both the unique mental correlates of each action and the unique behavioral regularities associated with each action. Progress has been made in investigating these issues in older children (see Flavell and Miller, 1998). A critical direction for future investigation is to explore these issues still earlier in ontogeny (Flavell and Miller, 1998).

2. *Infants' propensity to orient in response to an action is distinct from their relational encoding of the action.* There are multiple levels at which infants respond to the actions they observe. At one level, infants may respond to the actions of other people by orienting to specific aspects of the environment. At another level, infants may interpret these actions as instantiating a relation between the person and the object at which his or her actions are directed. Our findings indicate that these two levels of response are not always linked in development. Infants orient in response to a range of events and actions, only some of which they encode as object-directed. Moreover, in the case of gaze, infants show strong orienting responses many months before they become sensitive to the relation between looker and object.

One conclusion from these findings is that infants' orienting responses are not a simple reflection of their underlying comprehension of joint attention behaviors. These findings have strong implications for the approach of inferring infants' comprehension of an action based on their orienting responses. This approach

runs the risk of over- or under-attributing comprehension to infants, and it may entirely miss important components of action knowledge. More generally, our findings suggest that it is misguided to seek a single measure of action 'comprehension'. Both orienting and relational encoding are intelligent responses to the actions of social partners, and these two responses do not exhaust the behavioral propensities or levels of interpretation that infants or young children might engage in.

3. *There are varied developmental relations between these two levels of response.* Considering our findings in the context of the broader joint attention literature suggests that there can be varying developmental relations between orienting responses to and relational encoding of particular actions. In particular, the relation between these two levels of response appears to be different for gaze than for pointing. Infants orient in response to gaze by 3 to 6 months of age, but our findings indicate that it is not until 9 to 12 months that infants understand gaze as an object-directed action. By contrast, infants seem not to follow points at a distance until 12 months at the earliest, around or just after the period when they begin to encode pointing as object-directed.

An important direction for further study will be to verify these patterns within a single population, and in so doing investigate the ways that orienting and relational encoding may impact one another during development. It is possible that in some cases, orienting responses set up the conditions for infants' extracting information about the object-directedness of the action to which they are responding. This may be the case for gaze. Alternatively, in other cases, infants may not spontaneously orient in response to an action until they have gleaned insight into its object-directedness. It is possible that this is true for pointing.

## CONCLUSION

Although infants' responses to gaze and pointing initially follow different developmental pathways, our findings suggest that these pathways converge to yield a more general insight about attentional relations between 9 and 12 months of age. It is at this point that infants begin to construe two distinct actions, one done with the hands and the other with the eyes, as involving a connection between actor and object. This insight would enable infants to extract the rich and multi-faceted information that referential actions can provide. Indeed, recent findings indicate that in the months following their first birthdays, infants do just that. By 12 to 14 months, infants use gaze to predict a person's subsequent actions (Phillips, Wellman, and Spelke, 2002), interpret a person's emotional expressions as being about the object at which she gazes (Moses *et al.*, 2001; Repacholi, 1998), and interpret the words a person utters as naming the object at which she directs referential behaviors (Woodward, 2004).

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