4 Learning from and about the Social World

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In no other period of ontogeny is achievement more critical than in infancy. In the first months, infants must overcome limited coordination, not to mention immature social and cognitive abilities. Infants must achieve feats such as communicating their needs without spoken language; sucking, reaching, and grabbing to explore the world; distinguishing between threatening and safe situations; deciding upon which people to attend to or avoid, whom and what to focus on; and determining how to use the information that people give them. Not only do infants have to master many skills in a few short months, but the way that they achieve these skills and the context in which they achieve them in the early months will set the stage for later development and success.

Human infants engage these developmental tasks in a social context that provides both support and challenge. On one hand, the actions of social partners support infants' attention to and learning about the world. Indeed, much of what children learn in the first years of life depends critically on interactions with social partners. On the other hand, making full use of this rich social support requires that the infant mounts organized and selective responses to others' actions. That is, learning from social partners is a two-way street, requiring social-cognitive capacities in the learner as well as a supportive social context. In this chapter, we consider young infants' ability to meet these challenges in order to learn from and learn about the social world.

Our focus on these issues highlights the role of the environment and experience in supporting developmental achievements. As the chapters in this volume document, the social environment and the experiences it supports have profound and wide-ranging effects on development in

To answer this question, we developed an interpersonal contingency paradigm. In this paradigm, we had a mother and her infant sit in different rooms and interact over a television monitor. Eye-to-eye contact was achieved by filming through one-way mirrors (see Striano, Henning, & Stahl 2006). This setup allowed us to carefully manipulate key elements on the ongoing interaction. We asked the mothers to interact with their infants as they normally would, albeit via a television monitor. What the mothers did not know was that the infants would observe their behavior delayed by one second for part of the social interaction. We chose a one-second delay based on prior research on adult conversation suggesting that matching of speech rhythms is related to perceived quality of interaction and interpersonal attunement. We also know that adult conversational partners tend to match pause duration both within and between turns (Jaffe & Feldstein 1970), and that pauses during speech that exceed a duration of one second are perceived as disruptive (Clark 1996). This "vocal congruence" is thought to reflect interpersonal attunement, as evidenced by more positive ratings of relationships by adults whose speech rhythms are more tightly matched (Feldstein & Welkowitz 1978). In these early face-to-face interactions, parents often mirror the infant's behavior in affective quality and properties such as intensity and rhythm (Stern 1985; Gergely & Watson 1999). Moreover, parental responses generally occur within one to two seconds after an infant's behavior (van Egeren, Barratt, & Roach 2001; Keller et al. 1999; Nicely, Tamis-LeMonda, & Bornstein 1999; Papousek & Papousek 1987). Therefore, in addition to form and content, the timing of parental behavior provides infants with cues for detecting socially relevant behavior.

For the current study we tested approximately 40 3-month-old infants (Striano, Henning, & Stahl 2006). Infants interacted for a total of four minutes with their mother, two minutes which were presented live and two minutes in which the mother's behavior was presented with a delay of one second. In the delay condition, all of the mother's behavior was contingent and all aspects were delayed by one second (the effect being something akin to a long-distance video chat with a slow computer modem). Based on research on early temporal coordination in caregiver–infant interaction (e.g., Beebe et al. 1988; Crown et al. 2002), and given infants' early abilities in temporal perception (e.g., Lewkowicz 2000), we expected that by 3 months of age infants would detect a change in timing of maternal responses. Mothers tend to respond to infants within a one-second range (see Keller et al. 1999; Papousek & Papousek 1987). Also, when talking to 3-month-olds, adults' vocal utterances are less than one second in duration,

and their vocal pauses are close to one second (Stern et al. 1977). Based on this promptness of response latency, the duration of adult vocal phrases and pauses, and the successful use of a one-second time interval in analyses of contingency in mother–infant interaction (e.g., Bigelow 1998; Symons & Moran 1994), we expected that a one-second delay would be within the range detectable by infants.

We measured the amount of time that infants gazed at their mother as a function of condition. We found that at 3 months of age infants gazed reliably more at their mother when she was live compared to when she was delayed by one second. These results show that by 3 months, infants are sensitive to temporal aspects of communicative signals directed at them. Such sensitivity ultimately helps them to achieve new goals, as they are able to attend to more relevant social information and use this to guide their attention outside of the dyad, or into triadic interactions. Sensitivity to interpersonal timing may also come to play a role in triadic contexts in which two partners' interaction is about a third entity, as timing may provide cues about the referential aspects of communicative signals. Understanding referentiality requires understanding that signals are about something and are perceived as being relevant. Relevance of communicative signals is determined not only by the quality of information, but also by the timing of such signals. In studies assessing older infants' understanding of the intentions underlying others' actions (e.g., Carpenter, Akhtar, & Tomasello 1998; Tomasello & Barton 1994), adults utter expressions such as "There!" or "Whoops!" to mark a performed action as a success or failure of achieving the intended goal. The timing of these cues is likely essential for infants to perceive the performed action as intentional or accidental, once they understand intentionality. When 12-month-old infants encounter a new situation and are given the choice between checking someone who has previously engaged with them in a contingent interaction compared to a noncontingent interaction, they selectively look toward the contingent partner. In sum, there is a close link between what infants detect in dyadic interaction and the people they choose to consult when learning about the world. A key to learning achievement in infancy is attending to relevant people.

From Dyadic to Triadic Interaction. By the middle of the first year of postnatal development, interactions become increasingly triadic in nature. Now rather than exchanging and sharing affect, infants increasingly use others to guide their attention to the outside world. These interactions are known as triadic interactions, and they are essential for skills such as language learning and object learning (Tomasello 1995).

This shift from dyadic to triadic interactions is demonstrated in one study in which we had had infants of 3, 6, and 9 months interacting with an adult stranger. Infants sat across from the adult. We measured social interaction between infant and adult in several ways. In one condition, the joint-attention condition, the adult coordinated attention between the infant and a toy on the infant's side. She did this by shifting her gaze between the infant and the toy while talking about the toy in a positive tone of voice. In another condition, the look-away condition, the adult looked away at the toy while vocalizing in a positive way, but without shifting her attention back and forth. We compared these conditions to a normal dyadic (face-to-face) interaction in which the adult talked to the infant and did not look at the object.

We found that at all ages infants discriminated among these three interactive conditions. However, the way that infants discriminated among these types of interactions varied according to age. At 3 months of age, infants preferred the dyadic interaction, whereas, at the older ages, infants preferred (or at least looked more at the adult during) joint-attention interactions (Striano 2004; Striano & Stahl 2005). The likely reason for this is that the demands placed on the 6- and 9-month-olds are very different from the demands placed on a 3-month-old. At older ages, infants are capable of manipulating objects and moving around, whereas at younger ages this is much harder without assistance (Campos & Sternberg 1981). Social interactions between infants and adults start out primarily dyadic (Stern 1985; van Wulfften Palthe & Hopkins 1993). This changes when the need for triadic interactions becomes more important – as infants begin to interact with unfamiliar objects and situations, and as they must become sensitive to cues directed at them. In terms of helping infants to achieve goals, it is important that social contexts are adjusted to the infant's goals and abilities.

Using Social Cues to Learn. A sensitivity to joint attention is essential for learning. For example, by 18 months of age, infants use others' gaze toward objects to learn labels (see, e.g., Baldwin 1993). In order to benefit from triadic attention or joint attention, an infant must have developed an ability to integrate a number of social and cognitive skills. When do infants use triadic social cues to gain information about new things? The function of joint attention for the infant in terms of gaining knowledge remains poorly understood. Few studies have addressed the issue of how triadic interaction involving adult, infant, and object facilitates learning about objects in the surrounding world. Although many studies indicate that infants modify

their own behavior according to the social signals they receive, little is known about the influence of the behavior of the social partner on infants' processing of the surrounding world. Some research has shown that maternal behavior during mother–infant play sessions is related to 4-month-old infants' ability to recognize and discern a familiar from a novel stimulus. Specifically, infants whose mothers were less involved during toy play (e.g., vocalization, visual encouragement of attention) exhibited higher novelty preference – the type of visual preference that is associated with superior information processing (Miceli et al. 1998).

Itakura (2001) tested older infants (9- to 13-month-olds) to assess whether social and nonsocial events led to differential behavior on subsequent visual preference tasks. In this study, infants observed either the mother point to one of two line drawings (social event) or saw one of the line drawings blink (nonsocial event). In both conditions, infants looked longer at the stimulus-enhanced drawing (i.e., the one that was pointed at or the one that blinked). However, when the line drawings were presented again alone (without pointing or blinking), only the infants who were in the social condition showed a significant difference in their preference for the drawing that had been pointed at versus the one at which the mother had not pointed. Thus, looking behavior was influenced by the preceding social and nonsocial events.

In our research we have started to address the issue of how cues provided by adult social partners are beneficial to infants in these contexts. We examined the effects of differing social cues on object processing in 9- and 12-month-old infants (Striano et al. 2006). In a within-subject design, an adult experimenter spoke to the infants about a novel object in one of two conditions. In the joint-attention condition, the experimenter spoke to the infant about the toy while alternating gaze between the toy and the infant. The object-only condition was identical, except that the experimenter looked to the toy and to a spot on the ceiling, but never to the infant. In the test trials, infants viewed the toy used in the social interaction along with a novel toy. The 12-month-old infants looked to the novel toy equally following both conditions. In contrast, 9-month-olds looked to the novel toy significantly longer following the joint-attention condition relative to the object-only condition. These results suggest that joint-attention interactions aided object processing in the 9-month-old infants, but not in the 12-month-old infants. This indicates that, by 12 months of age, infants learned about the object as long as some social cue was provided, whether it was directed only at the object (i.e., object only) or both to the infant and the object (i.e., joint attention).

In subsequent studies, using similar paradigms (see Cleveland & Striano 2007; Cleveland, Schug, & Striano 2007), we were able to show that by 7 months of age infants profited from joint-attention interactions. Learning about objects was enhanced when infants viewed novel toys in the context of a joint-attention social cue. In a series of studies, we tested infants as young as 4 months of age. We found that 4- and 5-month-old infants did not benefit from joint-attention interactions (Cleveland & Striano 2007; Cleveland et al. 2007). This is interesting, given that, by 3 months of age, infants are already sensitive to joint-attention or triadic cues (Striano & Stahl 2005; Striano et al. 2007). However, when we observed their behavior in the types of paradigms described above, we found that they do not show a preference for one object over another. One reason for this result may be the sensitivity of our measure. That is, young infants have a limited behavioral repertoire. May it be possible that their brain is processing information based on social cues that we do not observe in behavior? This is one question that we put to the test.

Infants' Use of Social Cues as Measured by ERP. To assess the way that the infant brain may be detecting social cues and using these cues to process the world, we measure event-related potentials, or ERPs (a more detailed description of our methods can be found in Striano & Reid 2008). Event-related potentials are derived from electrical brain activity related to a stimulus that we present to the infant. This measure can tell us something about the way that infants are processing information over the course of milliseconds and well before the onset of a behavioral response. In the past 10 years, knowledge of how the functional brain develops has increased dramatically (Johnson 2005). One component of the infant ERP that is well mapped in terms of cognitive properties is the mid-latency *negative component*, or Nc. The Nc occurs approximately 300–700 milliseconds after stimulus onset, is most prominent at fronto-central electrodes, and is thought to relate to the development of memory processes during the first 12 postnatal months (Webb et al. 2005). In our study, infants interacted with an adult in one of two conditions. In the joint attention condition, the adult looked at the infant and then at the computer screen, which displayed a new object. In the non–joint attention condition the adult looked at the computer screen only while talking and vocalizing. We measured ERPs as infants looked at the object presented on the screen. For a trial to be included, infants needed to look at the adult and then to the object presented on the computer screen. We predicted an enhanced Nc for objects that infants viewed in the context of joint attention compared to non–joint

attention contexts. Our results confirmed these predictions. We found that at 9 months of age, the infant brain responded differently toward objects that have been cued by joint attention versus non–joint attention contexts. We found an enhanced negativity, which is an index of attention, already at 300 milliseconds after stimulus onset. These results were helpful as they demonstrated the usefulness of this new paradigm to understand how the infant brain processes information as a function of social cues.

Because ERPs provide a more sensitive measure of the way that infants process information, could we also find signs that much younger infants were gaining something from joint attention interactions? Recall that behavioral findings showed that at 4 and 5 months of age, infants did show evidence of differential attention to objects when these were presented in a joint attention context. In a recent study, we asked whether 5-month-old infants would process objects better as a function of joint attention contexts. The setup differed from the prior study in a couple of ways. Infants interacted with an adult in two different ways. In one condition, the joint attention condition, the adult looked at the infant's face and then to the object on the computer monitor and back to the infant. In the non–joint attention condition, the adult looked at the infant's chest and then to the object on the computer monitor and back to the infant's chest. This way we were able to control for movement cues and facial information. What differed across conditions was that there was direct eye contact in the joint attention condition and not in the non–joint attention condition. Following an interaction phase in which infants saw objects in these two conditions, they were then presented again with the objects. Like in the prior study, we measured how 5-month-old infant brains processed information as a function of social interaction. We found an enhanced Nc after stimulus onset when objects were presented in the context of joint attention interaction (Parise et al. 2008). These results were parallel to what we found with the 9-month-olds. What is important to recall is that at 5 months of age, in the behavioral studies (Cleveland et al. 2007) we did not see evidence that infants used joint attention cues. When we used a more sensitive measure, however, and in particular when we assessed how the brain was processing information in joint attention contexts, the picture was different. The sensitivity to joint attention cues was more than a sensitivity; it was functional – at the level of brain activity. We have obtained similar results with infants as young as 3 months of age (Hoehl, Wiese, & Striano 2008; Hoehl & Striano 2008) and extended these findings to language learning (Hirotani et al. 2009).

These results are important because they suggest that brain measures can give us information about development that behavior alone cannot. It

also shows that although young infants primarily engage in dyadic interactions, they are using social cues to learn about the world in very specific ways. Social cues not only guide infants' attention to the external world, but infants are picking up on the precise referents of these social cues (Hoehl et al. 2008; Hoehl & Striano 2008). This is important not only for understanding the relation between brain and behavioral development across typical ontogeny, but especially for the early identification of infants who may be at risk for later social cognitive impairments such as autism. That is, we predict that an infant whose brain is not manifesting enhanced processing of relevant social information might be at risk for a range of impairments. We expect that many infants would have difficulty in parsing social information, in detecting the relevance of information, and in using these cues to interact and learn most effectively.

Implications. In order to achieve learning, infants must attend to relevant social cues. Caregivers, in turn, must be sensitive to the rapidly developing cognitive, motor, and perceptual skills that influence which cues are advantageous. These findings show that the mechanisms that give way to language and object learning start in very early infancy. For this reason, it is important to engage infants in person and object play in the early months, whether this is at home or in school settings. These findings also suggest that using sensitive measures such as event-related potentials may be one way to predict some infants who may show later social or cognitive impairments.

Learning about Social Partners

The research just described makes clear the critical role of social partners in guiding infants' engagement with and learning from the external environment. This process is a two-way street, with adult behaviors and infant sensitivities working hand in hand from the start. As this process plays out, infants are also learning about the social partners with whom they are interacting. Specifically, during the first years of life, children come to view other people as intentional agents, understanding that human movements are structured by goals and states of attention rather than simply being physical movements through space. We turn now to focus on this aspect of social cognition – the ability not only to attend and respond to others' actions, but also to conceptualize others' actions as intentional.

This ability to analyze others' actions as intentional is of fundamental importance. By adulthood, it pervades social cognition from the initial encoding of event structure to long-term memory for, reasoning about, and

communication about events (see Shipley & Zacks 2008). In development, intention understanding undergirds the conceptual distinction between animate agents and inanimate objects, provides a critical foundation for language learning (Baldwin & Moses 2001; Tomasello 1999), and provides the foundation for children's emerging theory of mind (Barresi & Moore 1996; Wellman 1992). How early can this cornerstone of social cognition be traced in development?

Observers of infant social behavior have long hypothesized that infants understand other people as intentional agents. Indeed the rich and adaptive social sensitivities described in the first half of this chapter can be construed as being driven by infants' understanding of others as intentional agents. However, on their own, infants' spontaneous responses to others' actions often leave open the question of whether, and when, infants represent others' actions as intentional. On one hand, infants' social responses may lead to overestimation of their intention understanding. To illustrate, debates have persisted as to whether infants' spontaneous tendency to follow others' gaze direction reflects an understanding of the person's state of attention (e.g., Bretherton 1991; Tomasello 1995) or instead is driven by behavioral conditioning or other low level factors (Moore & Corkum 1994). On the other hand, reliance on infants' overt social responses can also lead to underestimation of infants' understanding of others' intentions because infants may understand something about others' intentions before they can control complex social responses. To illustrate, it has been argued that the lack of robust triadic and communicative behaviors early in the first year of life reflects a lack of insight into others' intentions (e.g., Behne et al. 2005; Tomasello 1999). However, as we describe next, there is now strong evidence against this conclusion.

To gain clearer insights into the nature of infants' understanding of intentional action, researchers have recruited visual habituation methods, which are appropriate for even very young infants and can provide insight into how infants represent the structure of events. Infants, like adults, tend to look longer at novel stimuli following habituation to a repeated stimulus. Thus, infants' visual responses can shed light on their conceptualization of observed events because they provide evidence concerning the kinds of changes infants detect and attend to. A common approach is to compare infants' responses to post-habituation test events that alter either the perceptually obvious surface properties or the conceptually central aspects of the original event. In the social domain, this approach has been recruited to ask whether infants represent others' actions as structured by intentions rather than as simply physical movements through space. This approach

has yielded several critical insights concerning infants' knowledge about their social partners. We turn to these now.

Early in the First Year of Life, Infants Discern the Intentional Structure of Others' Actions

Adults view even the simplest, most concrete actions as driven by intentions. Imagine a woman who reaches across a table to grasp a coffee cup. Although the movement of the woman's arm could be described in purely physical terms, that is not how we see it. Rather, we understand the action as goal-directed (she is reaching for the coffee cup) and thus we view the relation between the woman and the cup as more central to the event than the details of her movements. By 5 months of age, infants see it the same way. Having been habituated to an event in which a person reaches for and grasps an object, infants respond selectively to changes in the goal of the action compared to changes in the physical movements involved (Woodward 1998; see Woodward 2005, and Woodward et al. 2009 for reviews). That is, infants show a strong novelty response (sustained looking) when the actor moves through the same path to grasp a new object and no such response when the actor moves through a new path to grasp her prior goal object. These findings indicate that infants represent human actions in terms of the relation between agent and goal, that is, as goal-directed. Recently, we found that young infants' understanding of action goals is evident not only in their visual responses to others' actions, but also in their overt social responses. Seven-month-old infants selectively imitate the goals of actions they have observed (Hamlin, Hallinan & Woodward 2008; Mahajan & Woodward in press).

Critically, infants' response to action goals is selective for events involving animate agents and goal-directed actions. Infants do not respond to "goal" changes when the moving entity is not readily identified as an agent (Guajardo & Woodward 2004; Hofer, Hauf, & Aschersleben 2005; Mahajan & Woodward in press; Woodward 1998), or when the action is ambiguous (Hamlin et al. 2008; Luo & Johnson 2009; Woodward 1999). Across several experiments, infants have been presented with control events in which an inanimate object or a hand in an ambiguous posture that moves toward and contacts an object (e.g., Biro & Leslie 2007; Hamlin et al. 2008; Hofer et al. 2005; Mahajan & Woodward in press; Woodward 1998, 1999). These events entrain infants' attention in much the same way that intentional actions do – infants look at the contacted object in all cases. However, infants do not respond selectively to changes in the relation between "agent" and "goal" for these events. Taken together, the findings from these experiments indicated

that by 5 months, and in some cases 3 months (Gerson & Woodward under review; Sommerville, Woodward, & Needham 2005), of age infants do more than simply follow others' actions – they represent others' actions as goal-directed.

Infants' Understanding of Goal-Directed Action Is Enriched over the First Year of Life. Often findings of systematic abilities in young infants are taken as evidence that the abilities are innate, arising independent of experience. However, recent findings in the social domain highlight the plasticity of infants' knowledge. Infants' understanding of intentional action undergoes developmental change during the first year, and these changes suggest a strong role for experience.

Infants' sensitivity to action goals is first evident for simple, concrete actions, such as grasping or moving objects, by 5–6 months of age (Biro & Leslie 2007, Luo & Johnson 2009; Woodward 1998, 1999). Under supportive conditions, described in the next section, this sensitivity is evident at 3 months of age (Gerson & Woodward under review; Sommerville et al. 2005). However, a number of aspects of intentional action that are obvious to adults do not seem to be obvious to infants until later in the first year of life. To start, adults readily understand not only the goals that structure individual actions, but also the higher-level plans that structure strings of actions. For example, on seeing someone use a tool to obtain an object that is too far away to reach directly, adults readily understand the actions on the tool as being directed at the object, rather than only at the tool itself. That is, adults understand the actions on the tool as the means to the end of obtaining the object. By 10–12 months, infants engage in similar means–end reasoning, showing selective attention to changes in the ultimate goal as compared to changes in the tool used (Sommerville, Hildebrandt, & Crane 2008; Sommerville & Woodward 2005; Woodward & Sommerville 2000). Before 10–12 moths, infants seem unable to detect action plans, and, in some cases, misinterpret actions as only directed at the means, not the end (Sommerville & Woodward 2005).

Adults readily detect intentional actions that do not involve concrete contact with the object, for example, the intentional connections inherent in acts of attention. When a person turns to look at something, adults automatically infer a mental connection between the person and the object at which her gaze is directed. As detailed earlier, young infants are extremely sensitive to others' eyes and spontaneously follow their gaze shifts. However, these responses do not guarantee that infants understand the intentional relation between a person and the object of her attention. Indeed, using

the visual habituation paradigm, we found that 7-month-old infants follow an adult's gaze to an object under conditions in which they fail to compute that the adult is looking at the object (Woodward 2003a). Infants viewed a person who turned to look at one of two toys repeatedly during habituation. Then the locations of the toys were reversed and infants saw test events which disrupted either the relation between the person and the object of her attention (she turned to the prior side to fixate the other toy) or the person's physical movements (she turned to the other side to fixate the same object). Seven-month-old infants systematically followed the person's gaze to the objects, but they did not respond (with longer looking) to the change in relation between the person and the object of her attention. Twelve-month-old infants, tested in the same procedure, not only followed the adult's gaze, but also encoded the relation between the adult and the object of her attention, that is, they represented the adult's gaze as being object-directed (Woodward 2003a). Under more supportive conditions, 9-month-old infants have also shown sensitivity to the object-directed nature of gaze (Johnson, Ok, & Luo 2007). Further, by early in the second year of life, infants can use information about a person's focus of attention to predict and interpret her subsequent actions, integrating information about a person's focus attention with other aspects of her intentional action (Onishi & Baillargeon 2005; Phillips, Wellman, & Spelke 2002; Sodian & Thoermer 2004; Southgate, Senju, & Csibra 2007; Vaish & Woodward under review).

Central to mature folk psychology is the understanding that intentions reside within the person. By 3 years of age, children's explicit folk psychology represents intentions as "in the head" of the agent, that is, as private states (Wellman 1992). In addition to its conceptual significance, understanding the personal nature of intentions is critical for on-line social reasoning, allowing for the effective tracking and integration of a person's actions over time. Recent findings indicate that the seeds of this aspect of intentional understanding are evident by late in the first year of life, when infants begin to track action goals as specific to the individual agent. By 9 months of age, infants' propensity to track action goals in the habituation experiments described earlier is modulated by changes in the agent's identity. When the identity of the actor changes between habituation and test trials, infants no longer respond to changes in the action goal. That is, infants seem not to view the first actor's goals as relevant to the second actor's actions (Buresh & Woodward 2007). In contrast, when the actions involved information that should generalize across different individuals, in this case, the use of a linguistic label, infants used the first actor's actions to interpret the second actor's actions (Buresh & Woodward 2007). Therefore, by 9 months

infants are able to integrate information across different agents, but, like adults, they seem to understand that an individual's goals are person specific. Although these findings cannot tell us whether infants view goals as mental states per se, they do suggest that infants have begun to understand goals as residing in the individual.

To summarize, over the first year of life, infants' initial sensitivity to action goals grows into richer, more abstract conceptualizations of intentional action that reflect key aspects of mature folk psychology. Early in the first year of life, infants view a person's concrete actions as organized by goals. By the end of the first year, they can discern the higher-order plans that organize actions, they understand that people are connected to the objects of their visual attention, and they understand that intentions reside in individuals. These achievements provide the conceptual foundation for theory of mind. Indeed, recent findings demonstrate longitudinal continuity between these infant abilities and later explicit theory of mind. Infants' responses in visual habituation experiments that tap early intention understanding predict their subsequent responses, as preschoolers, on verbal theory-of-mind tasks (Wellman et al. 2004, 2008).

Infants' Sensitivity to Goal-Directed Action Is Related to, and Informed by Experience. Findings that infants' intentional action knowledge develops during the first year raise questions about the processes that drive these changes and suggest a strong role for learning and experience. Pursuing these issues requires departure from both typical ways of thinking about infant conceptual development and typical ways of studying it. When visual habituation techniques first revealed conceptual structure in infants, it was assumed that these abilities arose independent of experience, the product of evolved systems for ensuring the presence of basic conceptual abilities that are critical for survival (e.g., Spelke et al. 1992). However, basic, universal, and early-emerging abilities may also reflect the contributions of early and universal aspects of experience. Indeed, developmental systems often recruit reliable aspects of the environment to ensure the development of species-typical abilities. For example, bird song, navigation, and social imprinting in various species all depend on information from the environment to develop typically (Gallistel et al. 1991; Gottlieb 1991; Marler 1991). Certainly the ability to view others' actions as intentional is both a universal (in all typically developing humans) and critical for survival, and, as just described, this ability is evident during infancy. But these facts do not license the conclusion that this ability emerges independent of experience.

To establish how experience contributes to infants' social cognitive development, new kinds of empirical approaches are needed. Typically, infant cognition studies take a "snapshot" approach, testing what infants know at different ages, but not investigating the ways in which this knowledge varies among individuals or relates to variations in experience. In our work, we have begun to work against this trend, taking two strategies. First, we have undertaken correlational studies testing whether and how infants' emerging understanding of intentions relates to variations in the experiences that may contribute to this knowledge. Although correlational studies cannot support strong conclusions about causation, they do provide ecologically rich evidence about how infants' cognitive abilities relate to their broader experiences. Second, informed by correlational findings, we have begun to conduct intervention experiments, in which we alter infants' experience and assess the effects of this on their sensitivity to others' intentions.

Two general hypotheses guided our investigation of the factors that may contribute to infants' intentional action knowledge. First, it has been hypothesized that infants' own experience as intentional agents provides them with insights into others' intentions, helping them to understand others as "like me" (e.g., Meltzoff 2007; Tomasello 1999). Second, it has also been hypothesized that infants' engagement with social partners provides insights into others' intentions (e.g., Barresi & Moore 1996). Testing these general hypotheses requires methods that index infants' intention understanding independent of the factors that are hypothesized to affect it, and therefore we have recruited visual habituation methods as measures of infants' intention understanding in these studies (see Brune & Woodward 2007 for a discussion).

We began by focusing on periods during which infants' intention understanding is beginning to emerge and thus is variable across individuals. During these periods of emergence, we investigated the factors that correlate with infants' intention understanding by testing infants in both visual habituation methods and measures of their own actions and interactions with others. Our findings indicate that both kinds of factors correlate with infants' emerging intention understanding. To start, developments in infants' own actions correlate with developments in their sensitivity to others' intentions. At 10 months, infants are variable in their understanding of others' means–end actions, and this variability correlates with their own actions. Infants who are relatively skilled at means–end actions understand others' actions on tools as directed at the ultimate goal, whereas infants who are less skilled interpret the actions as directed at the tool itself (Sommerville & Woodward 2005).

Further, we found that variation in infants' experiences also correlates with their understanding of the object-directed nature of attention. As noted earlier, by 12 months, infants are sensitive to the relation between a person and the object of her attention, but younger infants are more variable in their sensitivity to this relation. Brune and Woodward (2007) tested a group of 10-month-old infants, assessing their understanding of attentional relations using habituation paradigms like those described earlier, for events involving gaze and events involving pointing. We also assessed infants' social responsiveness and social experiences, measuring their propensity to follow an adult's direction of gaze, their production of object-directed points, and their engagement with their caretakers in "supported" joint attention (i.e., times when the parent's actions draws infants into triadic attention).

Our findings revealed a pattern of specific relations among the factors we assessed. To start, although infants followed others' gaze robustly, gaze-following did not relate to infants' understanding of others' attention, thus pointing out that social responses may not always reflect underlying knowledge about others' actions. But other factors did correlate with infants' attention understanding. Infants who produced object-directed points understood others' points as implying a relation between the person and the object at which she pointed. Thus, in this case, infants' own actions correlated with their understanding of others' actions (see also Woodward & Guajardo 2002). We also found that infants' social experience correlated with their understanding of others' actions: Infants whose parents engaged them in more supported joint attention showed a stronger understanding of the object-directed nature of others' gaze shifts.

Taken together, these correlational findings raise the question of whether these aspects of infants' experience render changes in their intention understanding. We have begun to address this question by investigating the effects of infants' own actions on their understanding of others' actions. The strategy in these experiments is to intervene to support infants' engagement in a new form of goal-directed activity, and then assess the effects of this intervention on their understanding of others' actions. We began by testing infants at 3 months, an age at which infants do not typically show sensitivity to the goal-structure of others' actions and at which their own goal-directed actions are quite limited. Infants at this age are not yet skilled at reaching for objects, but they can learn to use Velcro-covered "sticky" mittens to apprehend objects by swiping at them (Needham, Peterman, & Barrett 2002). We tested whether engaging in sticky mittens actions would lead infants to view others' actions as goal-directed, and found that

it did: After sticky mittens practice, infants responded selectively to the goal-structure of reaching events that they observed in the habituation paradigm (Sommerville, Woodward, & Needham 2005). In recent work, we have found that infants' own engagement in the actions is critical. Infants who simply observe others using the mittens do not show the same benefit (Gerson & Woodward under review). Similar effects have been found in older infants as well: Infants who are trained to use a tool to retrieve a toy subsequently show sensitivity to the means–end goal structure of others' actions, and, as is the case for younger infants, this effect seems to depend on infants' own production of the action (Sommerville et al. 2008).

These findings demonstrate that infants' experiences, in this case their experience producing goal-directed actions, influence their understanding of others' actions. Self-produced experiences have long been assumed to be critical for development broadly construed (e.g., Piaget 1929). The current findings elucidate one way in which this broad assumption is true: Infants' engagement in actions that are structured with respect to a goal informs their analysis of others' actions as structured by goals. These results are consistent with recent hypotheses that developing social knowledge is structured, in part, by systems that govern the child's own actions (Decety & Sommerville 2003; Gerson & Woodward in press; Meltzoff 2007). Indeed, recent findings indicate that that these effects in infants may be mediated by neurocognitive representations in motor cortex that subserve both action production and action perception (Southgate et al. 2009).

These findings raise the question of whether and how other kinds of experiences, in particular interactions with social partners, shape infants' understanding of others' actions. Consistent with a number of proposals, our correlational findings (Brune & Woodward 2007) suggest that infants' engagement in triadic interactions with caretakers may support their understanding of attention in others. More generally, as hypothesized by Barresi and Moore (1996), we expect that situations in which infants are able to align their own intentional states with those of social partners may be particularly powerful contexts for helping them to understand others' intentions. Such contexts could include not only triadic attention, but also engagement in collaborative instrumental actions and emotion sharing. These issues are ripe for further investigation.

Chapter Conclusions

Human infants develop immersed in the social world, surrounded by the complex and potentially informative actions of other people. As we have

reviewed here, recent findings show that infants are prepared to thrive in this sea of action in two critical ways. To start, infants are highly responsive to others' actions, including the timing of others' contingent responses and their patterns of visual attention. Infants respond selectively to others' actions – differentiating between contexts in which attention is or is not directed at them, distinguishing between well-timed and ill-timed social responses, and using others' attention to guide their own attention to objects. Second, infants not only respond in adaptive ways to their social partners, they also understand social partners as intentional agents. Infants understand others' actions not as purely physical movements through space, but rather as actions structured by goals and objects of attention. Early in the first year, infants' show initial understanding of the intentional nature of others' actions, and this understanding broadens over the first year of life. Recent findings highlight the plasticity of this early-emerging social knowledge, indicating a strong role for experience in its development.

Thus, in the first year of life, infants are actively engaged in both *learning from* and *learning about* their social partners. The relation between these two aspects of early social learning seems obvious, but, surprisingly, has rarely been directly studied. Investigators tend to focus either on measures of social responsiveness or on measures of intention understanding, with few attempting to put the two together. The study by Brune and Woodward (2007) is an exception to this rule, and its findings suggest that there is a much to be learned by integrating these two approaches.

We suspect that the interactions between learning-from and learning-about are bidirectional. Infants' early sensitivity to critical aspects of human behavior seems likely to set the stage for discoveries about the intentions that structure others actions. For example, infants' close attention to others' eyes and gaze shifts not only leads infants to engage in triadic attention, it may also create conditions under which infants can align their own states of attention with those of others, and this may help infants to understand attention in others (see Barresi & Moore 1996). In turn, as infants attain new levels of intention understanding, these new insights seem likely to inform their future learning from social partners. Indeed, social learning in the second year of life recruits the aspects of intention understanding that emerge in the first year of life. As examples, by 18 months, infants use others' states of attention to inform their word learning (Baldwin & Moses 2001), and they use an analysis of others' action goals to inform their imitative learning (Meltzoff 1995).

Both vantage points on early social learning, considering how infants learn from and learn about others, highlight the role of experience in

shaping foundational developmental abilities. Infants are attentive to and cognitively engaged with the actions of others. This engagement sets the foundation for later social learning, including the acquisition of language, culture, and systems of human knowledge they support.

Acknowledgments

The research reviewed in this chapter was supported by the Sofja Kovalevskaja Award of the Alexander von Humboldt Foundation to T. Striano and by grants from NICHD (R01–HD35707) and NSF (0446706) to A. Woodward.

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