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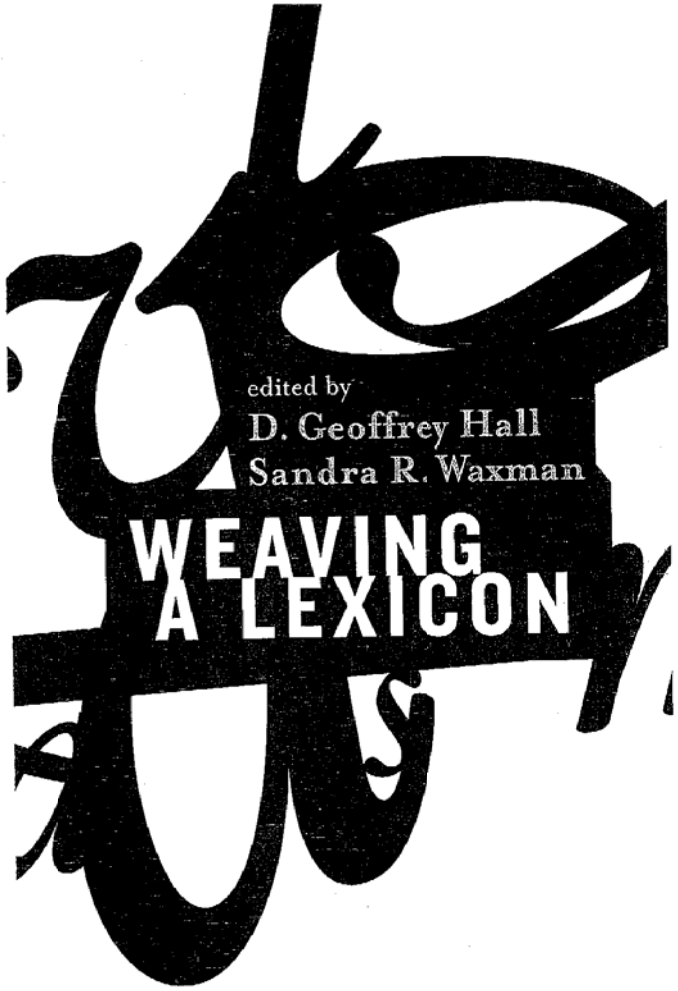

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Infants' Use of Action Knowledge to Get a Grasp on Words

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Word learning is both an act of associative learning and an act of symbolic learning. Words are associated with their referents in the minds of language users. In addition, mature users understand the specific kind of relation between a word and the aspect of the world it goes with, namely, that the word is a symbol used to refer to that object, property, or action.[1] This aspect of linguistic knowledge rests on more general folk psychological concepts such as attention and intention—when a word is used referentially, the speaker's intention is to draw attention to a particular entity by its use, or to call to mind a particular idea in her interlocutor. Both the associative and symbolic aspects of learning are critical. Without the ability to retain and organize associations in memory, it would be impossible to build a lexicon. And, as many theorists have pointed out, the language-learning enterprise would not get far without an understanding of the referential nature of the link between words and the world (Akhtar and Tomasello 2001; Baldwin 1995; Macnamara 1982; Tomasello 1999).

There is a long-held view that one of these aspects of word learning precedes the other in ontogeny. Specifically, it has been proposed that infants begin only with the very general ability to associate stimuli that co-occur, and thus learn to associate word sounds with the perceptual impressions with which they are usually experienced. In this view, the first words are disembodied associates, learned only by virtue of their contiguity with some aspect of the environment

(e.g., McShane 1979; Werker et al. 1998; Oviatt 1980). To illustrate, Werker and colleagues (1998) suggest that receptive word learning in 14-month-olds reflects the understanding that a given word "goes with" some object, but not that it "stands for" that object. These accounts further propose that at some point, this unconstrained associative learning is replaced by "truly linguistic" word learning. Some propose this change to take the form of a relatively sudden insight into the symbolic nature of words, analogous to Helen Keller's famous experience at the well (McShane 1979). Others suggest a more gradual transition, in which, over the course of successive associative-learning trials, infants become sensitive to the referential nature of words. Hollich and colleagues (Hollich, Hirsh-Pasek, and Golinkoff 2000) propose a related model. Although they believe that infants begin with a concept of reference, this concept is initially quite limited. They write,

> At first ... words label what the child has in mind. That is, reference is dominated by the child's tendency to associate a word with the object, action, or event that is temporally contiguous and/or perceptually salient, much as they learn the link between any two contiguous events. Later ... the child comes to perceive the intentionality of others and can then become an apprentice to a master language user. The child comes to realize the full symbolic nature of language. (p. 27)

In this chapter, I will take issue with this general view. I will argue that it is unlikely that infants ever begin by treating words as disembodied associates. In the infant's world, words are actions, and infants most likely draw on their understanding of action in making sense of words from the very beginning. In his classic analysis, Macnamara (1982) proposed that in ontogeny, the concept of reference is derived from an understanding of acts of referring. I will follow this proposal, considering what infants know about acts of referring, and in particular, how this knowledge might draw from developing concepts of intentional action. I will depart from Macnamara's analysis on a critical point: Macnamara was pessimistic about the possibility that concepts of referring or intention could be learned, and therefore proposed that this knowledge is innately given. However, researchers have recently suggested mechanisms by which intentional understanding could be constructed, and empirical work has

begun to lend support to these ideas (Baldwin and Baird 2001; Baldwin and Moses 1996; Barresi and Moore 1996; Gopnik and Meltzoff 1997; Woodward, Sommerville, and Guajardo 2001). These new ideas and findings bode well for the enterprise of constructing a developmental account of reference. As a first step in this enterprise, I will discuss recent findings that indicate the kinds of action knowledge that could contribute to infants' word learning, and the ways this knowledge might provide the basis for a developing understanding of acts of referring.

5.1 Two Ways That Adults' Actions Could Impact Infants' Word Learning

In investigating the development of word learning, it is important to consider the social context in which this learning occurs. Infants learn words from social partners who have strong effects on their attention, and, therefore, potentially strong effects on what they learn. At one level, adult actions direct infants' attention to particular parts of the world at particular points in time, and these shifts in attention could set the conditions for infants' learning to associate words with referents. For example, parents sometimes manipulate infants' attention by holding up or moving objects as they say the name for the object (Gogate, Bahrick, and Watson 2000), or pointing toward the object, thus setting up strong contiguity between hearing the word and seeing the referent. In addition, infants are sensitive to gaze direction from early in life (Butterworth and Cochran 1980), orienting their own eyes toward the objects others look at. Therefore, parents' patterns of gaze could highlight certain objects at the moment the relevant labels were uttered. If infants began only with very general associative-learning tools, these parental behaviors could ensure that they learned the right associations at least some of the time.

At another level, intelligent word learners do more than shift attention in response to the behaviors of their interlocutors. They interpret these actions as directed at, or related to, particular entities. For example, they understand that a person who looks at an object is likely to be attending to that object, and a person who

points at an object both attends to it and intends for someone else to attend to it. A learner with this level of knowledge would be much more successful at acquiring the correct word-world associations, not being fooled, for example, by the coincidence of staring at the cat at the moment her mother says "Time for your nap." More critically, an intelligent learner would be much further along in getting the right kind of mapping. She would be closer to interpreting the word not as a disembodied associate of the referent object, but instead, as a symbolic tool for referring to the object.

The work of Akhtar, Baldwin, Tomasello, and others has provided compelling evidence that by 18 to 24 months of age infants are intelligent word learners of this sort (see Akhtar and Tomasello 2001; Baldwin 1995; Baldwin and Tomasello 1998; Tomasello 1999 for reviews). Across many experiments, children at these ages respond in ways that suggest they are tracking the experimenter's intentions, and using this information to interpret the words she uses. They link words with referents when the speaker is linked to these referents by gaze and pointing, but not when these links are absent, and when the speaker appears to act purposefully but not when he or she acts apparently accidentally. Moreover, 18- to 24-month-old children can use behavioral evidence of attention and purposefulness to determine which of several potential referents was the intended referent, even in the absence of contiguity between the word and its referent.

Word learning, both productive and receptive, begins well before 18 to 24 months—half a lifetime or more earlier, by 9 to 12 months (Benedict 1979; Fenson et al. 1994; Huttenlocher 1974). Moreover, by 14 months infants are such expert word learners that they can acquire a new word-object mapping in the laboratory under conditions that are somewhat to extremely artificial (Schafer and Plunkett 1998; Waxman and Booth 2001; Werker et al. 1998; Woodward, Markman, and Fitzsimmons 1994). One possibility is that at this early point, infants learn words as disembodied associates, influenced, perhaps, by the attentional shifts induced by adult actions. Another possibility, however, is that even at this early point, infants draw on an analysis of the speaker's actions in order to interpret words.

5.2 A Test of Infants' Sensitivity to Referential Actions in Word Learning

If words are initially learned as unconstrained associates, the main determiners of word learning should be the contiguity between the experience of the word and the experience of the referent. To test whether this model is accurate, I borrowed a page from Baldwin's book, adapting her procedures for use with younger infants (Woodward 2003b). In prior work, I had had success in teaching 13-month-old infants new words in a brief laboratory session, using a specially designed multiple-choice paradigm as a measure of receptive learning (Woodward, Markman, and Fitzsimmons 1994). I used this paradigm in the current study. The goal was to equate the extent to which infants had their attention drawn to an object at just the moment a label was uttered, while varying whether or not the speaker was linked to the object by referential behaviors such as looking and pointing.

Two groups of 13-month-old infants were introduced to a novel word and a novel object. Infants in both groups encountered very similar situations. They sat at a table, across from two researchers. The first researcher established joint attention on the object with the child, calling her attention to it, and directing gaze and points toward the object. For both groups of infants, just as the infant looked at the toy, the second researcher uttered a nonce word, saying for example "Look Alice, it's the gombie." The procedure for the two groups differed only in terms of the second researcher's referential actions. For infants in the "object-reference" condition, the second researcher looked at and pointed toward the object of the infant's own attention. For infants in the "ambiguous-reference" condition, the second researcher looked at a video monitor, never looking or pointing toward the objects, and never looking at the infant during the procedure. In this case, the second researcher watched the camera feed on the monitor, so that she could time her utterances to coincide with the infant's attention to the object. Infants heard the new label a total of nine times during the training phase. They were also introduced to a second novel object, which

was not labeled. This second object served as the distractor on the comprehension test. To control for preferences for one particular object over another, every infant saw the same two objects. Half the infants had one of them paired with the label and the other half had the other one paired with the label. After training, a third experimenter entered the testing room and administered a multiple-choice test to assess the infant's comprehension of the new label. As in our prior studies, so that she could not influence infants' choices, this experimenter did not know which of the two objects had been paired with the label or whether the infant was in the object-reference condition or in the ambiguous-reference condition. She put both objects in a tray and asked the infant to "Get the gombie."

To test whether the manipulation played out as intended, we first coded infants' attention to the object and the experimenters during training. Our goal was to hold constant the attention-directing effects of the interaction, while varying the behavioral connection between the speaker and the object. First, we investigated the overall effects on infants' attention in the two conditions. Infants in the two conditions showed nearly identical patterns, attending most of the time to the object, then to the labeler, then to the experimenter who established joint attention. Next, we assessed the contiguity between infants' hearing the label and seeing the object. For each of the nine label utterances, we coded where the infant was looking at the time the label was uttered. Again, infants in the two conditions showed nearly identical patterns—both groups looked at the toy on average for three trials, the labeler five trials, and elsewhere on the remaining trial. Thus, infants in the two conditions had their attention directed in similar ways, and experienced the same degree of contiguity between hearing the word and seeing the referent object.

Nevertheless, infants in the two conditions performed quite differently on the comprehension test. Infants in the object-reference condition systematically chose the previously labeled object. In contrast, infants in the ambiguous-reference condition performed randomly on the comprehension test. Despite the fact that these infants had the object highlighted in attention and reliably paired with the word in the course of joint engagement with an adult, they did not form a mapping between word and object. Even early in the second

year, then, infants seem to require behavioral evidence for a referential connection between a person who utters a new word and the potential referent. In fact, a couple of infants gave us tantalizing evidence that they were trying to interpret the ambiguous labels as referring to some thing. When asked to "Get the gombie" they walked over to the video monitor, looking around as if searching for some object in that vicinity.

It is easy to see how the infants in the ambiguous-reference condition might have been fooled by our manipulation. After all, they were engaged in joint attention on the object at just the moment the word was uttered. But the infants were not fooled. They closely monitored the actions of each of the experimenters, and used this information to inform their word learning. From the earliest point that we can measure word learning in the laboratory, then, infants do not respond to words as sounds from nowhere. Neither are they blindly pushed about by the attention-directing behaviors of adults. These findings are inconsistent with the view that infants begin as general-purpose associators, linking in memory any experiences that reliably co-occur. They indicate that from very early on, infants filter their word learning through their understanding of action. These findings are consistent with other recent reports suggesting that early in the second year, infants are sensitive to referential actions in the context of hearing a new word (Baldwin and Tomasello 1998; Hollich, Hirsh-Pasek, and Golinkoff 2000).

These findings make sense when we consider that words, as first encountered by infants, are actions. Mature language users understand words as symbols with a life of their own—interpretable when heard on the radio, typed on a page, or scrawled on a wall. But for babies, words are first encountered as human behaviors. This leads to the question of the kinds of action knowledge infants have at their disposal to recruit in word learning.

5.3 Infants' Sensitivity to the Relational Structure of Action

In recent work, my students and I have investigated aspects of early action knowledge that might scaffold infants' initial interpretation of words. We have found that prelinguistic infants understand that

certain actions center on the relation between an agent and some object in the world. From an adult standpoint, this "object directedness" is a property of many intentional actions (Barresi and Moore 1996; Wellman and Phillips 2001; Woodward 1998; Woodward, Sommerville, and Guajardo 2001). As Barresi and Moore (1996, 107) described, adult folk psychology "represents the activities of agents that are directed at objects. Such activities include simple purposive actions or psychological orientations that are directed at real objects, such as seeing, fearing, or poking them, as well as more complex mental activities ... that may be directed at imaginary objects." Infants' sensitivity to this aspect of action seems to be limited at first. Before 9 months, infants seem to be sensitive to the agent-object relation for events involving grasping (Woodward 1998, 1999, 2003a; Woodward, Sommerville, and Guajardo 2001), and perhaps other instrumental actions (Jovanovic et al. 2002). It makes sense that infants would start here: grasping is ubiquitous in the environment, and is also one of the first instrumental actions that infants can produce themselves. Even at this early point, infants distinguish between grasping and apparently purposeless manual contact, construing the former but not the latter in terms of agent-object relations (Woodward 1999). From early in life, then, infants do not simply attend to physical contact between people and things, but instead focus more precisely on meaningful actions.

Between 9 and 12 months, infants' understanding of object-directed action is elaborated a way that may be particularly important for word learning—they begin to construe attentional behaviors, in particular looking and pointing, as being object directed. The actor-object relation is less concrete for gaze and pointing than for instrumental actions: these actions occur at a distance from the referent object, and, unlike grasping, do not generally have a visible impact on the object. Despite this lack of a concrete connection, for adults, these two actions are readily conceived of as indicating a relation between a person and the object of her gaze or point. Imagine a woman seated behind two toys, a ball and a bear, who turns to one side, directing her eyes toward the bear. Adults would probably describe this event in terms of the relation between the person and the object of her gaze—for example, "The woman looks at the

bear." Notice, however, that this event could be described in ways that make no reference to this relation (e.g., "She turned her head down and to the right"). If infants did not understand the object-directed nature of looking, they might focus on these aspects of the event.

In a recent series of studies (Woodward 2003a), I used the visual-habituation paradigm to investigate infants' sensitivity to the relational structure of looking events. Infants were habituated to an event such as the one described above. A woman, seated behind two toys, made eye contact with the infant, said "Hi. Look!", and then turned to look at one of the two toys. She then remained still, looking at the toy, until the infant looked away to end the trial. This was repeated until the infant's attention had declined to half its initial level. Then the toys were reversed, and infants saw two kinds of test events in alternation. In one, the woman turned to the same side as during habituation, this time looking at the other toy (new-toy events). This event preserved many of the features of the original event, but disrupted the relation between the woman and the object of her gaze. In the other test event, the woman turned to the other side, this time looking at the same toy as during habituation (new-side events). This event preserved the relational structure of the habituation event, but disrupted other features of the event. If infants, like adults, focus on the relation between looker and object, they should find the new-toy event more novel, and therefore watch it longer, than the new-side event. The findings differed as a function of age. Seven- and 9-month-old infants did not distinguish between the two kinds of test events, and, in fact, did not recover from habituation on test trials. It was as if these infants coded the objects in the display as being the same (the woman, the bear, and the ball again), and did not consider the relations between them. Twelve-month-olds, in contrast, looked longer on new-toy trials than on new-side trials, recovering on the former but not the latter. These infants, like adults, focused on the relation between the woman and the object of her gaze.

Notably, infants at all three ages responded to the woman's shift in gaze by orienting their own eyes toward the toy she looked at. During the very same test trials on which they failed to respond to the

change in actor-object relation, 7- and 9-month-old infants looked nearly twice as long at the object of the woman's gaze than at the other toy, and they followed the woman's gaze at levels indistinguishable from those of 12-month-olds. Thus, the younger infants were attentive to the woman's shift in gaze and were motivated to respond to it. At the same time, they seemed unaware of the looker-object relation—that is, of the fact that the woman was looking at the toy. This finding highlights the distinction, discussed earlier, between responsiveness to actions and knowledge about actions. Infants may respond to an action by orienting to some aspect of the environment, but this does not necessarily indicate that they understand the action in question as implying a connection between the agent and that entity. More generally, across several studies, we have found that infants' propensity to orient in response to an action does not always travel with their construal of that action as object directed (Woodward 1998, 1999, forthcoming).

In another recent study, Guajardo and I (Woodward and Guajardo 2002) found a very similar pattern for infants' comprehension of pointing as object directed. Twelve-month-olds, but not 9-month-olds, responded selectively to a change in the relation between a person who pointed and the referent object. This was true whether infants saw only a pointing hand or saw the actor's gaze coordinated with the point. In both cases the person who pointed touched the object with her index finger, thus eliminating the need to follow the point through space to the referent. Infants at both ages responded to this physical contact by orienting toward the pointing hand and the toy it indicated—that is, the point was a strong director of infants' attention. Nevertheless, 9-month-old infants seemed to be insensitive to the relational structure of the pointing event.

Between 9 and 12 months, then, infants begin to understand two actions, one done with the hands and the other with the eyes, as involving a connection between the person who performs them and some object. This co-occurrence in time suggests that at this age infants may attain a general insight about attentional connections between people and things. This conclusion converges with observations of infants' behavior in naturally occurring social interactions—

observers have long noted that between 9 and 12 months infants begin to "tune in" to their social partners, engaging in more shared attention and producing as well as responding to communicative gestures. The current findings provide evidence that this change in social responsiveness is accompanied by a change in infants' action knowledge, specifically, an emerging sensitivity to the relational structure of attentional behaviors.

To draw on this knowledge to inform word learning, infants must be able to relate utterances to the speaker's other object-directed actions. This ability would most likely rest on the more general ability to integrate separate actions and relate them to a common object. As yet, little is known about the development of this ability, except that it seems to be present by the end of the first year of life. To illustrate, 12-month-old infants, and some 10-month-olds, can relate the elements of a means-end sequence to an ultimate goal, for example interpreting a person's grasp of a box lid as directed at the toy within the box rather than at the box itself, so long as this analysis is consistent with the causal constraints in the situation (Sommerville 2002; Woodward and Sommerville 2000). In addition, 12- to 14-month-old infants expect that a person's gaze and manual actions will be directed toward the same target (Phillips, Wellman, and Spelke 2002; Spelke, Phillips, and Woodward 1995; Sodian et al. 2002).

To summarize, infants analyze certain actions in terms of their relational structure. This analysis goes beyond the surface level of motions and contact, and indicates that infants have begun to extract meaningful components of behavior. This analysis is first evident in 6- to 9-month-old infants' propensity to relate actors to goals for actions that appear purposeful, in particular, grasping, but not for manual contact that appears purposeless. Between 9 and 12 months, infants begin to relate actors to the objects of their attention, and also begin to relate actions in a sequence to one another in situations in which these relations are likely to be meaningful. These later developments seem to set the stage for language, providing support for infants' acquiring the right mappings between words and world, and also for their acquiring the right kind of mappings. I turn now to each of these issues.

5.4 Getting the Right Mappings

As discussed earlier, gaze and pointing are critical sources of information for word learners. Awareness of the relational nature of gaze and pointing would have a profound impact on infants' ability to learn words. For one, it would set the conditions for acquiring the right mappings. If infants are able to integrate information about the simultaneous actions a person produces, then the co-occurrence of utterances with actions such as gaze and pointing would lead them to relate words to aspects of the world to which the speaker is behaviorally connected. Infants would be able to respond to words not as disembodied sounds, but as actions that can be meaningfully related to other actions and to the environment. That is, they would be intelligent learners in the sense described earlier.

Besides making word learning accurate, knowledge about the relational structure of action may make word learning possible in the first place. Parents report the beginnings of word comprehension at 9 to 12 months (Benedict 1979; Fenson et al. 1994), just the time period during which infants become sensitive to the relational structure of gaze and pointing. Infants can form associations well before this age, and likely have heard thousands of uttered words, but before 9 to 12 months, they do not seem to form many word-world associations. Why would this be? Perhaps it is because infants younger than 9 to 12 months, lacking knowledge about attentional relations, must rely mainly on unconstrained associative learning, and this mechanism is an ineffective tool for interpreting linguistic input. By their very nature, words provide a medium for referring to absent entities, and speakers exploit this aspect of language routinely, even when talking to children. Thus, words may not covary with their referents reliably enough to support unconstrained learning. Without a lens to focus attention on particular potential mappings, infants would have little success at associating words with the correct aspects of the environment. I suggest that knowledge about attentional relations provides just such a lens, and thereby enables the first acts of word learning.

This suggestion assumes that gaze and pointing provide a useful lens—that is, that they reliably co-occur with utterances naming the

entity gazed and pointed at. This seems like a reasonable assumption, though more research is required to test it thoroughly. Most studies of parental labeling behavior have focused on episodes of joint attention, and during these episodes, gaze and pointing are directed at the objects that are labeled (see Carpenter, Nagell, and Tomasello 1998 for a review). But relational-action knowledge would be useful outside of joint-attention episodes as well, and little is known about covariation between gaze, pointing, and labeling in other contexts. If gaze and pointing were regularly related to spoken words more generally, action knowledge would enable infants to interpret words based on observing the actions and interactions of adults, even when the infants themselves were not participants in the interaction. This is an important point, because although joint-attention episodes are relevant for all kinds of social learning, they do not comprise the bulk of an infant's social and linguistic experience. In a review of studies with American families, Hoff and Naigles (2002) report that parents and infants engaged in joint attention only 11 to 29 percent of the time, even in conditions designed to maximize joint attention. Joint-attention episodes are likely to be even less frequent in cultures that allot children the role of observer more than the role of equal participant in conversational exchanges (Ochs and Schieffelin 1995; Rogoff et al. 1993). Infants' success at amassing vocabularies despite the relative infrequency of joint attention indicates that at least some of the time, infants are able to interpret words by analyzing observed behavior outside of social interactions. Indeed, a recent study has demonstrated this ability in 2-year-olds (Akhtar, Jipson, and Callanan 2001).

An open question is whether other aspects of action knowledge could support word learning. Older children draw on broad behavioral evidence—for example, 2-year-olds use behavioral cues that an action was purposeful or accidental to interpret new verbs (Tomasello and Barton 1994). As discussed above, by 6 to 7 months, infants represent grasping as a relational action, and distinguish between purposeful and apparently purposeless manual contact. It is possible that this aspect of action knowledge could highlight the link between words and the objects held by the speaker, as soon as infants are able to integrate information about distinct actions. Some researchers

report that, especially early on, parents are likely to manually manipulate objects while gazing at and labeling them (Gogate, Walker-Andrews, and Bahrick 2001), and this might reinforce infants' ability to relate words to referents. In addition, it might enable infants younger than 9–12 months to acquire some word-object mappings. In this case, the limiting factor on word learning would not be understanding of attentional actions per se, but rather the ability to relate distinct actions to a common object.

5.5 Getting the Right Kind of Mappings

Beyond allowing infants to focus on the right potential associations, action knowledge may set the conditions for infants acquiring the right *kind* of association between word and world—that is, an understanding of reference. The account I have sketched puts word learning in the right neighborhood, alongside of and connected to *developing* concepts of intentionality. I emphasize "developing" here because I believe it is unlikely that 9- to 12-month-old infants have an adultlike understanding of intentionality. Mature concepts of intention are embedded in rich webs of knowledge about psychological life and action. Infants lack much of this knowledge. Nevertheless, as the findings summarized so far suggest, even in the first year of life infants comprehend some aspects of intentional action. The challenge is to characterize the nature of infants' action knowledge and, by extension, the nature of their understanding of acts of referring.

Adults understand the relational structure of action in both psychological and behavioral terms. To illustrate, on observing a woman gazing at a set of keys on the sidewalk we can imagine her mental experience (her mind's-eye view of the keys), infer her likely resulting mental states (she is now aware that the keys are there, and has a belief about their location that could be false), and also predict her likely next actions (moving toward and picking up the keys). Adults also understand that different kinds of actions signal qualitatively different sorts of relations—for example, attending to an object versus having an instrumental intention toward an object. For mature language users, understanding acts of reference draws on much of this knowledge. First, an understanding of behavior-level patterns

allows us to identify and interpret acts of referring. Then, from the behavioral evidence, we make inferences about the intentions, attention, and mentally represented information at play in the situation. We understand that, in referring, a speaker intends to draw someone's attention to a particular entity or to convey information from his or her own mind to the mind of another person.

We do not yet know how much of this information infants represent when they analyze the relational structure of action and use these relations to interpret words. One possibility is that infants are sensitive to the relational structure of certain actions without yet understanding their psychological correlates. That is, infants might understand actor-object relations in purely behavioral terms—for instance, knowing that a person who looks at an object is likely to remain behaviorally connected to it, or knowing that particular actions predict particular outcomes or subsequent actions. A behavior-level analysis of the relational structure of action could account for much of the intelligent behavior of 1- and 2-year-old word learners. Specifically, it would focus attention on those word-world associations that are supported by meaningful action relations between speaker and referent.

To account for the ultimate form of linguistic symbols, analysis beyond the level of behavior is needed. Insight into the inner experiences that are expressed in action, and, in particular, an understanding of attentional states as distinct from other kinds of mental relations, would contribute uniquely and critically to children's understanding of words as tools for communicating ideas from one mind to another. When does this aspect of action knowledge emerge and become recruited for language? Findings with older children indicate the existence of partial understandings of mental life in early childhood, which are enriched and elaborated in the years that follow (Flavell 1988; Wellman 1992). In turn, parts of these partial understandings may be traceable to still earlier points in ontogeny. It is noteworthy that infants' action knowledge identifies just the relations that, in mature systems, are relevant to underlying intentions and attention. It seems plausible, therefore, that infants know something about these mental states. On the other hand, even if infants are initially limited to a behavioral analysis of action, this analysis

would provide a basis for subsequent discovery about the inner experiences that correlate with the observed relations. One contributor to this discovery might be word learning itself. As Baldwin and Moses (1996) have proposed, learning words and interpreting the language behavior of others may provide evidence for infants that other people have ideas.

A number of theorists have suggested another route by which infants might gain information about the inner states of others, namely, infants have access to their own inner experiences and may possess a system for relating information about the self to the actions of others (e.g., Blakemore and Decety 2001; Carpenter, Nagell, and Tomasello 1998; Gallese and Goldman 1998; Gopnik and Meltzoff 1997; Tomasello 1999). There is growing evidence that in adults, there are common neural representations for self-produced actions and the observed actions of others (see Blakemore and Decety 2001). There is not yet conclusive evidence that such representations play a role in development, but two findings from our lab are suggestive. Guajardo and I found that for infants between 9 and 12 months there was a strong relation between infants' own production of relational points and their understanding of observed points as relational (Woodward and Guajardo 2002), and Sommerville (2002) has found a similar correlation between infants' ability to produce instrumental action sequences and their understanding of others' actions.

Therefore, while infants most certainly lack aspects of action knowledge that contribute to mature language, even in infancy word learning seems to be connected to and informed by action knowledge. This sets up the conditions for the development of critical aspects of linguistic symbols, in particular, their function as tools for communicating ideas. This is not the first account to seek the origins of symbol understanding in prelinguistic social cognition. Many other accounts have done this, focusing particularly on the infants' developing participation in communicative interactions as both evidence of and a contributor to an understanding of others' communicative intentions (Bates et al. 1979; Bretherton 1991; Bruner 1978; Carpenter, Nagell, and Tomasello 1998; Tomasello 1999). The current account stresses a more general insight about inten-

tional relations between agents and entities in the world. This aspect of action knowledge could draw from infants' experiences engaging with communicative partners, and it would contribute to infants' understanding of others' actions in these contexts. However, this knowledge could emerge from other kinds of experiences as well (e.g., observing actions of others, reflecting on one's own actions), and it would allow infants to interpret utterances outside of joint-attention episodes.

In this chapter, I have been concerned with a critical piece of symbolic understanding, which, I have argued, draws on infants' developing understanding of intentional action. I have ignored other critical aspects of symbols. In particular, it is equally important for children to discover the ways words are *not* like other actions. Words are part of a formal conventional system. This system differs from other actions, and by virtue of these differences has a different kind of expressive power than other kinds of actions do (Goldin-Meadow, McNeill, and Singleton 1996; Macnamara 1982). The system consists of a particular class of forms, which are generated by combining a circumscribed set of phonemes. Elements in this system relate arbitrarily to their referents. Thus, for these forms, similarity is a poor cue to meaning or function. Forms in this system have syntactic as well as semantic properties. To acquire these aspects of words, infants need more than knowledge about intentions—they need to be able to extract the properties of the system itself. A number of recent findings indicate that 1-year-olds have not yet completed this aspect of symbol development (Namy 2001; Namy and Waxman 1998; Stager and Werker 1997; Woodward and Hoyne 1999). Terry Regier and I have proposed that some aspects of the formal symbol system could be the result of general process learning mechanisms, so long as these mechanisms are informed and constrained by social knowledge (Regier et al. 2001).

5.6 Conclusions

There is a certain elegance to the idea that infants begin to decipher language just by remembering the sounds they have heard while attending to particular parts of the world. This model attributes to

infants only the simplest and most general learning abilities. Moreover, there is no doubt that associative learning is a pervasive and powerful contributor to language acquisition at every point in development. But this elegant starting position brings in its wake a host of problems.

The problems I have focused on here pertain to the future of a learner who begins in this way. Uninformed and unconstrained, a child equipped with only associative learning would be ill-prepared to make sense of words. She would likely not succeed in extracting the right mappings between word and world, and certainly miss out on getting the right kind of mappings. Our recent findings indicate a route around these problems. Infants do not treat words as sounds in the air, but rather as actions of agents. By the end of the first year of life, infants are able to analyze the relational structure of action. They encode certain actions (including attentional actions) in terms of the relation between a person and the object of her action, they distinguish between purposeful actions and apparently purposeless movements, and they can relate actions to one another and to overarching goals. This sensitivity blossoms at just the time that infants begin to get a grasp on words' relations to the world—that is, at 9–12 months. Knowledge about the relational structure of action would impact word learning in at least two ways. First, by ruling out word-object co-occurrences that do not involve a meaningful relation between speaker and object, it would lead infants to focus on the right mappings. Second, by situating word learning alongside of and connected to action knowledge, it would provide a starting point for infants' acquiring the right kind of mappings. Our findings indicate that by 14 months, infants use this action knowledge to interpret words. If I am right, this "intelligent" word learning should be evident still younger, as soon as infants become sensitive to the relational structure of action.

In addition to these problems, the general associative model belies the complexities of the learning process. It assumes that infants acquire stable mappings whenever they experience contiguity between two stimuli—for example, when they view a picture while hearing a recorded voice speaking a novel word. But this turns out not to be the case. Werker and colleagues (1998) found that while 14-month-

olds could acquire word-picture associations under these conditions, 9-month-olds tested in the same procedure could not. They suggest that the ability to acquire word-object mappings should be viewed as a cognitive achievement because the arbitrary nature of the mapping provides few cues to support the connection between the two stimuli. More generally, based on their review of work on infants' intermodal learning, Gogate and her colleagues (2001) conclude that young infants do not readily acquire arbitrary mappings between sights and sounds, although they do readily associate stimuli that are intrinsically related, such as the visual properties of an object and the sounds it emits. These intrinsic relations involve redundant perceptual cues—for example, the visual and auditory features may share intensity shifts and commonalities in rhythm and tempo. Gogate and Bahrick (1998, 2001) hypothesized that these redundant cues would facilitate the acquisition of novel, arbitrary pairings. Consistent with this hypothesis, they found that 7-month-old infants can acquire a pairing between speech sound and object when synchrony between the object's motion and the timing of the speech sound was present, but not when it was absent. Most intriguingly for the present line of argument, in their experiments, synchrony between the speech sound and the object was achieved by showing infants a person's hands holding and moving the object as she spoke. Thus, the experiments provided just the behavioral evidence that I propose to be critical for extracting relations between words and objects.

Finally, assuming an unconstrained associative starting state can lead to problems for the other end of the theoretical spectrum as well. A number of theorists take this position as a "strawperson" to be argued against. This kind of argument sometimes leads to the impression that the only available positions are that infants learn words as disembodied associates or that they understand words as intentionally produced symbols in their fullest sense. This formulation makes it difficult to see how to bridge the gap. What would a partial understanding of reference or intention be like? By investigating infants' developing action knowledge, we may be able to formulate clearer hypotheses about the specific kinds of action knowledge that get word learning off the ground, and that, with time, develop into mature conceptions of intentions and reference.

That is, we could then make headway on the problem that Macnamara believed insoluble.

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Note

1. For the purposes of this chapter, I will consider the problem of learning words that refer to observable aspects of the world, leaving aside the weighty question of how children come to understand words that do not refer in this way.

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