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CHAPTER

16

The Human Infant as Imitative Generalist: A 20-Year Progress Report on Infant Imitation with Implications for Comparative Psychology

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INTRODUCTION

I propose that there are three key features of imitation in human infants. First, human infants are imitative generalists. The hallmark of normal infants is that they imitate a range of novel and arbitrary acts. Second, imitation is its own reward for the human young. Normal human infants are intrinsically motivated to "act like" other humans, a species-typical trait manifest in newborns. Human infants do not imitate solely, or most readily, as a means of obtaining food. Even if not obtaining food, praise, or other extrinsic rewards, normal human infants are driven to imitate the acts of conspecifics. Third, infant imitation is a bidirectional activity. Human parents are prolific imitators of their young infants. Experiments show that infants smile, increase their gaze at the imitator, and react distinctively to being matched. It will be suggested that reciprocal imitation games between parent and offspring provide ontogenetic roots for the growth of "theory of mind" in human children.

When I began work on imitation in human infants in the early 1970s, it was thought that human infants were poor imitators. Human infants were compared, perhaps unconsciously by observers, to adults or 5-year-olds. One cannot ask a human infant to "do as I do," and accordingly their imitative abilities were profoundly underestimated by traditional norms until the time they began to understand language. Infants may not imitate with the facility of a 5-year-old, but imitation in human infants is a useful touchstone or reference point for imitation in other animals, because language can be excluded. Infants provide a unique opportunity for investigating human imitation before language, before advanced symbolic development, and in the case of newborn imitation, even before "enculturation."

Learning more about human prelinguistic imitation should assist those interested in the biology, evolution, and comparative psychology of imitation. Reviews of animal imitation have sometimes not considered the new research on imitation in human infancy (e.g., Galef, 1988; Whiten & Ham, 1992, but see Russon & Galdikas, 1995; Visalberghi & Fragaszy, 1990). However, human infants are animals too. A comprehensive evolutionary picture needs to incorporate the human data. This chapter reviews two decades of progress made at both the empirical and theoretical level in understanding imitation in human infants.

At the empirical level, investigations have concerned:

a. methods used to distinguish nonverbal imitation from other forms of social learning
b. imitation of facial gestures
c. vocal imitation
d. imitation of novel acts
e. imitation of object-related acts
f. imitation after a memory delay
g. peer imitation
h. recognition of being imitated oneself

At the more theoretical level, there has been progress in:

a. relating imitation to other aspects of nonverbal cognition, especially cross-modal matching
b. connecting infant imitation to developing "theories of mind"

METHODOLOGY: DISTINGUISHING IMITATION FROM OTHER FORMS OF SOCIAL LEARNING

Twenty years ago, Meltzoff and Moore (1977) posed three questions about infant imitation: methods (what controls are necessary for distinguishing imitation from other forms of social learning?), existence (do newborns imitate?), and mechanism (what psychological processes underlie this behavior?). The same series of questions about methods, existence, and mechanism are now being worked through in studies on nonhuman animals (e.g., Byrne, in press; Byrne & Byrne, 1993; Custance, Whiten, & Bard, in press; Heyes & Dawson, 1990; Russon & Galdikas, 1995; Tomasello, this volume; Tomasello, Kruger, & Ratner, 1993; Tomasello, Savage-Rumbaugh, & Kruger, 1993; Visalberghi & Fragaszy, 1990; Whiten and Custance, this volume; Whiten, Custance, Gómez, Teixidor, & Bard, in press). The methodological progress made with human infants may be useful to those studying other animals, because similar problems arise whenever linguistic directions are excluded.

Cross-Target Procedure

Meltzoff and Moore (1977, 1983a,b) developed the "cross-target" design to distinguish imitation from other forms of social learning. In the cross-target design, infants' responses are compared across two (or more) different demonstrations by the same adult model. The power of the cross-target design is that it uses the same adult model, at the same distance, moving at the same rate, to perform different actions. For example, subjects are shown both a mouth-opening display and a tongue-protrusion display in a repeated-measures test using infants as their own controls. It is assessed whether the infants respond with more mouth openings to the mouth display than to the tongue display, and conversely respond with more tongue protrusions to the tongue display than to the mouth display. Imitation is demonstrated if the subject responds differentially and with high-fidelity matches to the same adult model demonstrating two different motor movements.

Using this design, the 1977 study reported imitation of four different body actions: lip protrusion, mouth opening, tongue protrusion, and sequential finger movement. The displays were selected to allow stringent cross-target comparisons. Note that there were two types of lip movements (mouth opening vs lip protrusion) and two types of protrusion actions (lip protrusion vs tongue protrusion). The results showed that when the body part was precisely controlled, when lips were used to perform two subtly different movements, infants still responded differentially. Moreover, when the same general movement pattern was demonstrated (protrusion) but with two different body parts (lip vs tongue protrusion), infants also responded differentially. This documented that infants were matching particular *acts,* not responding solely to the presence of a conspecific (the adult was present in all cases), activating a region of the body (oral region), or producing a general category of movements (e.g., protrusions).

Although we were the first to use the cross-target design with human infants, this design has also been used in the best studies trying to distinguish imitation from other forms of social learning in nonhuman animals (e.g., Dawson & Foss, 1965; Heyes & Dawson, 1990; Tomasello, Savage-Rumbaugh, & Kruger, 1993; Whiten et al., in press). Perhaps the cross-target design was independently invented by investigators in response to the same issue (how does an investigator separate imitation from other forms of social learning?).

Blind Scoring

A major difficulty with the work on humans before 1977 was that it used judges who were not free of observer bias; observers scored the infants' responses live while knowing what the subject had been shown. In all our studies infants responses were videotaped using two video cameras and tape decks. One system captured the infant, with no record whatever of the adult's behavior, and the other captured just the adult's display without record of the infant. The infants' responses were scored by observers who were uniformed about what display the infants had been shown.

FACIAL IMITATION: CROSS-MODAL MATCHING

It is useful to provide a brief review of the initial work on facial imitation, because it highlights several aspects of human imitation that became central to our theoretical position. In particular, the work on facial imitation led to the proposal that human infants were imitating on the basis of *cross-modal* matching (Meltzoff, 1990b; Meltzoff & Moore, 1977, 1983a, 1989, 1992, 1994).

To understand why facial imitation supports this inference, consider manual and vocal imitation. In imitating manual movements the infant can see the adult's hand and can also see their own hands. It is possible for infants to use visual guidance of their own motor movements to bring them into line with the movements they see. The same occurs in vocal imitation. The infant can use auditory guidance to achieve a perceived match to the auditorially specified target.

Of course, manual and vocal imitation both depend on generalizations by the infant. There are visual perspective differences between the infant's view of his own hands and the hands of others, and the hands are of different sizes and texture (Meltzoff & Moore, 1983b), but the possibility of a visual-visual match still exists. Infants will have seen their hands before (even if they do not look at them during the experiment), because they spend hours engaged in hand regard (Piaget, 1952).

The same argument applies to vocal imitation. Infants can hear themselves during the test and will no doubt have heard their own vocalizations before. Generalization is involved because the infants' own vocalizations will be of higher frequency than the adult's, will be perceived from a different place in space, and will partly be conveyed through bone conduction. Nonetheless, the comparison between demonstration and response can be made within a single modality, audition.

Both manual and vocal imitation are cross-modal in the sense that the subject must perform a motor act on the basis of what they saw (or heard). However, facial imitation is cross-modal in an additional, stronger sense. The additional sense is that within-modality comparisons between the external target and the infant's own response are completely excluded. In facial imitation the infant can see the adult's face, but their own face is invisible to them. If the subjects are young enough they will never have seen their own faces. Thus facial imitation demonstrates a double cross-modality: (a) it is cross-modal in the sense that all imitation involves cross-modal integration (motor responses based on perception), and (b) it is cross-modal in the stronger sense that no aspect of the model and the imitative response can be perceived via the same modality, only different modalities.

Based on this logical analysis, and certain empirical considerations concerning the organization of the response, Meltzoff and Moore (1977, 1983a, 1994) proposed that early facial imitation is mediated by "active intermodal mapping" (the AIM hypothesis). According to AIM, human infants are engaged in a matching-to-target process in which they actively compare the visual information about the seen body movements with the proprioceptive feedback from their own movements in space.

The AIM hypothesis supposes that young infants can detect and utilize cross-modal matches in form or structure (not merely timing) across different modalities. To pursue this hypothesis, we next investigated other instances of such cross-modal matching. One involved a test of cross-modal shape perception (Meltzoff & Borton, 1979). Infants were given a shape to feel in their mouths, but were prevented from seeing the shape. The shape was then withdrawn and the infants presented with a visual paired comparison between that shape and a different one. The results showed that human infants as young as 29-days-old could recognize shapes across modalities: they systematically looked longer at the shape they had previously explored orally. It was also shown that 18-week-old infants can perform auditory-visual matching between speech sounds and the particular lip movements that cause them (Kuhl & Meltzoff, 1982). Infants were visually presented a film loop of two faces articulating different speech sounds (/a/ as in "pop" and /i/ as in "peep") in synchrony with one another. The infants were auditorially presented with a tape loop of one of these phonetic units played over a loudspeaker located midway between the two faces. The results showed that infants preferentially looked at a face whose mouth movements matched these sounds: When listening to the /a/ sound, infants looked longer at the visual faces articulating /a/ versus /i/, and vice versa when listening to the /i/ sound.

It is interesting that the same species that imitates facial movements, also matches felt shapes to seen shapes, and matches the auditory and visual aspects of speech sounds. Meltzoff (1990b) and Meltzoff and Moore (1983a,b, 1994, 1995b) provide an detailed analysis of how cross-modal matching mediates facial imitation in human infants.

Range of Acts Imitated

The existence of early facial imitation initially surprised developmental psychologists (it had not been predicted by the then-dominant Piagetian stage theory). The effect has now been replicated in 12 independent laboratories in more than 24 experiments. Tongue protrusion has been the most widely publicized example, but over the past 20 years imitation of a wide range of other gestures has been documented, including lip, head, and finger movements, emotional expressions, cheek movements, and brow movements (Abravanel & Sigafoos, 1984; Field, Woodson, Cohen, Greenberg, Garcia, & Collins, 1983; Field, Goldstein, Vaga-Lahr, & Porter, 1986; Field, Woodson, Greenberg, & Cohen, 1982; Fontaine, 1984; Heimann, 1989; Heimann, Nelson, & Schaller, 1989; Heimann & Schaller, 1985; Jacobson, 1979; Kaitz, Meschulach-Sarfaty, Auerbach, & Eidelman, 1988; Kugiumutzakis, 1985; Legerstee, 1991; Maratos, 1982; Meltzoff & Moore, 1977, 1983a, 1989, 1992, 1994; Reissland, 1988; Vinter, 1986). If imitation in early infancy had been limited to one or two privileged acts (e.g., if tongue protrusion alone had been demonstrated, as was mistakenly believed for some time), this would weigh against the AIM hypothesis, which predicts more generative and productive imitation. However, it is now established that a wide range of gestures can be imitated and that young infants imitate strangers as well as mothers (Meltzoff & Moore, 1992, 1994).

Novel Acts

Early imitation is not limited to one or two privileged acts, but the question of response novelty is a complex one that merits further investigation (the reader is referred to Meltzoff, 1988c for a fuller discussion of the problem: "what is novelty"?).

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Meltzoff and Moore (1994) investigated whether young infants can imitate novel/unfamiliar facial acts. They showed 40 6-week-olds the following gestures: tongue protrusion to the side (TP_{side}, the novel act), tongue protrusion, mouth opening, and a baseline in which no facial gesture was shown. As expected, the spontaneous probability of producing TP_{side} was very low, and yet infants produced this behavior in response to an adult who did so. A microanalysis of the response also revealed that infants made errors that were self-corrected, especially in imitating the novel TP_{side} gesture. Adults make similar errors imitating novel acts—a first try that is close, combined with errors that are self-corrected. The discovery of error correction in the imitative response of infants is compatible with the AIM hypothesis, the notion that a true matching-to-target process is involved.

VOCAL IMITATION

Humans are the only mammals known to display "vocal learning"—the ability to acquire a species-specific vocal repertoire by hearing the vocalizations of adults and mimicking them (Konishi, 1989; Nottebohm, 1975). We share this ability with a few avian species (songbirds), and evolutionary biologists and ethologists have argued that it may represent a critical step in the evolution of speech and language (Hauser & Marler, 1992; Marler, 1974).

It has long been assumed that at some point during development young children become adept at mimicking the speech patterns they hear others produce. When do they display such an ability? There is circumstantial evidence that human infants can vocally imitate before the onset of meaningful speech, inasmuch as infant babbling sounds differ across cultures (see review by Kuhl & Meltzoff, 1996). Even to the casual ear, French babies sound distinctively French and different from American babies by about 24 months of age. It seems plausible that the linguistic input heard by infants in different cultures is the root cause of their different vocal productions.

We conducted an experimental study to investigate vocal imitation in human infants. Using the cross-target design, infants between 12 and 20 weeks of age were randomly assigned to three independent groups (Kuhl & Meltzoff, in press). Infants listened to a prerecorded signal of a female talker repeatedly producing one of three phonetic units, /a/, /i/, or /u/ (as in "hop," "heap," or "hoop"). The model was not live, but on tape, thus the possibility of unconscious shaping by the adult was excluded. Two types of scoring were conducted. The first was a computer-spectrographic analyses of the infants' vocalizations. This was a painstaking process that involved statistical analysis of more than 5500 acoustic measurements (for details, see Kuhl & Meltzoff, 1995). The second was perceptual scoring conducted by a trained phonetician.

The perceptual scoring was done by having a trained phonetician listen to each infant's productions and classify the productions as falling into the /a/, /i/, or /u/ category. The phonetician was kept uninformed as to the auditory stimulus presented to the infants being scored. The results showed imitation. Infants produced more /a/ vowels when listening to /a/ than when listening to /i/ or /u/; infants produced more /i/ utterances when listening to /i/ than when listening to /a/ or /u/; and finally infants produced more /u/ utterances when listening to /u/ than when listening to /a/ or /i/. It is informative for theories of imitation that Kuhl and Meltzoff's spectrographic analyses showed that infants were not duplicating the absolute frequencies of the adult, but rather the relationship among the frequencies, the internal structure or "pattern" of the vowel sounds.

Kuhl and Meltzoff (1996) have argued that vocal imitation of phonetic units plays a critical role in infants' acquisition of language. Different human languages use different phonetic units and prosodic structure. The endpoint of infancy is that infants "sound like" a speaker of their language, producing both the sound units and "accent" of their native language. Infants efficiently acquire the language-specific inventory of phonetic units, words, and prosodic features partly through imitation. Chomsky (1968, 1988) famously used syntax to argue his case for linguistic nativism. Our proposals about the role of imitation in language acquisition do not concern syntax, but the sound patterns of language that appear to be learned.

IMITATION OF OBJECT MANIPULATIONS: NOVEL ACTS AND DEFERRED IMITATION

For imitation to be of far-reaching significance in human development, infants will need to imitate not only body acts and speech sounds, but also tool use and other object-related behaviors. Moreover, they will need to imitate novel acts after significant memory delays. Human parents engage in purposeful pedagogy of the type "watch what I do," often demonstrating a new skill at a time and place far removed from when the infant has an opportunity to imitate. If the human young (or any species for that matter) could imitate acts immediately but *not* imitate after a lengthy memory delay, this would necessarily constrain theories about the role of imitation in the transmission of culture for that species (Galef, 1992; Heyes, 1993; Meltzoff, 1988a,e; Premack & Premack, 1994; Tomasello et al., 1993). Thus if we want to draw inferences to cultural transmission, we need to know about imitative generalization across time and space.

Meltzoff (1988b–d) conducted a series of studies relevant to these concerns.

One study with 14 month olds had three features: (a) imitation was tested after a 1-week delay, (b) infants were required to remember not just one demonstration but to keep in mind multiple different demonstrations, and (c) novel acts were used. One of the acts, bending forward from the waist and banging a panel with one's forehead, was not observed in 100 infants in free play, and certainly qualified as a novel display (baseline measures were also taken in the experiment, Meltzoff, 1988c).

Infants in the imitation group were shown six different acts on different objects on the first day of testing. Importantly, they were not allowed to touch or handle the objects. They were confined purely to watching the displays. Infants were then sent home for the 1-week delay. On returning to the laboratory, the infants in the imitation group were presented with the objects and their behavior videotaped for subsequent analysis. For infants in the adult manipulation control group, the adult manipulated the same objects during session 1, and produced the same "results" or "affordances" as he did in the imitation group; but he did so using different movement patterns (for further discussion about controlling for the affordances and results of the display, see Meltzoff, 1985, 1988c,d,e; Nagell, Olguin, & Tomasello, 1993; Tomasello, this volume; Tomasello, Savage-Rumbaugh, & Kruger, 1993; Whiten and Custance, this volume; Whiten et al., in press). We also used a second control group, a baseline control, in which the adult did not manipulate the test objects; he simply talked pleasantly to the mother and child on session 1 before the 1-week delay. This assessed the spontaneous likelihood of the infants producing the target acts when they returned to the laboratory for a second session.

The videotaped response periods were scored by coders who remained blind to the infants' experimental group. The results provided clear evidence for deferred imitation from memory after the delay. Fully 67% of the infants in the imitation condition leaned down and touched the panel with their heads, as compared to 0% in the other conditions ($p < .0001$). It was found that some infants could retain and imitate up to five different target acts after the delay, and 92% remembered and imitated at least three different acts.

Next investigated was deferred imitation after even longer delay intervals. Meltzoff (1995b) investigated imitation after retention intervals of 2 and 4 months. A total of 192 infants were tested and the effects of immediate and deferred imitation assessed. Importantly, in the deferred imitation condition infants were confined simply to observing the adult and were not allowed to engage in immediate imitation during the first session. The results again showed accurate imitation, including imitation of the novel head-touch display. Other work demonstrated deferred imitation when the features of the object were altered as compared to the adult's original, documenting an interesting kind of imitative generalization (Barnat, Klein, & Meltzoff, in press). That infants imitate *multiple* targets, including *novel* ones, after *lengthy delays* suggest that imitation is capable of playing a significant role in human development.

TUTOR INFANTS AND PEER IMITATION

The ecology of child rearing is changing in the United States. With the increase of women in the work force, infants are spending increasingly more time with peers in day-care settings. In all the previous experiments, adults were used as models. Do infants learn from and imitate their peers in day-care centers and other sites? In this series of studies we moved into the "field," examining peer imitation in day-care centers and homes (Hanna & Meltzoff, 1993).

The first study developed a controlled procedure for assessing peer imitation. Fourteen-month-old infants observed "tutor infants," 14-month-olds previously trained to play with the toys in novel ways. After observing the peer play with five objects, subjects left the test room. They returned 5 min later and were presented with the test objects in the absence of the peer. The results showed imitation. A second study used a day-care setting. The "tutor infant" was strapped into a car seat and driven to a variety of day-care sites. As the naive infants sat around a table, drinking juice, sucking their thumbs, and generally acting in a baby-like manner, the tutor picked up and acted on novel toys in particular ways. The naive infants were not allowed to approach or touch the toys. After a 2-day delay, a new experimenter (not the one who had accompanied the tutor) brought a bag of objects to the infants' homes and laid them out on a convenient table or floor. Neither the parent nor this new experimenter had been present in the day-care center 2 days earlier. The only person who knew what actions had been demonstrated was the subject. The results showed significant imitation, providing the first evidence for deferred imitation across a change in context (a shift from day care to home site).

Evidently even prelinguistic infants are influenced by their peer groups at school. The fact that human infants can transfer their imitative learning to a different environment from the one in which they observed the model, can do so after a long delay, and will imitate peers as well as adults, again supports the idea that imitation may play a role beyond the laboratory.

PERCEPTION VERSUS PRODUCTION: INFANTS RECOGNIZE WHEN THEY ARE IMITATED

Ethological studies have shown that human parents tend to imitate their young. Human parents shake objects when the infant does, slide them when they slide, and coo when they coo. Dyads often engage in long bouts of reciprocal imitation at the highchair or kitchen table—first the infant performs an act, then the parent, then the infant, and so on. Do infants notice they are being imitated? What function does reciprocal imitation serve in human ontogeny?

Experiments were set up in which adults purposely imitated infants, acting like biological mirrors. Three converging experiments were conducted using a total of 140 14-month-olds (Meltzoff, 1990a). The first study investigated whether infants showed any interest in their own behavior being reflected back to them. The infants sat at a table, across from two adults who sat side by side. All three participants were provided with replicas of the same toys. Everything the infant (I) did with his or her toy was mimicked by one of the adults (I′). It was as if I′ was tethered to the infant, a marionette under the child's control. The second adult, the nonimitator (NI), was not so tethered. It was hypothesized that infants would prefer to look at I′ and also smile at this adult more. We also thought that infants would test or probe the relationship with I′ by manipulating their own behavior in special ways. For example, infants might perform sudden and unexpected movements to probe the connection between their own acts and those of I′. Adults sometimes do this when they see themselves in a store video camera. The experiment was videorecorded and was subsequently scored by observers who were kept appropriately blind to the side of the I′ and NI. The results showed that infants looked significantly longer at I′, smiled more at I′, and directed more test behavior at I′ (Meltzoff, 1990a).

In the next study, the NI actively manipulated the toys in a particular way. The adult did "baby-like" things with the toys so that no preference for the imitating experimenter could be based solely on a preference for infantile actions (Lorenz, 1943, postulated preference for baby-like visual forms). This was achieved by using a yoked-control procedure. Two television monitors were situated behind the infants and in view of the adults. One monitor displayed the actions of the current infant, live. The other displayed the video record of the immediately proceeding infant. Each adult mimicked one of the infants on television. Both adults acted like perfect babies, but only one matched the particular actions of the subject himself. The results again showed that infants looked longer at I′, smiled more often at the adult, and directed more testing behavior toward that person.

How did the babies detect this relationship? Two kinds of information are available, what I will call *temporal contingency* versus *structural congruence*. According to the first alternative the infant need only detect that whenever he does *x* the adult does *y*. The infant need not detect that *x* and *y* are in fact equivalent, only that they are temporally linked. The second alternative is that the infant can do more than recognize temporal contingencies. In particular, the infant may be able to recognize that the actions of the self and other have the same form, that they are structurally congruent.

A third study was conducted in which the purely temporal aspects were controlled by having both experimenters act at the same time. Both experimenters sat with neutral expressions until the infant performed a target act from a predetermined list. If and only if the infant exhibited one of these target actions, both experimenters began to act in unison. I′ performed the infant's act; NI performed a different behavior from this list. What differentiates the two experimenters is not timing, but the structure of their actions vis-à-vis the subject. The results showed that the infants looked, smiled, and directed more testing behavior at I′ than at NI.

Evidently infants do not just recognize that another moves *when* they move (temporal synchrony), but recognize that another moves in the same *manner* as they do (structural congruence). Thus infants not only imitate others, but can recognize when the form of their own behavior is being matched. The fact that infants literally prefer (look longer at) adults who imitate them has social-developmental implications, and the discovery that infants can process the equivalence in the behavior, not merely the temporal contingencies, has potential developmental sequella which are elaborated in the final section of this chapter.

IMITATION AND THEORY OF MIND

From Piaget (1929) on, child psychologists have been interested in how children come to understand the mental states of their social partners. Recently, this has been dubbed "theory of mind" (ToM) research. The recent wave of ToM research was sparked by Premack and Woodruff's (1978) work with chimpanzees. It has been greatly expanded in both the comparative literature (e.g., Byrne & Whiten, 1988; Cheney & Seyfarth, 1990; Gómez, Sarriá, & Tarnarit, 1993; Povinelli & Eddy, in press a,b; Povinelli, Nelson, & Boysen, 1990, 1992; Povinelli, Parks, & Novak, 1991; Premack, 1988; Whiten, 1991) and child-development literature (e.g., Astington, Harris, & Olson, 1988; Gopnik, 1993; Wellman, 1990; Perner, 1991).

Human adults do not see others as mindless entities, but rather as beings, just like the self, who have beliefs, desires, and other mental states. Fodor (1987, 1992) argued that the adult belief-desire psychology is innately available to humans. Others suggest that in humans the attribution of mental states such as beliefs develops out of an ontogenetically earlier understanding of more primitive states such as attention and intention (e.g., Gopnik, Slaughter, & Meltzoff, 1994; Gopnik & Meltzoff, 1994; Meltzoff & Moore, 1995b; Tomasello, 1995; Tomasello, Kruger, & Ratner, 1993).

I have been particularly interested in the attribution of purposiveness and intention. Purposiveness is far "downstream" as it were, close to the action (behavior); it is not as far "upstream" as other psychological states such as beliefs. If there is ontogenetic change in understanding other minds, it seems likely that recognizing and understanding the purposiveness in other's behavior may be a foundational. (For related work in nonhuman primates the reader is referred to Menzel & Halperin, 1975 and Premack & Woodruff, 1978; for other work with human infants, see Tomasello & Barton, 1994.)

As adults, we believe that other people are not merely tracing physical movements in space but are aiming towards goals. We don't suppose that inanimate objects have such things as goals and intentions. Do prelinguistic infants interpret human behavior as intentional, purposive acts? If so, do they make the distinction between the movements of people and inanimate objects?

To address these questions, I traded on the infant's proclivity for imitation. However, this proclivity was used in a new, more abstract way. This time I was not interested in whether the infants imitated the literal surface behavior shown to them (established in many studies), but whether they read beyond the literal surface behavior to reenact something more abstract—the aim, intention, or goal of the act—even if it was not seen.

Infants were shown an unsuccessful act (Meltzoff, 1995a). For example, the adult tried to perform a behavior, but his hand slipped. Thus the object was not transformed in any way, and the goal state was not achieved. For other acts, the adult accidentally under- or overshot his target. To an adult, it was easy to read the actor's intentions. The experimental question was whether infants also read through the surface behavior. The infants, who were too young to provide verbal reports, informed us how they interpreted the event by what they imitated. The results showed that infants could infer the goal of the act, even though it was never seen or achieved. Most infants reenacted what the adult "meant to do," (the deep structure of the behavior), not what the adult actually did do (the surface structure).

Infants were randomly assigned to one of four independent groups. In the Demonstration$_{\text{(target)}}$ group, the adult demonstrated five target acts on different objects. The infants were presented with the objects, and it was measured whether they reproduced the target acts. This was straightforward imitation. The Demonstration$_{\text{(failed attempt)}}$ group provided the chief condition of interest. For this group the adult did not demonstrate the end state; the child merely saw the adult try but fail to achieve the target acts. Completed target acts were thus not observed. For example, the adult would try to pull apart an object, but his hand would accidentally slip off the end and the object would remain completely untransformed. In the

$\text{Control}_{\text{(adult maipulation)}}$ group, the adult showed neither the target acts nor the failed attempt to achieve them. Instead the adult manipulated the same object for the same length of time as in the Demonstration groups; moreover, the control acts were carefully designed to equate for spatial proximity, direction of movement, and other physical parameters with the Demonstration groups (see Meltzoff, 1995a for details). The $\text{Control}_{\text{(baseline)}}$ group assessed the likelihood that the target acts would occur spontaneously independent of the adult model.

The results showed that there were significantly more target acts produced in the two Demonstration groups than in the Control groups. Moreover, the $\text{Demonstration}_{\text{(target)}}$ and $\text{Demonstration}_{\text{(failed attempt)}}$ did not differ from one another (M = 3.80 and 4.00 of the 5 possible target acts respectively) and both significantly differed from the controls. Interestingly, the data showed that infants were as likely to perform the target after seeing the adult "trying but failing" as they were after seeing the full demonstration. It was as if the human infants saw directly through the surface behavior. Further analyses also showed that infants could readily imitate arbitrary surface behaviors with these objects. Infants produced more of the control actions in the adult-manipulation group than in the other groups. This confirmed that the Demonstrations were not simply prompting the infants to use an "affordance" of the objects, because infants used the *same* objects in two *different* ways, depending on the act demonstrated (cross-target design).

The foregoing experiment indicated that infants can pick up information from the failed attempts of human actors. What if infants see the same movements produced by an inanimate device? Do the spatial transformations in and of themselves "suggest" the target act? A device was built that did not look human but nonetheless could mimic the movements of the actor in the $\text{Demonstration}_{\text{(failed attempt)}}$ group. The device had a pincers that "grasped" the dumbbell on the two ends (just as the human hand did) and then pulled outward. These pincers then slipped off the cubes (just as the human hand did). The pattern of movements and the slipping motions were closely matched to the human hand movements.

A total of 60 infants were tested, and the videotapes scored by observers who were uninformed about group assignment. It was found that infants were visually riveted by both displays; visual attention to the displays exceeded 98% for both treatment groups. The infants were not more frightened by one display than the other. There was no social referencing (turning around toward the parent) during any of the displays. There was no fussing by any of the subjects during the test. Infants did not seem to behave differently when watching the human versus machine. However, the groups significantly differed in their tendency to produce the target act. Infants who saw the human's failed attempt were six times more likely to produce the target than infants in the other group, $p < .0005$. In fact the infants who saw the movements of the inanimate device behaved virtually identically to those in the first study who saw no demonstration at all.

Evidently, infants can infer an aim or goal from human action, but do not make this same ascription when similar movements in space are traced by an inanimate device. That human infants read human behavior but not machine movements in this way, has implications for developing a "theory of mind," as delineated below.

DEVELOPING THEORIES OF IMITATION

Three ideas can be abstracted from the empirical work with infants that might be useful reference points for work in evolutionary biology and comparative psychology. These ideas admittedly go beyond the data per se. They summarize at a more theoretical level what is known and generate predictions about future findings.

Human Infants Are Imitative Generalists

A species-typical, perhaps species-specific aspect of infant imitation is that it is ubiquitous: infants imitate a wide variety of acts in varied situations. Facial, manual, vocal, and object-related imitation has been documented; familiar and novel acts are imitated; both immediate and deferred imitation occurs; imitation can take place in the original setting or be transferred to novel contexts. Each adds a different piece to the puzzle.

Young infants imitate facial gestures such as mouth opening, lip protrusion, tongue protrusion, and head movements. Meltzoff and Moore proposed that facial imitation is mediated by active intermodal mapping (the AIM hypothesis). The crux of this view is that infants can, at some level of processing, apprehend the equivalences between body transformations they see and body transformations of their own whether they see them or not. On this account infant imitation, even early imitation, is a matching-to-target process. The goal or behavioral target is specified visually. Infants' self-produced movements provide proprioceptive information that is compared to the visually specified target.

Infants also imitate vocalizations. We suggested intramodal comparisons come into play in vocal imitation (Kuhl & Meltzoff, 1995, 1996). Infant cooing and babbling, which begins at about 4 weeks of age, allow extensive exploration and elaboration of a kind of auditory-articulatory map. During cooing, auditory events are related to the motor movements that caused them. Infants learn from cooing and babbling that articulatory movements of a particular type have specific auditory consequences. This experience then contributes to an ability to accurately achieve an auditorially specified target. We found developmental changes in vowel production between 12 and 20 weeks of age supporting the view that experience hearing others, hearing oneself, or both, makes a difference.

Infants also imitate actions on objects. The imitation of object-related acts raises a special methodological concern not presented by the imitation of pure body movements and vocal imitation. In object-related imitation one needs to be vigilant as to whether infants are simply striving to recreate the end state, result, or object transformation versus the specifics of the motor act itself (i.e., the form of body movement exhibited by the demonstrator). Tomasello and colleagues call the former "emulation" as opposed to imitation (Tomasello this volume; Tomasello et al., 1993; Tomasello, Savage-Rumbaugh, & Kruger, 1993; see also Wood, 1989). I concluded that human infants were not limited to emulation on the basis of experiments using controls aimed at distinguishing emulation from imitation, and by scoring the fidelity of the match (Meltzoff, 1985, 1988c,d). Perhaps the best existence of proof that infants were not limited in this way was provided by our novel object-related act. The adult leaned down and pushed a panel with his head. Infants imitated by bending forward and pushing the panel with their own heads. Further research in my laboratory has shown that 2-year-old infants will differentially push the panel with their heads, hands, or even their elbows depending on which was modeled. This demonstrates that they are able to imitate the body movements performed with an object and are not limited to recreating an affordance or result. Human infants can imitate the *means* used as well as the goal achieved.

Infants also demonstrate both immediate and deferred imitation. It has been found that human infants will imitate the behavior of a conspecific after delays of up to 4 months. Deferred imitation was demonstrated when the infant was barred from picking up or handling the test object during the initial exposure period. The infant simply watched the adult act during the first session. Memory and differential imitation of multiple acts after 4-month delays (with no immediate imitation) attest to the robust nature of imitative learning in the human infant. Other research found that infants will readily imitate peers as well as adults, strangers as well as mothers.

Human Infants Have an Inbuilt Drive to "Act Like" Their Conspecifics

For chimpanzees, it has been proposed that experience with human-like social interaction is essential for the emergence of imitation; Tomasello et al. (1993) reported that imitation was restricted to "enculturated" and not mother-reared chimpanzees. Whether enculturation is, in fact, a necessary condition for imitation by chimpanzees is a matter of current debate (Whiten and Custance, this volume; Whiten, et al., in press; see also Russon & Galdikas, 1993, 1995 for orangutans). Regardless of how this is resolved, it is clear that enculturation is *not* necessary in human infants: 42-min-old newborns imitate. Meltzoff and Moore (1983a) found imitation in a sample of 40 newborns with the mean age of 32-h-old and no infant was older than 72 h at the time of test. Human infants have an intrinsic motivation to imitate. Imitation may be a mechanism for enculturation, but it does not derive from enculturation in the human case.

The human infant's push to imitate is not restricted to the newborn. In the tests of imitation in older infants I was careful not to use food as a reward or goal to be obtained. This contrasts with the bulk of the studies on nonvocal imitation in animals. For example, in a recent experiment reporting imitation in a nonhuman primate, an artificial fruit (mechanical box) was constructed and presented to chimpanzees (Whiten et al., in press). The subjects could retrieve food from the center of the fruit box by duplicating the adult's retrieval strategy. In human infants, the recovery food is not necessary to motivate imitation. Imitation is an end in itself. Infants struggle to match the adult, self-correct if they do not get it right, and smile upon producing a matching behavior. Human infants derive joy in matching per se. Imitation is its own reward.[1]

imitate own reward
in humans, not
other primates

Imitation and the Roots of Theory of Mind

A central topic in developmental cognitive science is to investigate how and when children develop a "theory of mind," the understanding of others as psychological

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[1] Ongoing research in my laboratory with G. Dawson suggests that children with autism deviate from this species-typical pattern. Very young children with autism have an imitative deficit (for reviews, see Meltzoff & Gopnik, 1993; Rogers & Pennington, 1991). Interestingly, prelinguistic children with Down syndrome are adequate imitators (Rast & Meltzoff, 1995) and later do not exhibit the profound theory-of-mind deficit shown in autism (Baron-Cohen, 1989; Baron-Cohen, Leslie, & Frith, 1985). I have presented a theory of how imitation may be linked to the emergence of a theory of mind in humans (Gopnik & Meltzoff, 1994; Meltzoff, 1990a; Meltzoff & Gopnik, 1993; Meltzoff & Moore, 1995a,b).

beings having mental states such as beliefs, desires, emotions, and intentions. Although it is sometimes supposed that infants are born with an adult-like understanding of other people (Fodor, 1992), developmental psychologists have sought roots for the adult's understanding of the mental states of others.

I suggest that the ontogenetic foundation from which a theory of mind grows is the perception that others are "like me." Infants' primordial like-me experiences are based on their understanding of spatiotemporal patterns of body movements. Infants monitor their own body movements through proprioception and can detect cross-modal equivalents between movements as felt and movements they see performed by others. This opens up an interesting path of development, especially when coupled with the species-typical adult behavior of reciprocal imitation.

In humans, imitation is a bidirectional activity. Human adults not only adopt an explicit "do what I do" pedagogical style (which requires infant imitation to be fulfilled), they also are rabid imitators of their young for the first several years of an infant's life—sliding objects when their infants slide, banging when their infants bang, and cooing when they coo (Bruner, 1983; Stern, 1985; Trevarthen, 1979).

I suggest that when parents "mark" certain infant behaviors by imitating them, when they selectively mirror certain acts back to them, this has special significance to the infant not only because of the temporal contingencies, but because infants can recognize the structural congruence between the adult's acts and their own. Reciprocal imitation games are not only a form of nonverbal communication, but also serve as private tutorials during which infants consolidate and elaborate knowledge about self and other, and the fundamental identity between the two (Meltzoff & Gopnik, 1993; Meltzoff & Moore, 1995a,b).

Such experiences may delimit the class of entities to which infants ascribe psychological properties. Infants may come to see other people, but not things, as purposive beings because people can be imitated, are perceived to be like themselves, and engage in reciprocal imitation. The experimental findings suggest that 18-month-olds see people, but not things, in purposive terms.

The raw fact that infants can make sense of a failed attempt indicates that they have begun to distinguish surface behavior (what people actually do) from another deeper level. This is only an embryonic structure, but it is of critical importance for human development. This differentiation is fundamental to our "theory of mind," underwriting some of our most cherished human traits. Such a distinction is necessary for fluid linguistic communication, which requires distinguishing what was said from what was intended (Grice, 1957, 1969). It is the basis for our judgments of morality, responsibility, and culpability, all of which require distinguishing intentions from actual outcomes. In civil human interaction it is not solely, or even primarily, the actual behavior of our social partners that carries weight, but their underlying intentions. Research indicates that 18-month-olds have begun to understand the acts of other humans in terms of a psychology involving goals, aims, or intentions, not solely in the physics of the literal movements in space. In this sense they already have a primitive, nonverbal building block for developing a theory of mind.

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REFERENCES

Abravanel, E., & Sigafoos, A. D. (1984). Exploring the presence of imitation during early infancy. *Child Development,* **55,** 381–392.

Astington, J. W., Harris, P. L., & Olson, D. R. (1988). *Developing theories of mind.* New York: Cambridge University Press.

Barnat, S. B., Klein, P. J., & Meltzoff, A. N. (in press). Deferred imitation across changes in context and object: Memory and generalization in 14-month-old infants. *Infant Behavior and Development.*

Baron-Cohen, S. (1989). The autistic child's theory of mind: A case of specific developmental delay. *Journal of Child Psychology and Psychiatry,* **30,** 285–297.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition,* **21,** 37–46.

Bruner, J. S. (1983). *Child's talk: Learning to use language.* New York: Norton.

Byrne, R. W. (in press). Skill learning by imitation: Understanding hierarchical organization. In S. Bråten (Ed.), *Intersubjective communication and emotion in ontogeny.* New York: Cambridge University Press.

Byrne, R. W., & Byrne, J. M. E. (1993). Complex leaf-gathering skills of mountain gorillas (*Gorilla g. beringei*): Variability and standardization. *American Journal of Primatology,* **31,** 241–261.

Byrne, R. W. & Whiten, A. (Eds.). (1988). *Machiavellian intelligence: Social expertise and the evolution of intellect in monkeys, apes and humans.* Oxford: Clarendon Press.

Cheney, D. L., & Seyfarth, R. M. (1990). *How monkeys see the world: Inside the mind of another species.* Chicago: University of Chicago Press.

Chomsky, N. (1968). *Language and mind.* New York: Harcourt Brace Jovanovich.

Chomsky, N. (1988). *Language and the problem of knowledge: the Managua lectures.* Cambridge, MA: MIT Press.

Custance, D. M., Whiten, A., & Bard, K. A. (in press). Can young chimpanzees (*Pan troglodytes*) imitate arbitrary actions? Hayes & Hayes (1952) revisited. *Behavior.*

Dawson, B. V., & Foss, B. M. (1965). Observational learning in budgerigars. *Animal Behaviour,* **13,** 470–474.

Field, T., Goldstein, S., Vaga-Lahr, N., & Porter, K. (1986). Changes in imitative behavior during early infancy. *Infant Behavior and Development,* **9,** 415–421.

Field, T. M., Woodson, R., Cohen, D., Greenberg, R., Garcia, R., & Collins, E. (1983). Discrimination and imitation of facial expressions by term and preterm neonates. *Infant Behavior and Development,* **6,** 485–489.

Field, T. M., Woodson, R., Greenberg, R., & Cohen, D. (1982). Discrimination and imitation of facial expressions by neonates. *Science,* **218,** 179–181.

Fodor, J. A. (1987). *Psychosemantics: The problem of meaning in the philosophy of mind.* Cambridge, MA: MIT Press.

Fodor, J. A. (1992). A theory of the child's theory of mind. *Cognition,* **44,** 283–296.

Fontaine, R. (1984). Imitative skills between birth and six months. *Infant Behavior and Development,* **7,** 323–333.

Galef, B. G., Jr. (1988). Imitation in animals: History, definition, and interpretation of data from the psychological laboratory. In T. R. Zentall & B. G. Galef (Eds.), *Social learning: Psychological and biological perspectives* (pp. 3–28). Hillsdale, NJ: Erlbaum.

Galef, B. G. (1992). The question of animal culture. *Human Nature,* **3,** 157–178.

Gómez, J. C., Sarriá, E., & Tamarit, J. (1993). The comparative study of early communication and theories of mind: ontology, phylogeny, and pathology. In S. Baron-Cohen, H. Tager-Flusberg, & D. J. Cohen (Eds.), *Understanding other minds: Perspectives from autism* (pp. 397–426). New York: Oxford Medical Publications.

Gopnik, A. (1993). How we know our minds: The illusion of first-person knowledge of intentionality. *Behavioral and Brain Sciences,* **16,** 1–14.

Gopnik, A., & Meltzoff, A. N. (1994). Minds, bodies, and persons: Young children's understanding of the self and others as reflected in imitation and theory of mind research. In S. T. Parker, R. W. Mitchell, & M. L. Boccia (Eds.), *Self-awareness in animals and humans* (pp. 166–186). Cambridge: Cambridge University Press.

Gopnik, A., Slaughter, V., & Meltzoff, A. (1994). Changing your views: How understanding visual perception can lead to a new theory of the mind. In C. Lewis & P. Mitchell (Eds.), *Children's early understanding of mind: Origins and development* (pp. 157–181). Hillsdale, NJ: Erlbaum.

Grice, H. P. (1957). Meaning. *Philosophical Review,* **66,** 377–388.

Grice, H. P. (1969). Utterer's meaning and intentions. *Philosophical Review,* **78,** 147–177.

Hanna, E., & Meltzoff, A. N. (1993). Peer imitation by toddlers in laboratory, home, and day-care contexts: Implications for social learning and memory. *Developmental Psychology,* **29,** 701–710.

Hauser, M. D., & Marler, P. (1992). How do and should studies of animal communication affect interpretations of child phonological development? In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 663–680). Timonium, MD: York Press.

Heimann, M. (1989). Neonatal imitation, gaze aversion, and mother-infant interaction. *Infant Behavior and Development,* **12,** 495–505.

Heimann, M., Nelson, K. E., & Schaller, J. (1989). Neonatal imitation of tongue protrusion and mouth opening: Methodological aspects and evidence of early individual differences. *Scandinavian Journal of Psychology,* **30,** 90–101.

Heimann, M., & Schaller, J. (1985). Imitative reactions among 14–21 days old infants. *Infant Mental Health Journal,* **6,** 31–39.

Heyes, C. M. (1993). Imitation, culture and cognition. *Animal Behavior,* **46,** 999–1010.

Heyes, C. M., & Dawson, G. R. (1990). A demonstration of observational learning in rats using a bidirectional control. *The Quarterly Journal of Experimental Psychology,* **42B,** 59–71.

Jacobson, S. W. (1979). Matching behavior in the young infant. *Child Development,* **50,** 425–430.

Kaitz, M., Meschulach-Sarfaty, O., Auerbach, J., & Eidelman, A. (1988). A reexamination of newborn's ability to imitate facial expressions. *Developmental Psychology,* **24,** 3–7.

Konishi, M. (1989). Birdsong for neurobiologists. *Neuron,* **3,** 541–549.

Kugiumutzakis, J. (1985). *Development of imitation during the first six months of life* (Uppsala Psychological Reports No. 377): Uppsala, Sweden: Uppsala University.

Kuhl, P. K., & Meltzoff, A. N. (1982). The bimodal perception of speech in infancy. *Science,* **218,** 1138–1141.

Kuhl, P. K., & Meltzoff, A. N. (1995). Vocal learning in infants: Development of perceptual-motor links for speech. In K. Elenius & P. Branderud (Eds.), *Proceedings of the XIIIth International Congress of Phonetic Sciences* (pp. 146–149). Stockholm: Stockholm University.

Kuhl, P. K., & Meltzoff, A. N. (1996). Evolution, nativism, and learning in the development of language and speech. In M. Gopnik (Ed.), *The biological basis of language.* New York: Oxford University Press.

Kuhl, P. K., & Meltzoff, A. N. (in press). Infant vocalizations in response to speech: Vocal imitation and developmental change. *Journal of the Acoustical Society of America.*

Legerstee, M. (1991). The role of person and object in eliciting early imitation. *Journal of Experimental Child Psychology,* **51,** 423–433.

Lorenz, K. Z. (1943). Die angeborenen Formen möglicher Erfahrung. *Zeitschrift für Tierpsychologie,* **5,** 235–409.

Maratos, O. (1982). Trends in the development of imitation in early infancy. In T. G. Bever (Ed.), *Regressions in mental development: Basic phenomena and theories* (pp. 81–101). Hillsdale, NJ: Erlbaum.

Marler, P. (1974). Constraints on learning: Development of bird song. In N. F. White (Ed.), *Ethology and Psychiatry* (pp. 69–83). Toronto: University of Toronto Press.

Meltzoff, A. N. (1985). Immediate and deferred imitation in fourteen- and twenty-four-month-old infants. *Child Development,* **56,** 62–72.

Meltzoff, A. N. (1988a). Imitation, objects, tools, and the rudiments of language in human ontogeny. *Human Evolution,* **3,** 45–64.

Meltzoff, A. N. (1988b). Imitation of televised models by infants. *Child Development,* **59,** 1221–1229.

——Meltzoff, A. N. (1988c). Infant imitation after a 1-week delay: Long-term memory for novel acts and multiple stimuli. *Developmental Psychology,* **24,** 470–476.

Meltzoff, A. N. (1988d). Infant imitation and memory: Nine-month-olds in immediate and deferred tests. *Child Development,* **59,** 217–225.

Meltzoff, A. N. (1988e). The human infant as *Homo imitans.* In T. R. Zentall & B. G. Galef (Eds.), *Social learning: Psychological and biological perspectives* (pp. 319–341). Hillsdale, NJ: Erlbaum.

Meltzoff, A. N. (1990a). Foundations for developing a concept of self: The role of imitation in relating self to other and the value of social mirroring, social modeling, and self practice in infancy. In D. Cicchetti & M. Beeghly (Eds.), *The self in transition: Infancy to childhood* (pp. 139–164). Chicago: University of Chicago Press.

Meltzoff, A. N. (1990b). Towards a developmental cognitive science: The implications of cross-modal matching and imitation for the development of representation and memory in infancy. In A. Diamond (Ed.), *Annals of the New York Academy of Sciences. Vol. 608: The development and neural bases of higher cognitive functions* (pp. 1–31). New York: New York Academy of Sciences.

Meltzoff, A. N. (1995a). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology,* **31,** 838–850.

Meltzoff, A. N. (1995b). What infant memory tells us about infantile amnesia: Long-term recall and deferred imitation. *Journal of Experimental Child Psychology,* **59,** 497–515.

Meltzoff, A. N., & Borton, R. W. (1979). Intermodal matching by human neonates. *Nature,* **282,** 403–404.

Meltzoff, A. N., & Gopnik, A. (1993). The role of imitation in understanding persons and developing a theory of mind. In S. Baron-Cohen, H. Tager-Flusberg, & D. Cohen (Eds.), *Understanding other minds: Perspectives from autism* (pp. 335–366). New York: Oxford University Press.

Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science,* **198,** 75–78.

Meltzoff, A. N., & Moore, M K. (1983a). Newborn infants imitate adult facial gestures. *Child Development,* **54,** 702–709.

Meltzoff, A. N., & Moore, M. K. (1983b). The origins of imitation in infancy: Paradigm, phenomena, and theories. In L. P. Lipsitt (Ed.), *Advances in infancy research* (Vol. 2, pp. 265–301). Norwood, NJ: Ablex.

Meltzoff, A. N., & Moore, M. K. (1989). Imitation in newborn infants: Exploring the range of gestures imitated and the underlying mechanisms. *Developmental Psychology,* **25,** 954–962.

Meltzoff, A. N., & Moore, M. K. (1992). Early imitation within a functional framework: The importance of person identity, movement, and development. *Infant Behavior and Development,* **15,** 479–505.

Meltzoff, A. N., & Moore, M. K. (1994). Imitation, memory, and the representation of persons. *Infant Behavior and Development,* **17,** 83–99.

Meltzoff, A. N., & Moore, M. K. (1995a). A theory of the role of imitation in the emergence of self. In P. Rochat (Ed.), *The self in early infancy: Theory and research* (pp. 73–93). New York: North Holland-Elsevier Science Publishers.

Meltzoff, A. N., & Moore, M. K. (1995b). Infants' understanding of people and things: From body imitation to folk psychology. In J. Bermúdez, A. J. Marcel, & N. Eilan (Eds.), *The body and the self* (pp. 43–69). Cambridge, MA: MIT Press.

Menzel, E. W., & Halperin, S. (1975). Purposive behavior as a basis for objective communication between chimpanzees. *Science,* **189,** 652–654.

Nagell, K., Olguin, R. S., & Tomasello, M. (1993). Processes of social learning in the tool use of chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). *Journal of Comparative Psychology,* **107,** 174–186.

Nottebohm, F. (1975). A zoologist's view of some language phenomena with particular emphasis on vocal learning. In E. H. Lenneberg & E. Lenneberg (Eds.), *Foundations of language development* (Vol. 1, pp. 61–103). New York: Academic Press.

Perner, J. (1991). *Understanding the representational mind.* Cambridge, MA: MIT Press.

Piaget, J. (1929). *The child's conception of the world.* New York: Harcourt Brace.

Piaget, J. (1952). *The origins of intelligence in children.* New York: International Universities Press.

Povinelli, D. J., & Eddy, T. J. (in press a). Chimpanzees: Joint visual attention. *Psychological Science.*

Povinelli, D. J., & Eddy, T. J. (in press b). What young chimpanzees know about seeing. *Monographs of the Society for Research in Child Development.*

Povinelli, D. J., Nelson, K. E., & Boysen, S. T. (1990). Inferences about guessing and knowing by chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology,* **104,** 203–210.

Povinelli, D. J., Nelson, K. E., & Boysen, S. T. (1992). Comprehension of role reversal in chimpanzees: Evidence of empathy? *Animal Behavior,* **43,** 633–640.

Povinelli, D. J., Parks, K. A., & Novak, M. A. (1991). Do rhesus monkeys (*Macaca mulatta*) attribute knowledge and ignorance to others? *Journal of Comparative Psychology,* **105,** 318–325.

Premack, D. (1988). "Does a chimpanzee have a theory of mind?" revisited. In R. W. Byrne & A. Whiten (Eds.), *Machiavellian intelligence: Social expertise and the evolution of intellect in monkeys, apes and humans.* Oxford: Oxford University Press.

Premack, D., & Premack, A. J. (1994). Why animals have neither culture nor history. In T. Ingold (Ed.), *Companion Encyclopedia of Anthropology* (pp. 350–365). New York: Routledge & Kegan Paul.

Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences,* **4,** 515–526.

Rast, M., & Meltzoff, A. N. (1995). Memory and representation in young children with

Down syndrome: Exploring deferred imitation and object permanence. *Development and Psychopathology,* **7,** 393–407.

Reissland, N. (1988). Neonatal imitation in the first hour of life: Observations in rural Nepal. *Developmental Psychology,* **24,** 464–469.

Rogers, S. J., & Pennington, B. F. (1991). A theoretical approach to the deficits in infantile autism. *Development and Psychopathology,* **3,** 137–162.

Russon, A. E., & Galdikas, M. F. (1993). Imitation in free-ranging rehabilitant orangutans (*Pongo pygmaeus*). *Journal of Comparative Psychology,* **107,** 147–161.

Russon, A. E., & Galdikas, B. M. F. (1995). Constraints on great apes' imitation: Model and action selectivity in rehabilitant orangutan (*Pongo pygmaeus*) imitation. *Journal of Comparative Psychology,* **109,** 5–17.

Stern, D. N. (1985). *The interpersonal world of the infant.* New York: Basic Books.

Tomasello, M. (1995). Joint attention as social cognition. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origins and role in development.* Hillsdale, NJ: Erlbaum.

Tomasello, M., & Barton, M. E. (1994). Learning words in nonostensive contexts. *Developmental Psychology,* **30,** 639–650.

Tomasello, M., Kruger, A. C., & Ratner, H. H. (1993). Cultural learning. *Behavioral and Brain Sciences,* **16,** 495–552.

Tomasello, M., Savage-Rumbaugh, E. S., & Kruger, A. C. (1993). Imitative learning of actions on objects by children, chimpanzees, and enculturated chimpanzees. *Child Development,* **64,** 1688–1705.

Trevarthen, C. (1979). Communication and cooperation in early infancy: A description of primary intersubjectivity. In M. Bullowa (Ed.), *Before speech* (pp. 321–347). New York: Cambridge University Press.

Vinter, A. (1986). The role of movement in eliciting early imitations. *Child Development,* **57,** 66–71.

Visalberghi, E. & Fragaszy, D. (1990). Do monkeys ape? In S. Parker & K. Gibson (Eds.), *Language and intelligence in monkeys and apes: Comparative developmental perspectives* (pp. 247–273). New York: Cambridge University Press.

Wellman, H. M. (1990). *The child's theory of mind.* Cambridge, MA: MIT Press.

Whiten, A. (Ed.) (1991). *Natural theories of mind: Evolution, development and simulation of everyday mindreading.* Cambridge, MA: Basil Blackwell.

Whiten, A., Custance, D. M., Gómez, J.-C., Teixidor, P., & Bard, K. (in press). Imitative learning of artificial fruit processing in children (*Homo sapiens*) and chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology.*

Whiten, A., & Ham, R. (1992). On the nature and evolution of imitation in the animal kingdom: Reappraisal of a century of research. In P. Slater, J. Rosenblatt, C. Beer, & M. Milinski (Eds.), *Advances in the study of behavior* (Vol. 21, pp. 239–283). New York: Academic Press.

Wood, D. (1989). Social interaction as tutoring. In M. H. Bornstein & J. S. Bruner (Eds.), *Interaction in human development* (pp. 59–89). Hillsdale, NJ: Erlbaum.