

The Imitative Mind

Development, Evolution, and Brain Bases

edited by

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1 Elements of a developmental theory of imitation

Andrew N. Meltzoff

Imitation promises to be a hot research topic in the coming decade. Interest in imitation spread from a small band of aficionados to the broader community of cognitive scientists, evolutionary biologists, neuroscientists, philosophers, and developmental scientists. What is sparking such widespread growth in this topic?

First, discoveries in developmental psychology have altered theories about the origins of imitation and its place in human nature. We used to think that humans gradually learned to imitate over the first several years of life. We now know that newborns can imitate body movements at birth. Such imitation reveals an innate link between observed and executed acts, with implications for brain science, and also reveals a primordial connection between the infant and caretaker, with implications for emotional development and intersubjectivity.

Second, there has been a change in the perceived value of developmental research. In classical psychological theories the child's mind was regarded as the antithesis of the adult mind. Adults were viewed as rational, planful, and operating with coherent perceptions; whereas infants were portrayed as slaves of the here-and-now, devoid of reason, and experiencing James' "blooming, buzzing, confusion." Scientists often assumed greater similarities between college students and rats than between college students and infants. This impeded scientists from using infants as informants about adult cognition. As experimental techniques improved, infants became good sources of information about fundamental principles of human thought. The increased value of developmental research brought studies of infant imitation to the foreground.

Third, evolutionary biologists have devised ways of comparing imitation in humans and nonhuman animals, and imitation has become a tool for examining continuities/discontinuities in the evolution of mind and intersubjectivity (Byrne, this volume; Tomasello & Call, 1997; Whiten, this volume). Darwin inquired about imitation in nonhuman animals, but in the last ten years, there has been a greater number of controlled studies of imitation in monkeys and great apes than there had been in

the previous hundred years. The results indicate that monkey imitation is hard to come by in controlled experiments, belying the common wisdom of “monkey see monkey do.” Nonhuman primates and other animals (e.g., songbirds) imitate, but their imitative prowess is more restricted than that of humans. The evolutionary basis of imitation will continue to be informative as direct cross-species comparisons are made.

Fourth, neuroscientists and experimental psychologists have discovered imitation. They are focused on the brain and psychological mechanisms connecting the observation and execution of actions, including the exploration of “mirror neurons” (e.g., Decety, this volume; Prinz, this volume; Rizzolatti, Fadiga, Fogassi, & Gallese, this volume).

Finally, the artificial intelligence community is beginning to create androids that can learn by registering the user’s movements, rather than by line-by-line programming. This new endeavor is called “learning by example” (Berthouze & Kuniyoshi, 1998; Billard & Dautenhahn, 2000; Billard, Dautenhahn, & Hayes, 1998; Dautenhahn & Nehaniv, in press; Mataric & Pomplun, 1998). Learning by imitation is prompting an increased cross-fertilization between the fields of robotics and human psychology (Demiris *et al.*, 1997; Hayes & Demiris, 1994; Schaal, 1999).

Information in an imitative act

From a neuroscience and cognitive science perspective, the fundamental question posed by imitation concerns the mechanism that underlies it – the *How*-question. Consider what is involved in an act of imitation. The observer perceives the demonstrator’s acts, uses visual perception as the basis for an action plan, and executes the motor output. This involves vision, cross-modal coordination, and motor control. If imitation takes place after a significant delay, memory and the representation of action come into play. For brain scientists, this is obviously a highly informative vein to mine in both verbal and nonverbal subjects.

Imitation also allows investigation of fundamental social processes. Cultures differ in customs, rituals, and technologies. Imitation provides a mechanism for a kind of Lamarckian evolutionary change in human societies by which adults pass on “acquired characteristics” to their young. Imitation also provides an avenue of nonverbal communication through the language of gestures. For example, new research indicates that young children use imitation as a way of determining a person’s identity. If children are unsure about whether they have seen you before, they will reintroduce a game – often an imitative game – they had played with you to probe whether you are “the same individual again” (Meltzoff & Moore, 1994, 1998).

This chapter analyzes both the cognitive and the social aspects of imitation from a developmental approach. Special consideration will be given to the mechanism linking the perception and production of acts. I will propose that human infants code human acts within a “supramodal” framework that unites the observation and execution of motor acts and that this observation/execution system is innate. However, it is equally important that infants are not compelled to go immediately from perception to motor performance. Young children can observe a novel behavior on one day and imitate the next day. They also imitate in a selective and interpretive fashion (Meltzoff & Moore, 1997). The implications for memory and representation will be examined.

I will also examine the connection between infant imitation and childhood theory of mind. A developmental model is proposed: my thesis is that motor imitation is a foundation for the later development of empathy and a theory of mind. According to this view, empathy, role-taking, and theory of mind depend on the fundamental self-other equivalence first realized in infant imitation. Infants first grasp that others are “like me” in action; from this they develop the more mature notion that others are “like me” in abstract ways – having desires, emotions, intentions, and other internal states just like mine. The mechanisms of development are examined.

Mirror neurons and development

“Mirror neurons” in the premotor cortex of the monkey brain discharge both when an action is observed and when it is executed (e.g., Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Fogassi, & Gallese, this volume; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Related findings in humans using PET and fMRI reveal common brain regions subserving both the perception and production of actions (e.g., Decety *et al.*, 1994, 1997; Decety & Grèzes, 1999; Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Grèzes & Decety, 2001; Iacoboni *et al.*, 1999).

These are dramatic discoveries, but research from a developmental perspective would be valuable. Consider the case of a mirror neuron that discharges to “grasping-with-the-hand.” This same cell fires regardless of whether that act is performed by the monkey or observed in another actor. A cell that discharges in both cases could mean that “grasping” is an innate act, and that prior to experience the cell is tuned to this category of action whether performed by the self or the other. Alternatively, it could mean the monkey has seen himself perform this action many times. If the monkey has watched himself perform grasping motions, there would have been repeated experience of linking the motor execution with the

perception of the act. Observation and execution occur in synchrony whenever the monkey watches himself grasping with his hand. After such experience, the visual perception of “grasping” by another animal could activate neurons based on a *visual* “equivalence class” between the sight of one’s own and another’s hand.

If this analysis is correct, mirror neurons could result from learning and visual generalization. It is now critical for theories to investigate the ontogeny of mirror neurons. One needs to determine whether: (a) an animal is born with mirror neurons, (b) these neurons activate the first time the animal sees an act executed, or (c) the mirror neuron is activated only after an observation/execution association is built up over time. Developmental work with infant monkeys would help to clarify the origins of mirror neurons.

Imitation and experience

I have been using the word “imitation” broadly, but not all imitation is of the same type. Certain types of imitation are even more informative for brain and cognitive theories than others. From a developmental perspective, there are distinctions, for example, between imitation of hand movements and imitation of facial movements.

Human children can imitate hand movements in the first six months of life (Meltzoff & Moore, 1977, 1997; Piaget, 1962; Vinter, 1986). One possible mechanism would be for the infant to look at his or her own hand and use visual guidance as a way of achieving a match between self and other. The manual movements of self and other can both be seen. Visual pattern matching would specify when the target was achieved.

Such visual guidance is not trivial (see Goldenberg & Hermsdörfer, this volume). Infants must compare another’s behavior to their own, despite differences in body size and perspective. Nevertheless, the visual system provides “form constancy” that would allow infants to extract equivalences across changes of size, visual orientation of the hand, and color. Also, young infants engage in hand-regard during the early months, so they have experience in watching their own hands move and transform. In principle, then, they have learning experiences in linking the observation and execution of manual acts.

Facial imitation presents a deeper puzzle. Newborn infants can see another’s face, but they have never seen their own faces. There are no mirrors in the womb. Newborns can feel their own face move but have no access to the feeling-of-movement in others. There seems to be a gulf between self and other. It is no wonder that psychological theories from Freud to Piaget considered the imitation of facial actions as

a milestone developmental achievement. The age at which infants were thought to imitate facial gestures was about one year old. Facial imitation at younger ages was theorized to be impossible – infants were supposed to lack the connection between observation and execution prior to associative experiences and reinforcement training.

Facial imitation: innate observation-execution links

Infant facial imitation is a behavior that assesses the link between observation and execution of motor actions. The empirical findings at first surprised psychologists. They showed that infants could imitate prior to the learning experiences, indicating an innate mapping between observation and execution.

In an early study, imitation of facial gestures was documented in two- to three-week-old infants (Meltzoff & Moore, 1977). A first question was whether infants would confuse all “protrusion” movements with one another. The results showed they did not inasmuch as they distinguished lip protrusion from tongue protrusion. A related question was whether infants could differentiate two movements using the same body part. The results showed they distinguished lip opening versus lip protrusion. Thus, the infants’ responses were not global reactions to the sight of a face in general, not an arousal reaction, but were based on specific mappings.

This work implies that there is an intrinsic connection between perception and production. However, if we take the developmental viewpoint seriously, the subjects are not young enough. They were two weeks old and perhaps could have learned the relevant associations during early mother-child play. The definitive test requires newborns.

The relevant study involved 40 newborn infants with a mean age of 32 hours old. The oldest child in the study was 72 hours old, and the youngest was just 42 minutes old at the time of test. The results showed that human newborns imitate facial acts (Meltzoff & Moore, 1983, 1989). Newborn imitation provides an “existence proof” for a neural mapping between observed and executed movements in human infants.

Early imitation is not restricted to one or two oral movements. Imitative effects have been reported for a range of facial and manual movements (see Meltzoff & Moore, 1997, for a review). A sample of the acts that can be imitated include: tongue protrusion, lip protrusion, mouth-opening, hand gestures, head movements, cheek and brow motions, eye blinking, and components of emotional expressions (Abravanel & DeYong, 1991; Abravanel & Sigafos, 1984; Field, Goldstein, Vaga-Lahr, & Porter, 1986; Field *et al.*, 1983; 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, 1983, 1989, 1992, 1994; Reissland, 1988; Vinter, 1986).

Infants in the first months of life are not limited to imitating while the target is in the perceptual field. In one study a pacifier was put in the child's mouth during the time that the adult demonstrated the target. The adult then terminated the display, assumed a neutral facial expression, and only then removed the pacifier. The results showed that infants can initiate perceptually absent models from memory (Meltzoff & Moore, 1977). In a further study, the delay between observation and production was increased to 24 hours. Infants watched gestures on one day and then returned to the laboratory to see the same person with a neutral face on the next day. Infants imitated after this lengthy delay (Meltzoff & Moore, 1994). Evidently, infants can store a representation of what they see another person do and imitate on the basis of that stored representation.

Other evidence also fits the idea that infant imitation is mediated by a stored representation. Imitative responses do not "pop out" fully formed. Infants correct their efforts. For example, when infants are shown a novel act such as tongue-protrusion-to-the-side, they begin by activating the correct body part, the tongue, and making small movements. They gradually modify this behavior so that it more and more accurately matches the gesture they see. This modification occurs with no feedback from the adult, who is either absent or sits with a neutral face (Meltzoff & Moore, 1994, 1997).

AIM mechanism

Meltzoff and Moore (1997) provided a detailed model of the mechanism underlying infant facial imitation. We hypothesized that infant imitation involves "active intermodal mapping" (AIM). Figure 1.1 provides a conceptual schematic. The crux of the AIM hypothesis is that infant imitation involves a goal-directed matching process. The goal or behavioral target is specified visually. Infants' self-produced movements provide proprioceptive feedback that can be compared to the representation of the observed act. AIM proposes that such comparison is possible because the observation and execution of human acts are coded within a common framework. We call it a "supramodal act space." AIM does not rule out direct imitation of certain elementary acts on "first try" without any need for feedback, but it allows for such proprioceptive feedback and correction of responses. Metaphorically, we can say that exteroception (perception of others) and proprioception (perception of self) speak the

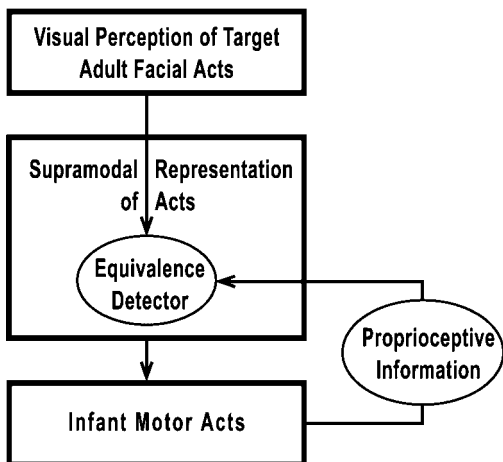


Figure 1.1. The AIM hypothesis for how infants perform facial imitation. (From Meltzoff & Moore, 1997.)

same language; there is no need for associating the two through prolonged learning because they are intimately bound at birth. Meltzoff and Moore (1995, 1997) provide further analysis of the common metric of equivalence between observed and executed acts as it subserves imitation in human newborns.

This idea of a supramodal coding of human acts that emerged from developmental psychology is highly compatible with Prinz' theory of common coding, which derived from cognitive experiments with adults (Prinz, 1990, 1992, this volume). It also dovetails well with the neuroscience discoveries about the brain bases for coupling observed and executed acts (Decety, this volume; Decety, Chaminade, & Meltzoff, in press; Jacoboni *et al.*, 2001; Rizzolatti, Fadiga, Fogassi, & Gallese, this volume). An interesting challenge will be to determine the extent to which these mechanisms for linking perception and production are phylogenetically and ontogenetically related.

Imitation and identity: the uses of infant imitation

How do infants use imitation in their social interaction with people, and what good does it do them?

An interesting idea is that infants may use imitation to probe the identity of people. Adults keep track of individuals as they move and change in the visual field (Kahneman, Treisman, & Gibbs, 1992). Developmental

studies indicate that infants are also concerned with keeping track of individuals (e.g., Meltzoff & Moore, 1998; Leslie, Xu, Tremoulet, & Scholl, 1998; Wilcox & Baillargeon, 1998; Xu & Carey, 1996). Of course, infants use facial features to help them identify people (they can recognize their mother's face), but there is growing evidence that they do not wholly rely on visual features. Infants also use a person's actions to determine who the person is.

In one study we presented six-week-old infants with people who were coming and going in front of them, as would happen in real-world interaction. The mother appeared and showed one gesture (say, mouth opening). Then she exited and was replaced by a stranger who showed a different gesture (say, tongue protrusion). The experiment required that infants keep track of the two different people and their gestures (Meltzoff & Moore, 1992).

When infants visually tracked the entrances and exits they imitated each person without difficulty. But we also uncovered an interesting error. If the mother and stranger surreptitiously changed places, infants became confused: is it the same person with a different appearance, or a new person in the old place? The visual features were suggesting one thing (new person) but the spatial cues were suggesting another (same old person). Infants used imitation as a means of settling this conflict. Infants stared at the new person, stopped behaving, and then intently produced the *previous* person's gesture.

Meltzoff and Moore hypothesized that when infants are confused about the identity of a person, they are motivated to test how the person will respond to actions. It is their way of asking: "Are you the one who does *x*?" Of course, adults use language to determine identity. We can ask: "Can you repeat the secret password?" Infants use an imitation game to check whether the adult responds with the "secret password in action." A series of further studies on imitation and identity reinforce this point (Meltzoff & Moore, 1994, 1995, 1998).

The discovery, then, is that human infants use imitative games to check the identity of the person in front of them. If infants see a person of unknown identity sitting in front of them with a neutral face, infants will often "imitate" an action that person has done in the past. This is a social-cognitive use of early imitation before verbal language is possible. It is a way of probing "Who are you?" or "Didn't we play this game before?" Infants probe whether the person acts correctly, because actions and expressive behaviors of people are identifiers of who the person is. It is not just what a person looks like (visual cues), or the spatial context of the encounter (spatial cues), but also a person's actions that determine their identity for infants.

Speech perception and production

Facial imitation involves the cross-modal processing of facial movements. There are other phenomena involving cross-modal knowledge of faces. One such domain is speech. Empirical work reveals perception-production links in speech that closely parallel the perception-production links shown in motor imitation.

Mapping sound to sight

Work with adults shows that the speech code is not exclusively auditory or motor, but is fundamentally multimodal in nature. A striking example is the illusion that occurs when an auditory soundtrack of /b/ is combined with a visual film of a person articulating the consonant /g/. Subjects report perceiving the consonant /d/ despite the fact that this consonant was not delivered to either sense modality (McGurk & MacDonald, 1976). The illusory percept is a “blend” or “intermodal best fit” that takes into account both the auditory and the visual-motor information.

Speech information is even blended when the auditory and visual information come from a special tape of two talkers of different genders. In an experiment involving college students, a male football player’s face (a face with whiskers, a large neck, and thick jaw bone) was paired with a high-pitched female voice (Green, Kuhl, Meltzoff, & Stevens, 1991). Viewers accurately reported seeing a male face and hearing a female voice, without any perceptual blends or illusions regarding gender. These same subjects, however, automatically blended the speech information and perceived the illusory /d/.

At what age does cross-modal speech perception develop? In one study four-month-old infants were presented with a baby-sized auditory-visual lip-reading problem. They viewed two faces, side by side, one pronouncing the vowel /a/ (as in “pop”) and the vowel /i/ (as in “peep”). While viewing the two faces, infants heard one of the vowels (either /a/ or /i/) played from a loudspeaker located midway between the two faces. The film was arranged so the mouths on both faces opened and closed in perfect synchrony.

The results showed that infants who heard the vowel /a/ looked longer at the face pronouncing /a/, and the infants who heard the vowel /i/ looked longer at the vowel /i/ (Kuhl & Meltzoff, 1982, 1984; Kuhl, Williams, & Meltzoff, 1991). There were no temporal clues or spatial clues, because the sound came from midline and was synchronized with both faces. The only way infants could solve this problem is by recognizing cross-modal correspondence between the auditory and visual speech

information, recognizing that a mouth shape of a certain kind goes with a speech unit of a certain form. Work in other laboratories has replicated and extended this work (MacKain, Studdert-Kennedy, Spieker, & Stern, 1983; Walton & Bower, 1993).

Mapping sound to production: vocal imitation

The previous experiment involved the matching of seen and heard speech. What about motor production? Can infants imitate the sounds they hear, producing the correct articulatory movements on the basis of auditory input? This was examined in a study of infant vocal imitation at three ages: twelve, sixteen, and twenty weeks of age (Kuhl & Meltzoff, 1996). Each infant listened to one of three vowels, /a/, /i/, or /u/ for fifteen minutes (five minutes for each of three days). Infants' vocalizations were recorded and analyzed perceptually by having them phonetically transcribed and analyzed via computerized spectrographic techniques.

The results demonstrated vocal imitation. Infants produced significantly more /a/-like utterances when exposed to /a/ than when exposed to /i/ or /u/ and so on for each of the vowels. There was a developmental progression such that the twenty-week-olds were better imitators than the younger infants, but infants imitated at all three ages.

If fifteen minutes of laboratory exposure to a vowel is sufficient to influence infants' vocalizations, then infants bathed in the ambient language of the culture could be affected (Kuhl, Tsao, Lui, Zhang, & de Boer, 2001). In fact, one can see the effects of such vocal imitation in cross-cultural work. By one year of age infants from different cultures babble differently. French infants babble with French speech units, Russian infants with Russian, and Japanese with Japanese (de Boysson-Bardies, Sagart, & Durand, 1984; de Boysson-Bardies, Halle, Sagart, & Durand, 1989; Gopnik, Meltzoff, & Kuhl, 1999).

Speech as a supramodal representation

Evidently, human speech, just like human body acts, is represented in a way that is not strictly unimodal. The auditory signal influences behavior in two other domains. The auditory signal influences where infants *look*. The auditory signal also influences the *motor* system. We hypothesize that both these phenomena, lip reading and vocal imitation, are underwritten by an infant speech code that is supramodal in nature and related to the common action code that subserves facial imitation (Kuhl, 2000; Kuhl & Meltzoff, 1982, 1984).

Object imitation and memory

Adults do not simply vocalize and move their bodies. Adults also act on the world of objects. We act on hammers, levers, wheels, and keyboards. If imitation is to fulfill its value in the transmission of culture and the use of artifacts, young children will need to be able to imitate the use of tools and other objects.

The data indicate that as soon as infants become capable of handling objects, imitation of object-directed acts begins to preoccupy them. One field observation from Western households will suffice. At about one to two years old, the baby's favorite plaything is a toy telephone. There is nothing "natural" about holding objects to our ear while we speak to invisible people. Why do infants do it? Although such behavior seems to have the hallmarks of imitation (it is not culturally universal, caretakers do not explicitly train it), developmentalists have conducted controlled laboratory studies to test this. These experiments also use imitation to investigate memory.

Memory without language

Imitation from memory goes beyond the direct coupling of an observation/execution system. It introduces memory and the representation of action. Cognitive psychologists have established that not all memory is the same (Schacter, 1996; Squire, Knowlton, & Musen, 1993; Wheeler, Stuss, & Tulving, 1997). For example, there is a distinction between retaining a familiar action or habit (habit memory) versus remembering information from one brief observation, without previous experience with the actions or objects (nonhabit or declarative memory).

Keeping the different types of memory in mind, laboratory experiments have investigated whether human infants must imitate the target act immediately in order to retain it in memory. In these studies, the children watched adults manipulate objects, but the children were not allowed to touch the objects. A delay was imposed, and then children were given the objects. Using this so-called "observation-only" design (Meltzoff & Moore, 1998), deferred imitation has been documented in infants as young as six to nine months of age (Barr, Dowden, & Hayne, 1996; Heimann & Meltzoff, 1996; Meltzoff, 1988b).

There is also evidence that a brief exposure to a novel act is enough to sear it into the memory of a toddler. In one study, infants witnessed a bizarre act, an adult who leaned forward and pressed a panel with his forehead. The infants were not allowed to handle the panel during the display. When they were given the panel one week later, 67 per cent of the infants duplicated the novel head-touch behavior. Such a novel

use of the forehead was exhibited by 0 per cent of the controls, thus the object's properties alone did not call out the response à la an "affordance" (Meltzoff, 1988a). This research documents deferred imitation of a novel act after a brief exposure.

Deferred imitation has been used to explore the duration of preverbal memory. The results show that six- to nine-month-olds can imitate after a 24-hour delay (Barr, Dowden, & Hayne, 1996; Meltzoff, 1988b); twelve-month-olds after a four-week delay (Klein & Meltzoff, 1999); and infants in the second year after delays of four months or longer (e.g., Bauer & Wewerka, 1995; Meltzoff, 1995b). Evidently, preverbal infants can learn from watching and need not perform the target act immediately – observation and execution can be broken apart in time.

If children are to use deferred imitation in everyday life, it requires not only memory but also a certain freedom from context specificity. An adult can watch someone use a tool in one setting and recall that behavior in a new setting. Such "decontextualization" is important for language acquisition (Hockett, 1960); words are not just used in a single context but must be used flexibly in new settings.

In one study investigating context specificity, twelve-month-olds were shown target acts at home and one week later given their recall test in the laboratory. The results showed successful imitation (Klein & Meltzoff, 1999). In another study, toddlers in a day-care center watched "expert children" who were trained to use objects in peculiar ways. Two days later the observer children were tested at home. The results showed that the toddlers took their school lessons home with them and imitated after the two-day delay and contextual change (Hanna & Meltzoff, 1993). Finally, a study showed that fourteen-month-olds generalized their imitation across changes in the size and color of the test object (Barnat, Klein, & Meltzoff, 1996).

The findings support several inferences about the representation of human actions on objects: (a) these representations can be formed from observation alone; (b) they persist over lengthy delays and changes of context; (c) these representations are a sufficient basis on which to organize action. Human toddlers imitate, but they have loosened the shackles between observation and execution; they can tolerate long delays and radical shifts in context. (Interestingly, children with autism have difficulties with such memory-based imitation, Dawson, Meltzoff, Osterling, & Rinaldi, 1998.)

Roots of theory of mind and intersubjectivity

People are more than dynamic bags of skin that move, manipulate objects, and vocalize. Persons also have beliefs, desires, and intentions that

underlie and cause the surface actions. One cannot directly see the underlying mental states, but it is an essential part of our adult understanding of people that others have them. “Theory of mind” research investigates the development of this understanding of other minds (Flavell & Miller, 1998; Perner, 1991; Taylor, 1996; Wellman, 1990).

Where does this tendency to treat others as sentient beings come from? Are we born with a theory of mind, naturally attributing mental states to others? Do we learn it in school?

Goals and intentions

A nonverbal procedure, called the “behavioral re-enactment technique,” was devised to investigate the roots of theory of mind (Meltzoff, 1995a). The procedure capitalizes on imitation, but uses this proclivity in a new, more abstract way. It investigates children’s ability to read below the visible surface behavior to the underlying goals and intentions of the actor.

One study involved showing eighteen-month-old children an unsuccessful act, a failed effort. For example, the adult “accidentally” under- or overshot his target, or he tried to perform a behavior but his hand slipped several times. Thus the goal-state was not achieved. To an adult, it was easy to read the actor’s intentions although he did not fulfill them. The experimental question was whether children also read through the literal body movements to the underlying goal of the act. The measure of how they interpreted the event was what they chose to re-enact. In this case the “correct answer” was not to copy the literal movement that was actually seen, but the actor’s goal, which remained unfulfilled.

The study compared infants’ tendency to perform the target act in several situations: (a) after they saw the full target act demonstrated, (b) after they saw the unsuccessful attempt to perform the act, and (c) after it was neither shown nor attempted. The results showed that

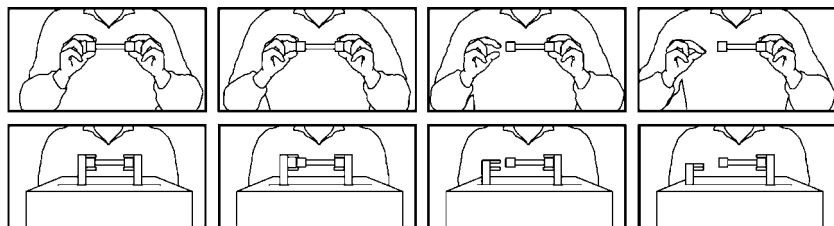


Figure 1.2. Human demonstrator (top panel) and inanimate device mimicking these movements (bottom panel). Infants attributed goals and intentions to the person but not to the inanimate device. (From Meltzoff, 1995a.)

eighteen-month-olds can understand the goals implied by unsuccessful attempts. Children who saw the unsuccessful attempt and infants who saw the full target act both produced target acts at a significantly higher rate than controls (Meltzoff, 1995a). Evidently, young toddlers can understand our goals even if we fail to fulfill them.

A recent experiment extended this work. In this study, eighteen-month-olds were shown the standard failed attempt display, but they were handed a trick toy. The toy had been surreptitiously glued shut before the study began (Meltzoff, 1996). When children picked it up and attempted to pull it apart, their hands slipped off the ends of the cubes. This matched the surface behavior of the adult. The question was whether this duplication of the adults' behavior satisfied the children. Was it their goal? The results suggested it was not. They repeatedly grabbed the toy, yanked on it in different ways, and appealed to their mothers and the adult. Fully, 90 per cent of the children immediately looked up at the adult after failing to pull apart the trick toy (mean latency less than two seconds), and they vocalized while staring at the adult. They had matched the adult's surface behavior, but evidently they were striving toward something else. This work reinforces the idea that the toddlers are beginning to focus on the adult's goals, not simply their surface actions. It provides developmental roots for the importance of goals in organizing imitation in older children and adults (Chaminade, Meltzoff, & Decety, in press; Gattis, Bekkering, & Wohlschläger, this volume; Gleissner, Meltzoff, & Bekkering, 2000; and Bekkering, Wohlschläger, & Gattis, 2000).

If children are attending to the goal of the actor they should be able to achieve the target using a variety of means. This was tested in a study of eighteen-month-olds using a dumbbell-shaped object that was too big for the infants' hands. The adult grasped the ends of the large dumbbell and attempted to yank it apart, but his hands slid off so he was unsuccessful in carrying out his intentions. The dumbbell was then presented to the child. Interestingly, the infants did not attempt to imitate the surface behavior of the adult. They used different means from the adult, but toward the same end. For example, they put one end of the dumbbell between their knees and used both hands to pull it upwards, or put their hands on inside faces of the cubes and pushed outwards, and so on. This again supports the hypothesis that young children are sensitive to adult goals and are not confined to imitating surface behavior.

People versus things

In the adult psychological framework, human acts are goal-directed but the motions of inanimate objects are not (Heider, 1958). When do

children begin to make this distinction between the acts of people and the motions of inanimates?

A study investigated how eighteen-month-olds respond to an inanimate device that mimicked the movements of the actor. An inanimate device was constructed that had poles for arms and mechanical pincers for hands. It did not look human, but it traced the same spatiotemporal path and manipulated the dumbbell-shaped object very similarly to the human (Fig. 1.2, bottom panel).

The results showed that the children did not attribute a goal or intention to the movements of the inanimate device when its pincers slipped off the ends of the dumbbell. Although the children were not frightened by the device and looked at it as long as at the human display, they simply did not see the sequence of movements as implying a goal. Children were no more likely to pull apart the toy after seeing the failed attempt of the inanimate device than they did in baseline levels (Meltzoff, 1995a). However, when the inanimate device successfully pulled the dumbbell apart, the children did successfully do so. This shows that children can pick up certain information from the inanimate device, but not other information (concerning intentions and goals).

Grounding a theory of mind

The raw fact that infants can make sense of a person's failed attempt indicates that they have begun to distinguish surface behavior (what people actually do) from another deeper level. They now imitate what the adult *meant to do* versus what he actually did do.

This differentiation is fundamental to our theory of mind and underwrites 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 (Bruner, 1999; Grice, 1969). It is the basis for our judgments of morality, responsibility, and culpability, which require distinguishing intentions from actual outcomes. In civil human society it is not solely, or even primarily, the actual behavior of our social partners that carries weight, but their underlying intentions. The research indicates that eighteen-month-olds have begun to understand the acts of other humans in terms of a psychology involving goals, aims, and intentions, not solely the physics of the motions in space. In this sense they have adopted a primitive building block for a theory of mind. Recent advances in cognitive neuroscience complement this developmental work by suggesting there may be shared cortical regions for coding action, understanding goals/intentions, and processing theory-of-mind problems (e.g., Blakemore & Decety, 2001; Frith & Frith, 1999).

Concluding remarks on the importance of imitation in human development

The modern empirical findings establish a rich, innate foundation for human development. Infants are not blank slates waiting to be written on. They are born with predispositions, perceptual biases, and representational capacities. The research on infant imitation reveals three important aspects of the preverbal mind: cross-modal coordination, memory, and intersubjectivity.

Imitation and cross-modal coordination

Classical developmental theory held that the sense modalities were uncoordinated at birth (Piaget, 1952, 1954). The work on imitation discussed in this chapter suggests that infants use a “supramodal” code that unites input from different sensory modalities into one common representational framework. This provides a bridge between perception and production. From a developmental viewpoint it is interesting to consider that infants bring this multimodal processing of information to the task of language acquisition. It serves them well, because language can be seen as well as heard (lip reading), can be picked up through touching the lips (Tadoma method), and refers to multimodal events in the world. If the sense modalities were as separate as classical developmental theory supposed, imitation would be impossible and language learning would be delayed (Gopnik & Meltzoff, 1997).

Imitation and memory

Research on infant imitation has contributed to theories of memory development. The research shows that infants are not confined purely to recognition memory. Deferred imitation establishes that infants can *recall* absent information without language. Moreover, infant deferred imitation provides a developmental perspective on cognitive science and neuroscience discussions about multiple memory systems. The results suggest that preverbal humans are not limited solely to habit/procedural memory. Infants can remember novel acts without having performed the act themselves at the time of observation (i.e., without having developed a “habit”). These results suggest that both habit and declarative memory systems are functional in early infancy, rather than an initial habit memory system giving rise to a later-maturing nonhabit memory system (Howe & Courage, 1993; Meltzoff, 1995b; Meltzoff & Moore, 1998; Barr & Hayne, 2000).

Imitation as a precursor to theory of mind

Philosophers have long wondered how we come to ascribe beliefs, desires, and intentions to others – in short where our “theory of mind” comes from. New research shows that eighteen-month-olds have already adopted an essential aspect of the adult theory of mind, namely that people (and not things) act in purposeful, intentional ways. However, this framework does not come out of nowhere. It has developmental roots.

My thesis is that imitation provides a foundation for developing a theory of mind. Below is a sketch of a three-step developmental process. It shows how an organism with the imitative capacities of human infants could gain some purchase on other minds.

(1) *Innate equivalence between self and other.* Infants can imitate and recognize equivalences between observed and executed acts. This is a “starting state,” as documented by motor imitation in newborns. This innate mapping between self and other provides a jump-start for theory of mind.

(2) *Selflearning.* As infants perform particular bodily acts they have certain mental experiences. Behaviors are regularly related to mental states. For example, when infants produce certain emotional expressions and bodily activities, such as smiling or struggling to obtain a toy, they also experience their own mental states. Infants register this systematic relation between their own behaviors and underlying mental states.

(3) *Others in analogy to the self.* When infants see others acting similarly to them, they project that people are having the same mental experience as they themselves have when performing those acts. They use the behavioral state mappings registered through their own experience to make inferences about the internal states of others. In short, given the innate state (step #1 above) and the knowledge that behavior X maps to mental state X' in their own experience (step #2), infants have relevant data to make inferences about relations between the seen behavior of others and the underlying mental state (step #3). Other research demonstrates that such an inferential process is well within the capacity of human infants (Gopnik *et al.*, 1999; Gopnik & Meltzoff, 1997; Meltzoff, Gopnik, & Repacholi, 1999).

Recast in a different way: infants gain an understanding of others by analogy with the self. They use knowledge of how they feel when they produce an expression to infer how another feels. Infants imbue the acts of others with “felt meaning,” because they are able to recognize the similarities between their own acts and those of others. Their experience of what it feels like to perform acts provides a privileged access to people not afforded by things. It prompts infants to make special attributions to people not made to inanimate things that do not look or act like them.¹

Innate structure combined with developmental change

The crux of the developmental theory offered here is that imitation sets children on a trajectory for learning about the other's mind. The "like-me-ness" of others, first manifest in imitation, is a foundation for more mature forms of social cognition that depend on the felt equivalence between self and other. The Golden Rule, "Treat thy neighbor as thy self" at first occurs in action, through imitation. Without an imitative mind, we might not develop this moral mind. Imitation is the bud, and empathy and moral sentiments are the ripened fruit – born from years of interaction with other people already recognized to be "like me." To the human infant, another person is not an alien, but a kindred spirit – not an "It" but an embryonic "Thou."

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Note

- 1 In real-world social interaction, learning is bidirectional. Infants learn about others by analogy to the self, but they also learn about themselves, their powers, and potential, through interaction with others. Parents and peers lead children to perform novel acts and gain self understanding that is not possible through independent discovery in social isolation (Meltzoff *et al.*, 1999).

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