1 Imitation and Other Minds: The "Like Me" Hypothesis

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1.1 Introduction

Human adults and children effortlessly learn new behaviors from watching others. Parents provide their young with an apprenticeship in how to act as a member of their particular culture long before verbal instruction is possible. A wide range of behaviors—from tool use to social customs—are passed from one generation to another through imitative learning. In western cultures, toddlers hold telephones to their ears and babble into the receivers. The children of Australian aborigines would not do this, one suspects. There is no innate proclivity to treat pieces of plastic in this manner, nor is it due to Skinnerian learning. Imitation is chiefly responsible.

Imitation evolved through Darwinian means but achieves Lamarckian ends. It provides a mechanism for the "inheritance" of acquired characteristics. Imitation is powerful and can lead to rapid learning; it is essentially no-trial learning.

Imitation is rare in the animal kingdom. Many animals watch their conspecifics and engage in similar activities, but this is often mediated by less complex processes than imitation. Definitions of imitation can be tricky, but the canonical case of imitation, at least the most interesting case for theory, occurs when three conditions are met: (1) the observer produces behavior similar to that of the model, (2) the perception of an act causes the observer's response, and (3) the equivalence between the acts of self and other plays a role in generating the response. Equivalence need not be registered at a conscious level, but if it is not used at any level in the system (neurally, cognitively, computationally), the soul of imitation has been snatched away.

1.2 Connecting Imitation, "Like Me," and Understanding Other Minds

Over the past decade, I have developed the thesis that infant imitation is connected with the perception of others as "like me" and understanding others' minds (Meltzoff, 1990b; Meltzoff & Moore, 1995; Meltzoff & Brooks, 2001; Meltzoff, 2002a). There is a growing consensus among philosophers, evolutionary psychologists, and neuroscientists that this trio of concepts fit together (e.g., Goldman, 1992b, 2000; Gordon, 1995a; Tomasello, 1999; Rizzolatti et al., 2002).

My thesis is that imitation and understanding other minds (often referred to as a theory of mind or mind reading) are causally related. But which way does the causal arrow run? Some have argued that understanding other minds, especially judgments of others' intentions, underlies imitation (e.g., Tomasello et al., 1993a). This puts the cart before the horse, in my opinion. I wish to show that imitation, and the neural machinery that underlies it, begets an understanding of other minds, not the other way around. Table 1.1 provides a sketch for how such a developmental pathway might work.

Step 1 is ensured by innate equipment. Imitation by newborns provides evidence that the observation and execution of human acts are innately coupled. We hypothesized that this is mediated by a "supramodal" representation of acts (Meltzoff & Moore, 1977, 1997). Progress has been made in specifying the neural underpinnings of imitation, as will be elaborated later in this chapter.

Step 2 is based on individual experience. Through everyday experience infants map the relation between their own bodily states and mental experiences. For example, there is an intimate relation between striving to

Table 1.1
Emergence of understanding other minds from simpler beginnings—the case for normal human ontogeny

Imitation Intrinsic connection between observed and executed acts, as manifest by newborn imitation (Meltzoff & Moore, 1997).
↓
First-person experience Infants experience the regular relationship between their own acts and underlying mental states.
↓
Understanding Other Minds Others who act "like me" have internal states "like me."

achieve a goal and concomitant facial expression and effortful bodily acts. Infants experience their own unfulfilled desires and the simultaneous facial and postural behavior that accompanies such states. These experiences contribute to a detailed bidirectional map linking mind and behavior, at least in the infant's own case.

Step 3 involves a projection. When infants see others acting similarly to how they have acted in the past, they project onto others the mental state that regularly goes with that behavior. This could not occur if infants saw no equivalence between their acts and those of others (ensured by step 1), nor would it proceed very far if there was no binding between their own internal states and bodily acts (step 2). Infants imbue the acts of others with felt meaning, not through a process of step-by-step formal reasoning, but because the other is processed as "like me."

Clearly, this is only a partial story about understanding other minds. The mental states most amenable to this analysis are purposive action, desires, visual perception, and basic emotions. For these, there is a relatively close coupling between the underlying mental states and their expression in bodily action (step 2). Further developments are needed for understanding false beliefs and other mental states, which are farther from the action, as it were (e.g., Astington & Gopnik, 1991; Bruner, 1999; Flavell, 1999; Harris, 1989; Humphrey, 2002; Meltzoff et al., 1999; Wellman, 1990, 2002; Perner, 1991a). Development is also required to understand that the thoughts and feelings of the self and the other may *diverge*. This crucial human ability is probably beyond the grasp of young infants, but it is central to adult perspective-taking (i.e., being able to mentally "stand in another's shoes" even though those shoes are recognized to be a poor fit for oneself). The proposals offered in this chapter chiefly focus on the initial foothold for interpreting others as bearers of psychological properties commensurate with one's own. This is relevant for philosophical, neurological, and psychological theory building, because if we don't have a valid characterization of the initial state, our models of mentalizing will have a shaky foundation.

1.3 Imitation of Novel Acts

It does not take an experiment to convince us that human adults imitate. The evidence for animal and infant imitation, however, has been more contentious. The debates often come down to two factors: (1) the novelty of the acts copied and (2) the temporal delay between stimulus and response. Suppose an organism only imitates familiar behaviors. One would want to take special care to differentiate this from spontaneous, coincidental production of the act. Similarly, if imitation is restricted to immediate reproduction, if the organism can only mirror synchronously and with no delay, one would need special controls to check whether this can be reduced to lower-level entrainment mechanisms.

It is notoriously difficult to define novelty in imitation by animals and humans. Piaget reported that 1.5-year-old infants imitated novel behaviors such as "hitting my shoulders with my hands (the movement one uses to get warm)" and throwing a temper tantrum after seeing another child do so (Piaget, 1951/1962). One could quibble about whether these are novel. Animal researchers try to approach the problem by testing multistep sequences (often composed of familiar acts); they suggest that particular serial orders can be considered novel and would not arise by chance in the absence of the demonstration (R. Byrne, 2002c; R. Byrne & Russon, 1998; Whiten, 2002a).

The most convincing cases of novel imitation, however, occur when the behavior is not in the subject's repertoire to begin with. For example, if I wanted to test whether adults are capable of imitating a novel act, I might demonstrate touching my bellybutton with my elbow. We are motorically capable of these acts (otherwise failure would be uninformative), but they are not routines. One cannot record an organism's entire lifetime of experience, but sufficiently unusual behaviors with a baseline rate of zero are reasonable tests of the imitation of novelty.[1]

To test whether human infants are capable of imitating novel acts, I used 14-month-old infants. The act chosen was leaning forward to touch a rectangular box with one's forehead. The delay imposed between stimulus and response was 1 week (Meltzoff, 1988a). It was not a matter of the adult's act entraining the infant. Imitation had to occur based on a memory.[2]

1. Some behaviorists have argued that there may be no such thing as novel imitation, even in adults. The idea is that unless one has recorded the organism's entire history, there is always a chance that the subject has done (and been reinforced for) the behavior in the past. The more accepted consensus is that the imitation of novelty can be tested using behaviors that are not familiar routines, have a baseline rate of near zero in the absence of modeling them, and are "arbitrary" (no survival value for the species) in and of themselves (see Meltzoff, 1988a, p. 474, for an extended discussion of novelty in imitation).

2. The infants came into the laboratory on day 1 and observed the act. They were not allowed to touch or handle the object and were sent home before returning a week later. In followup studies, the parents were blindfolded or were not initially in the room, so that they were kept completely unaware of the gesture shown to the infant (Hanna & Meltzoff, 1993; Klein & Meltzoff, 1999).

Figure 1.1
Imitation of a novel act by 14-month-old infants. None (0%) of the controls produced this behavior. There is a social-game quality to human imitation. Infants often smile after accurate imitation, as shown in panel 6. (From Meltzoff, 1999b.)

The results showed that infants imitated after the 1-week delay (figure 1.1). Fully 67% of the infants duplicated the act, with a mean latency of 3.1 seconds after they were given the box. The control groups confirmed that 0% of the infants who had not seen the target behavior produced the behavior spontaneously. In the affordance control group, infants were simply given the object. This tested whether the object had visible properties that automatically provoked the response; the data showed it did not. In the stimulus-enhancement control group, an adult manipulated the object but refrained from performing the target act. This tested whether drawing infants' attention to the object led them to produce the behavior; it did not. An independent laboratory replicated this finding and confirmed that head touching was not an automatic response based on the object's properties, because there were conditions under which infants chose to duplicate the adult's behavior and conditions under which they did not (Gergely et al., 2002).

1.3.1 Implications for Theory

These tests have the following implications:

- Infants imitate novel acts.

- Infants imitate from memory and are not restricted to immediate resonance.
- Infants can imitate the means used (head touching); hence they are not limited to emulation.
- Infants use other people to learn about and expand their own actions. The imitation of novelty suggests a bidirectional flow of information—a "like you" as well as a "like me" pathway (probably supported by the same underlying mechanism).

1.4 "Like Me": Recognition of Being Imitated from Behavioral and Neuroscience Perspectives

We have shown that infants imitate novel acts, which demonstrates a linkage from observation to execution. The shorthand is that infants map from the other to the self. The "like me" hypothesis suggests that they also can go in the reverse direction, recognizing when someone acts as they do; in shorthand, mapping from the self to the other. One way of testing this idea is to run imitation in the reverse direction. This entails evaluating whether subjects can recognize that they are being imitated.

The situation of being imitated is a special one. It is not the temporal contingency that makes it special. Physical objects may come under temporal control, but only people who are paying attention to you and acting intentionally can match the form of your acts in a generative fashion. Only people can systematically act "like me." If infants can recognize when an entity is acting "like me," this would allow them to make a distinction between people and all other entities in the world.[3]

I tested whether infants recognize when another acts "like me" and the affective consequences of this experience. A broad range of ages was used, from 6 weeks to 14 months old. One experiment involved 14-month-old infants and two adults. One of the adults imitated everything the baby did; the other adult imitated what the previous baby had done. Although both adults were acting in perfectly infantile ways, and were good controls for one another, the infants reacted differentially. The results showed that the infants looked longer at the person who was imitating them and also smiled more often at that person (Meltzoff, 1990b).

3. This does not deny that infants recognize conspecifics by vision and audition, as do other animals. The idea is that over and above this they also register others as acting "like me." This distinction has not been tested in the animal literature. It would be useful to test whether great apes can recognize when others are acting "like me" based on an equivalence in the *form* of the actions (not just the temporal contingencies).

These results could be based on the detection of temporal contingency, so in the next study both adults acted at the same time. When an infant produced a behavior from a predetermined list, both adults simultaneously sprang into action. One imitated the infant, the other performed a mismatching response. Thus both were temporally contingent. The results showed that the infants looked significantly longer and smiled more at the adult who was imitating them. Evidently infants recognize a deeper commonality between self and other beyond timing alone. I would argue that there are neural mechanisms for recognizing "congruent with me," not just "contingent on me."

We also discovered that infants exhibited what I termed *testing behavior*, as if probing the causal relations between acts of the self and the other. Infants watched the adult imitate them and then made sudden and unexpected movements while staring at the adult. They would suddenly freeze all actions and then switch abruptly from one act to another, while inspecting the adult as if to see if he followed. This seems to go beyond simple resonance and mirror neuron activity, because the subject is purposely acting *differently* from what they observe. This pattern of behavior is exhibited down to about 9 months of age. However, this is not an innate reaction. We set up studies matching the mouth opening and closing of 6-week-olds. The baby's attention was attracted, but it did not lead the baby to systematically switch to tongue protrusion or another gesture. There was no testing. Young infants process specific behavior-to-behavior mapping, whereas the older infants go beyond this and understand the abstraction of a matching game per se, where the notion is "you will do what I do" with substitutable behaviors. Mutual imitation and the question of "who is imitating whom" is not only apparent in toddlers but also in older children (Asendorpf, 2002; Nadel, 2002) and adults.

1.4.1 Neuroscience Findings

We designed a positron emission tomography (PET) study to investigate the neural correlates of adults' recognition of being imitated by another person (Decety et al., 2002). The subject either imitated or was imitated by an experimenter who was visible from inside the scanner. The results indicated that the right inferior parietal lobe was specifically activated when the subjects recognized that they were being imitated by the other, as opposed to performing the action freely or imitating someone else. We hypothesized that the right inferior parietal lobe is involved in sorting out agency and differentiating actions produced by the self from matching actions observed in others: "Did I will that or did he?" Further neuroscience work strongly supports this view (Chaminade & Decety, 2002 and Decety and Chaminade, vol. 1, ch. 4).

1.4.2 Implications for Theory

These tests have the following implications:

- Infants recognize that they are being imitated.
- This "like me" recognition is based on the structural congruence between the self and the other, not simply temporal information.
- Older infants test the self–other correspondence, probing the agency involved.
- The right inferior parietal lobe plays a role in differentiating like-actions generated by the self and the other.

1.5 Understanding Others' Goals and Intentions: Developmental and Neuroscience Perspectives

We have considered evidence about two types of mappings:

Other → self (novel imitation)
Self → other (recognition of being imitated)

Human infants are facile at both forms of imitation, but surely adults do more. A crucial component is the psychological attributions they make. For example, if I see someone struggling to pull an object apart, I do not merely code their movements, I ascribe goals and intentions to the person.

Are we born making these attributions to the actions of others? Does this ability emerge with language? Theory of mind research addresses such questions in 3- and 4-year-old children (e.g., Flavell, 1999; Harris, 1989; M. Taylor, 1996). To begin to examine this issue at the preverbal level, I (Meltzoff, 1995) developed a procedure called the behavioral reenactment technique. The procedure capitalizes on imitation, but it uses this proclivity in a new, more abstract way. It investigates the ability to read below the visible surface behavior to the underlying goals and intentions of the actor.

One study involved showing 18-month-old infants an unsuccessful act (Meltzoff, 1995, experiment 1). For example, an adult "accidentally" under-

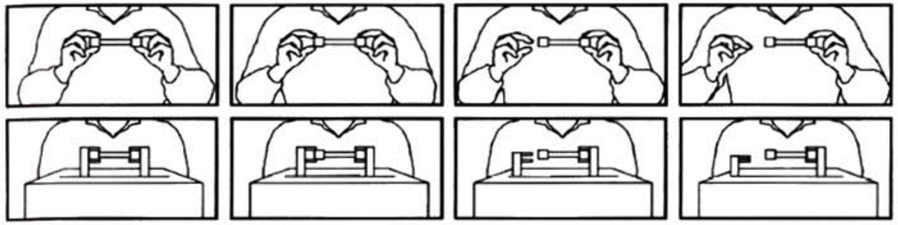

Figure 1.2
The display used to test infants' understanding of intention. The top row shows the unsuccessful attempt to separate the dumbbell by the human demonstrator. The bottom row shows a mechanical device mimicking these same movements. Infants treated the former but not the latter within a psychological framework involving goals or intentions; see the text for details. (From Meltzoff, 1995.)

or overshot a target, or tried to perform an act but his hand slipped several times; thus the goal state was not achieved (figure 1.2, top). To an adult, it was easy to read the actor's intention although he did not fulfill it. The experimental question was whether infants also saw beyond the literal body movements to the underlying goal of the act. The measure of how they interpreted the event was what they chose to reenact. In this case the correct answer was not to imitate the 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: (1) after they saw the full target act demonstrated, (2) after they saw the unsuccessful attempt to perform the act, and (3) after it was neither shown nor attempted. The results showed that 18-month-olds can infer the unseen goals implied by unsuccessful attempts. Infants who saw the unsuccessful attempt and infants who saw the full target act both produced target acts at a significantly higher rate than controls. Evidently young toddlers can understand our goals even if we fail to fulfill them.

I (Meltzoff, 1999b) sought to determine the earliest age at which infants inferred unfulfilled goals. The results suggest that this capacity is not innate, but first develops between 9 and 15 months of age. Infants that were 15 months old behaved much like the 18-month-olds in the original study. Those that were 9 months old, however, did not respond above baseline levels to the demonstrations of unsuccessful attempt, although they could succeed if the adult demonstrated successful acts. Bellagamba and Tomasello (1999) replicated the effect in 18-month-olds and also found that 12-month-olds were too young to respond in this way, so there is converging evidence for an important developmental change at approximately 1 year of age.

If infants can detect the underlying goal or intention of the human act, they should also be able to achieve the act using a variety of means. I tested this in a study of 18-month-olds using a dumbbell-shaped object that was too big for the infants' hands. An adult grasped the ends of the dumbbell and attempted to yank it apart, but his hands slid off, so he was unsuccessful in carrying out his intention. The dumbbell was then presented to the infants. It is interesting that the infants did not attempt to imitate the surface behavior of the adult. Instead, they used novel ways to struggle to get the gigantic toy apart. They put one end of the dumbbell between their knees and used both hands to pull it upward, or put their hands on inside faces of the cubes and pushed outward, and so on. They used *different means* than the experimenter, but these acts were directed toward the *same end*. This fits with my (Meltzoff, 1995) hypothesis that the infants had determined the goal of the act, differentiating it from the surface behavior that was observed.

Work by Want and Harris (2001, 2002) goes further and shows that 3-year-old children benefit from observing others using multiple means to achieve a goal. They benefit more from watching an adult change a failed attempt into a successful act than from watching the demonstration of successes alone. Other work also underscores the importance of goals in imitation (Bekkering et al., 2000; Gleissner et al., 2000).

In an adult framework, people's acts can be goal directed and intentional, but the motions of inanimate devices are not; they are governed purely by physics, not psychology. Do infants interpret the world in this way? In order to begin to assess this, I designed an inanimate device made of plastic and wood (Meltzoff, 1995; see figure 1.2, bottom). The device had short poles for arms and mechanical pincers for hands. It did not look human, but it traced the same spatiotemporal path that the human actor traced and manipulated the object much as the human actor did. The results showed that infants did not attribute a goal or intention to the movements of the inanimate device when its pincers slipped off the ends of a dumbbell. The infants were no more (or less) likely to pull the toy apart after seeing the unsuccessful attempt of the inanimate device than infants in the baseline condition. This was the case despite the fact that the infants pulled the dumbbell apart if the inanimate device successfully completed this act. Evidently infants make certain attributions to an inanimate device, but not others; they can understand successes, but not failures. (Successes lead to a change in the object, whereas failures leave the object intact and therefore must be interpreted at a deeper level.)[4]

As adults, we can describe the behaviors of others using either physical or psychological terms. Strict behaviorists stick to the former description precisely because they eschew appealing to invisible psychological states. By 18 months of age, infants are no longer behaviorists, if they ever were so. They do not construe the behavior of others simply as, "hold the dumbbell and then remove one hand quickly," but rather construe it as an effort at pulling. And they interpret the actions of people differently than the motions of inanimate devices.

However, finding a surprising competence at 18 months of age does not preclude further development. The adult view about intention is something like this: If another person desires x and believes that doing y will bring about x, he will intend to do y, independently of and perhaps contrary to my own beliefs, desires, and intentions about the matter. Infants are using a simpler construal. The 18-month-olds appreciate the goal-directedness of a human action (an unsuccessful attempt), but this does not mandate that infants ascribe the mature adult notion of intention as a first-person experience in the mind of the actor (see Meltzoff, 1995, pp. 847–848, for a fuller analysis).

1.5.1 Neuroscience Findings

We designed a nonverbal task in which adults processed the goals of actions while they were undergoing PET scanning (Chaminade et al., 2002).

4. The line of studies using the dumbbell rule out several alternative interpretations. Although some of the other stimuli used in the original study may contain clues about the affordances of an object (Huang et al., 2002), the dumbbell provides a critical test. The dumbbell remains immobile during the adult's efforts. The object never changes. Thus no affordance is revealed, nor is end-state information shown that can lead to learning by emulation. Moreover, the inanimate device traces the same spatial path as the human movements, so physically following the outward motions does not yield the response. It is therefore important that the dumbbell yielded statistically significant data when the results were analyzed individually (Meltzoff, 1995, p. 843). The effect with this particular object does not lend itself to lower-order interpretations such as those suggested by Huang et al. (2002). It is also worth noting that the distinction between the person and device is not attributable simply to infants being inhibited in the case of the inanimate device (as speculated by Heyes, 2001a) because: (1) infants imitated the device when it performed the action successfully and (2) 100% of the infants approached and picked up the toy after it was manipulated by the inanimate device, and there were no signs of wariness (see Meltzoff, 1995, pp. 844–845, for details).

The subjects watched an adult building a tower out of Lego blocks. In one condition, the subjects had to infer the adult's goal from watching the means used (they saw partial movement of the blocks, but the end state of the construction was obscured). In another condition, they had to infer the means from seeing the end state (the final tower was shown, but the movement of blocks needed to achieve the construction was obscured). The results revealed that the medial prefrontal lobe was specifically activated when the subjects were forced to infer the goal. The medial prefrontal region is known to play a critical role in adult theory-of-mind tasks (e.g., Blakemore & Decety, 2001; C. Frith & Frith, 1999). This fits well with the arguments in this chapter because it supports, at a neural level what we had hypothesized based on the developmental results—a relation between extracting goals from actions in a simple motor task and higher-order attribution of intention.

1.5.2 Implications for Theory

These experiments have the following implications:

- Infants code human acts in terms of goals.
- Infants can infer goals from people's unsuccessful attempts.
- Once infants represent these goals, they can achieve them by multiple means.
- Infants make different attributions to people than to inanimate devices; they make primitive psychological attributions to entities that are "like me."[5]
- The medial prefrontal lobe is involved in discerning the intentions of others.

1.6 Understanding Others' Perception

For adults, certain bodily movements have particular meanings. If a person looks up into the sky, bystanders follow his or her gaze. This is not imitation; the adults are trying to see what the person is looking at. Adults realize that people acquire information from afar, despite the spatial gap between perceiver and object. When do we ascribe perception to others? Is there a stage when head turns are interpreted as purely physical motions

5. We have not isolated the criteria infants use for making these attributions. For example, it could be features (eyes, face), action patterns (articulated limb movements), or other social-communicative cues to the presence of agency (S. Johnson, 2000).

with no notion that they are *directed toward* the external object, no notion of a perceiver?

Some developmental psychologists have taken this conservative stance (Corkum & Moore, 1995). They argue that the infant visually tracks the adult's head as it rotates; this is a physical motion in space and so the infant's own head is dragged to the correct hemi-field. Once it is there, the object is encountered by happenstance. Presto! Infants turn in the direction of adults, but it is all done by the laws of physics and geometry; psychology has nothing to do with it. I believe that infants can do more than this.

A recent study examined whether infants understand the object-directedness of adult attentive movements (Brooks & Meltzoff, 2002). Two identical objects were used, and the adult turned to look at one of them with no other cues. For one group of infants, the adult turned to the target object with *eyes open*, and for the other, the adult turned with *eyes closed*. The adult's head movement was identical in both. The findings showed that 12- to 18-month-old infants turned selectively, seeking out the target significantly more often when the adult turned with eyes open than with eyes closed. Furthermore, a microanalysis showed that the infants fixated on the distal object for a longer time when they followed the adult's open eyes. This visual inspection is important because the object, in itself, is the same whether the adult turns with open or closed eyes. The object takes on special valence because it is looked at by another person. The infants also pointed to the object more when the adult looked at it with open than with closed eyes. This involves a different motor movement than the adult's, indicating that the symmetrical head movement is not purely imitation (figure 1.3).

This is sophisticated behavior, but it is not based on innate knowledge. Recent research shows that 9-month-olds turn just as readily in the direction of an adult's head turn, regardless of whether the adult's eyes are open or closed (Brooks & Meltzoff, 2003). Nine-month-olds do not take into account the status of the adult's perceptual organs, the eyes.

Inanimate obstacles can also block one's view. Brooks and Meltzoff (2002) conducted another experiment, duplicating all aspects of the first, but using a headband and a blindfold. The headband allowed the adult to have visual access to the object, whereas the blindfold blocked the adult's visual access. The results were very different than the eye-closure case. The 12-month-olds turned to follow the adult even when the adult wore a blindfold. This is not just a matter of blindfolds causing some general suppression of activity. Quite the contrary; infants make the mistake of

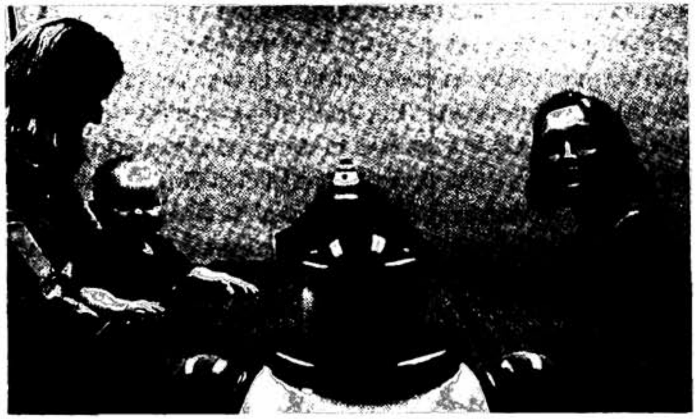

Figure 1.3
Gaze following by 1-year-old infants. Infants selectively look when the adult turns with eyes open versus eyes closed, showing they take into account the status of the adult's eyes, not just the gross direction of head movement.

following the "gaze" of the adult wearing the blindfold. They refrain from looking when the adult has closed eyes, but do turn to look when the adult has a blindfold. It is as if they do not understand that blindfolds block perception.[6] Perhaps they understand eye closure more easily than blindfolds, because experience with their own eyes teaches them that this biological movement cuts off visual perception in their own case. Other explanations are possible, but if it could be substantiated, it would be a particularly compelling case of "like me" projection.

One way of testing this is to give infants first-person experience with blindfolds. Meltzoff and Brooks (2004) conducted such a study, and the results are very provocative. One group of 12-month-old infants was shown that opaque objects blocked their view. Their view was blocked when the blindfold was held to *their* eyes, and was restored again when the blindfold was removed. This experience had nothing to do with the experimenter's viewpoint; it was a first-person experience. In the critical test, the adult put the blindfold over her own eyes. This was the first time the infants were presented with the blindfolded adult. The results showed that infants now

6. The journal paper also considers several other possible interpretations and provides data bearing on them. For example, the infants were not wary of the blindfold or eye closures.

interpreted the blindfold correctly. They did not turn when the adult wore the blindfold. In further control groups the infants were allowed to familiarize themselves with the blindfold, but without experiencing blocking of the view. This had no effect. They still mistakenly followed the blindfolded adult's "gaze" in this case.

1.6.1 Implications for Theory

This work has the following implications:

- One-year-old infants follow the gaze of adults.
- They understand adult gaze as directed at an object, not as a meaningless body movement.
- One-year-old infants interpret some obstacles to perception (eye closure) differently than others (blindfolds).
- First-person experience with blindfolds changes infants' interpretation of others who wear blindfolds. Crucially, they use first-person experience to make third-person attributions.

1.7 Nature's Share: What Is Innate?

Theorists are drawn to questions about the origins of action coding and seeing others as psychological agents. This question can be addressed from evolutionary, developmental, and neural viewpoints.

1.7.1 Does Experience Play a Role in Mirror Neuron Development?

There is a burgeoning literature in neuroscience concerning the coding of actions and how organisms map observed actions onto their own acts. Mirror neurons are perhaps the most celebrated example (Rizzolatti et al., 1996a; Rizzolatti, vol. 1, ch. 1, and Gallese, vol. 1, ch. 3). Are mirror neurons innate? This may be the case, but the role of experience in forming mirror neurons deserves more consideration than it has been given.

Mirror neurons are activated whether a monkey sees or performs the act of grasping an object. These neurons seem to code the act, regardless of whether it is performed by the self or the other. The developmental question I would ask is whether this is an innately specified coding. It may not be. Adult monkeys have repeatedly watched themselves grasp objects. Mirror neurons could code visuomotor associations forged from such learning experiences. Such gradual learning, if it occurs, would influence the philosophical implications that can be drawn (see e.g., Goldman, vol. 2, ch. 2 and Gordon, vol. 2, ch. 3).

There are two ways of testing whether mirror neurons develop through experience. One is to test newborn monkeys. A second approach is selective rearing in which the experimenter arranges a situation that prevents monkeys from visually monitoring their own grasps, for example, by wearing a collar that blocks the view of their hands. The critical question for theory is whether mirror neurons can be found in the brains of such animals. If both populations have functioning mirror neurons, it would suggest that mirror neurons do not emerge from learned associations of repeatedly seeing oneself grasp an object. It would be widely agreed, I think, that it is uncertain how these results would turn out.

1.7.2 Innate Facial Imitation

If one's question concerns origins, developmental studies are crucial. The philosopher's queries about man's original nature are not directly answered by tests of adult animals and neurologically damaged adult humans. These need to be supplemented with tests of human young. Facial imitation provides such an opportunity. Human infants have a natural collar; they cannot see their own faces. If they are young enough, they will never have had a chance to see themselves in a mirror or to learn the associations in question. Human neonates provide a direct test of the correspondence problem: how we come to relate acts of self and other.

Meltzoff and Moore (1983a, 1989) discovered that newborns imitate facial acts. The mean age of these infants was 32 hours. The youngest child was 42 minutes old at the time of test. Facial imitation suggests an innate mapping between observation and execution in the human case. Moreover, the studies provide information about the nature of the machinery infants use to connect observation and execution. The studies require a little patience to get through, but it is worth it, because the starting state is so vital for theories.

In Meltzoff and Moore (1977), 12- to 21-day-olds were shown to imitate four different gestures, including facial and manual movements. The infants confused neither actions nor body parts. They responded differentially to tongue protrusion with tongue protrusion and not lip protrusion, showing that they can identify the specific *body part*. They also responded differentially to lip protrusion versus lip opening, showing that different *action patterns* can be imitated with the same body part. This is confirmed by research showing that infants differentially imitate two different kinds of movements with the tongue (Meltzoff & Moore, 1994, 1997). Such differential imitation and other evidence cited later suggests that imitation is not a diffuse arousal response of the type suggested by Jones (1996) (for further review and analysis, see Meltzoff, 2002b).

Tongue protrusion is researchers' favorite choice in studies of early imitation. Sometimes this is construed as meaning that tongue protrusion is the only gesture that can be imitated (Anisfeld, 1996). However, "most common" is not the same as "only one." The tongue protrusion gesture is commonly used because it is the most dramatic case, and it is the easiest to score from videotape. However, there are many published studies documenting a range of acts that can be imitated, as the following list shows.

- Mouth opening: Fontaine, 1984; Heimann, 1989, 2002; Heimann et al., 1989; Heimann & Schaller, 1985; Kugiumutzakis, 1999; Legerstee, 1991; Maratos, 1982; Meltzoff & Moore, 1977, 1983a, 1992, 1994
- Hand movements: Meltzoff & Moore, 1977; Vinter, 1986
- Emotional expressions: Field et al., 1983, 1986, 1982
- Head movements: Meltzoff & Moore, 1989
- Lip and cheek movements: Fontaine, 1984; Kugiumutzakis, 1999; Meltzoff & Moore, 1977; Reissland, 1988
- Eye blinking: Fontaine, 1984; Kugiumutzakis, 1999
- Two types of tongue protrusion: Meltzoff & Moore, 1994, 1997

In all, there are more than twenty-four studies of early imitation from thirteen independent laboratories. The empirical evidence from multiple laboratories moves us beyond the "lone" tongue-protrusion notion. Nonetheless, young infants cannot imitate the full range of gestures copied by older children, and there is development in imitation. For example, I have argued that the neonate is less self-conscious about imitating than the older child (Meltzoff & Moore, 1997).

The chief question concerns the neural and psychological processes linking the observation and execution of matching acts. How do infants solve the correspondence problem? Two discoveries are key.

First, early imitation is not restricted to immediate duplication. In one experiment, the infants had a pacifier in their mouths so that they couldn't imitate during the demonstration (Meltzoff & Moore, 1977). The pacifier was then withdrawn. The results were that the infants initiated their imitative response in the subsequent 2.5-minute response period while looking at a passive face. In a more dramatic example, 6-week-olds performed deferred imitation after a 24-hour delay (Meltzoff & Moore, 1994). The infants saw a gesture on one day and returned the next day to see an adult with a passive-face pose. The infants stared at the face and then imitated the gesture from long-term memory.

Second, infants correct their imitative response. They converge on the match without feedback from the experimenter. An infant's first response to seeing a facial gesture is activation of the corresponding body part. For example, when infants see an adult protrude his or her tongue, there is a quieting of other body parts and an activation of the tongue. They do not necessarily protrude their tongue at first, but may elevate it or move it inside the oral cavity. The important point is that the tongue, rather than the lips or fingers, is energized before the movement is isolated. It is as if young infants isolate *what* part of their body to move before knowing *how* to move it. Meltzoff and Moore (1997) call this organ identification. Neurophysiological data show that visual displays of parts of the face and hands activate specific brain sites in monkeys (Desimone, 1991; Gross, 1992; Gross & Sergent, 1992; Jellema et al., 2002; Perrett et al., 1992; Rolls, 1992) and related work is emerging in human studies (Buccino et al., 2001). These new neuroscience findings fit closely with the finding of correct activation of a body part by neonates. Specific body parts could be neurally represented and serve as a foundation for imitation in infants.

1.7.3 Active Intermodal Mapping Hypothesis

Meltzoff and Moore proposed that facial imitation is based on active intermodal mapping (AIM) (Meltzoff & Moore, 1977, 1994, 1997). Figure 1.4 provides a conceptual schematic of the AIM hypothesis. The key claim is that imitation is a matching-to-target process. The active nature of the matching process is captured by the proprioceptive feedback loop. The loop allows infants' motor performance to be evaluated against the seen target and serves as a basis for correction. 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, because it is not restricted to modality-specific information (visual, tactile, motor, etc.). Metaphorically, we can say that exteroception (perception of others) and proprioception (perception of self) speak the same language from birth; there is no need for "association." AIM does not rule out the existence of certain basic acts that can be imitated on first try without the need for feedback, but it allows proprioceptive feedback and the correction of responses for novel acts. A more detailed analysis of the functional architecture of AIM and its proposed solution to the correspondence problem is provided elsewhere (Meltzoff & Moore, 1997).

This hypothesis of a supramodal framework that emerged from developmental science fits well with proposals from cognitive science (the common coding thesis of W. Prinz, 2002) and discoveries in neuroscience

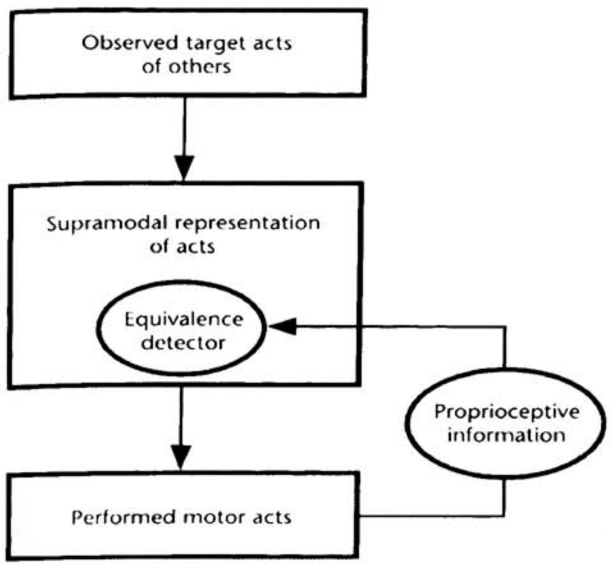

Figure 1.4
The AIM hypothesis for imitation. (From Meltzoff & Moore, 1997.)

concerning shared neural substrates for perception and action (Decety, 2002c; Iacoboni et al., 1999; Rizzolatti et al., 2001; vol. 1, chs. 1 by Rizzolatti, 2 by Iacoboni, 3 by Gallese, and 4 by Decety and Chaminade). An important task for the future is to analyze the commonalities and differences in these proposed mechanisms, and relevant papers are beginning to emerge (e.g., Meltzoff & Decety, 2003; Rizzolatti et al., 2002).

1.7.4 Implications for Theory

The work described in the preceding section has the following implications for theory.

- Newborns imitate facial acts that they have never seen themselves perform.
- In humans there is an innate observation-execution pathway.
- This is mediated by structures that allow infants to defer imitation to another point in time and to correct their imitation without feedback from the experimenter.
- Recent discoveries in developmental psychology, adult cognitive science, and neuroscience are converging to help us specify at multiple levels of analysis the *lingua franca* uniting perception and production.

1.8 The Importance of Development in Understanding Other Minds: A Third Way

Fodor thinks that infants innately assign adult commonsense psychology to people:

> Here is what I would have done if I had been faced with this problem in designing Homo sapiens. I would have made a knowledge of commonsense Homo sapiens psychology innate; that way no one would have to spend time learning it.... The empirical evidence that God did it the way I would have isn't, in fact, unimpressive. (Fodor, 1987, p. 132)

The opposing school is that newborns lack any inkling that other humans have psychological properties. It is claimed, for example, that the child is born a "solipsist" (Piaget, 1954) or is in a state of "normal autism" (Mahler et al., 1975), treating people the same as things. It is a long way, probably an impossible path, from there to commonsense psychology.

Modern developmental scientists, including myself, have been trying to develop a third way. It grants far more to the newborn than the second view, while stopping short of the first. In my view, infant imitation and the neural representations that underlie it provide an innate foundation for building adult commonsense psychology, but infants do not possess the adult framework to begin with. Infants imitate at birth, but they do not infer intentions from the unsuccessful efforts of others or understand "perception" in others. This is hardly grounds for Fodorian nativism; God apparently did not give young infants a full-blown commonsense psychology. It is equally true, however, that young infants outstrip Piagetian theory. What we seem to need is a new theory of development, a "starting-state nativism" that includes a rich understanding of people and things but still leaves gaps to be filled in by structured experience.

1.9 "Like Me" Theory: A Developmental Sketch

Imitation indicates that newborns, at some level of processing, no matter how primitive, can map actions they see performed by others onto actions of their own body. Human acts are especially relevant to infants because they look like the infant feels himself to be and because they are events that infants can intend. When a newborn sees a human act, it may be meaningful: "That seen event is like this felt event."

The innate capacity to construe certain movements in the environment as "me relevant" has cascading developmental effects in infants. First, the world of material objects can be divided into those entities that perform these acts (people) and those that do not (things). Second, the *lingua franca* of human acts provides access to other people that is not afforded by things.[7]

The ability of young infants to interpret the bodily acts of others in terms of their own acts and experiences gives them a tool for cracking the problem of other minds (vol. 2, chs. 2 by Goldman, and 3 by Gordon). This idea can be developed further by applying the model from table 1.1 to the examples of following a gaze and understanding the other's intentions.

The crux of the "like me" hypothesis is that infants may use their own intentional actions as a framework for interpreting the intentional actions of others. Consider the goal-directed striving and try-and-try-again behavior used in my behavioral reenactment studies (Meltzoff, 1995). Infants have goals and act intentionally. They have experienced their own failed plans and unfulfilled intentions. Indeed, in the second half-year of life they are obsessed with the success and failure of their plans. They mark such self-failures with special labels. Psycholinguistic research shows that among the toddler's earliest words are "uh-oh," and in England, "oh bugger." They use these terms to comment on a mismatch between their own intentions and real-world outcomes (Gopnik & Meltzoff, 1986). They also experiment with unsuccessful efforts by repeating the solution (and the failure) numerous times until it comes under voluntary control. During such episodes, infants often vary the means and try and try again. When an infant sees another act in this same way, the infant's self-experience could suggest that there is a goal, plan, or intention beyond the surface behavior. Thus, infants would interpret an adult's failed attempts, and the behavioral envelope in which they occur, as a pattern of strivings, rather than ends in themselves. In

7. Infants with sensory or motor deficits, such as blindness or motor paralysis, present an interesting case. Because AIM postulates organ identification and a supramodal framework, the deficits can be compensated for. Development may be slowed, but not blocked. Supramodal representation allows one modality to substitute for another; for example, facial organs and actions may be identified by tactile exploration in the case of blindness. Autism presents another interesting case. Young children with autism have profound deficits in understanding other minds (e.g., Baron-Cohen et al., 1993, 2000), and our own studies of autism reveal deficits in the same imitation tasks we used with typically developing infants (G. Dawson et al., 1998). Others have also reported deficits on other imitation tasks (for a review, see S. Rogers, 1999). These results from autism are highly compatible with the framework presented here (Meltzoff & Gopnik, 1993), but are also open to alternative interpretations.

short, infants could come to understand the goals and intentions of others through experience with their own intentions: "Those acts are intentional, just like mine."

Similarly, understanding another's gaze could benefit from one's own perceptual experiences. Infants in the first year of life imitate head movements and eye blinking (Fontaine, 1984; Meltzoff, 1988a; Meltzoff & Moore, 1989; Piaget, 1951/1962). They thus can register the similarity between their own head movements and those of others and between their own eyelid closures and those of others. The subjective experiences that infants gain from turning in order to see could thus be used to make sense of the similar actions of others. Moreover, the infant's experience is that closing its own eyes cuts off perceptual access. Because infants can map their own eye closures onto the eye closures of others (as shown by the imitation of blinking), there is an elementary foundation for understanding perception in others. This also makes sense of the fact that young infants have more advanced understanding of what it means for others to close their eyes than they do of others wearing blindfolds (Brooks & Meltzoff, 2002). Our intervention experiment gave them first-person experience with blindfolds, and they were immediately able to use this to understand the blindfold-wearing other in a new way (Meltzoff & Brooks, 2004). This seems to be a using first-person experience to interpret others and therefore lends support to the model in table 1.1.

It has long been thought that the equivalence between self and other is integral to our adult commonsense psychology (J. Baldwin, 1906; Hume, 1740/1984; Husserl, 1953/1977; Nietzsche, 1881/1977; Smith, 1759/1976). Empathy, role-taking, and all varieties of putting yourself in someone else's shoes emotionally and cognitively seem to depend on this. The problem has always been that this equivalence was thought to be a late achievement in ontogeny and dependent on language. The findings from developmental science, suggest that infants already register the equivalence between acts of self and other. It is innate. This equivalence colors infants' very first interactions and interpretations of the social world and is foundational for human development.

1.10 Booting Up a Baby to Read Minds

There is a kinship between the problem of understanding other minds and the problem of imitation. This kinship is not merely a surface similarity; the two problems are causally related from the perspective of developmental science and neuroscience.

Philosophers are struck by the fact that we experience our own thoughts and feelings but do not see ourselves from the outside as others see us. We perceive visual and auditory signals emanating from others but do not directly experience their mental states. There seems to be a wide gulf between knowing the self and the other.

Likewise, developmental scientists and neuroscientists are struck by the correspondence problem in imitation. Infants can see an adult's face but cannot see their own faces. They can feel their own face move but have no access to the feeling of movement in others. Facial imitation exposes the gap between self and other most dramatically, but the same issue is posed by other types of imitation in both adults and animals.

Fodor is correct that solipsism and blank-slate empiricism are too impoverished to characterize the human starting state. However, this does not mean that adult commonsense psychology is implanted in the mind at birth or matures independent of experience. Here is an alternative to Fodor's creation myth. Nature designed a baby with an imitative brain; culture immerses the child in social play with psychological agents perceived to be "like me." Adult commonsense psychology is the product.[8]

Acknowledgments

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8. See comments on this chapter by Harris (vol. 2, ch. 8.1, p. 173) and Humphrey (vol. 2, ch. 8.2, p. 178); see also Goldman, vol. 2, ch. 2, p. 79; Gordon, vol. 2, ch. 3, p. 95; and Anisfeld, vol. 2, ch. 4, p. 107. ED.