

# Imitation, Memory, and the Representation of Persons

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Imitation was tested both immediately and after a 24-hr retention interval in 6-week-old infants. The results showed immediate imitation, which replicates past research, and also imitation from memory, which is new. The latter finding implicates recall memory and establishes that 6-week-olds can generate actions on the basis of stored representations. The motor organization involved in imitation was investigated through a microanalysis of the matching response. Results revealed that infants gradually modified their behavior towards more accurate matches over successive trials. It is proposed that early imitation serves a social identity function. Infants are motivated to imitate after a 24-hr delay as a means of clarifying whether the person they see before them is the same one they previously encountered. They use the reenactment of a person's behavior to probe whether this is the same person. In the domain of inanimate objects, infants use physical manipulations (e.g., shaking) to perform this function. Imitation is to understanding people as physical manipulation is to understanding things. Motor imitation, the behavioral reenactment of things people do, is a primitive means of understanding and communicating with people.

imitation	memory	mental representation	faces	cross-modal
	motor coordination	self	communication	
		theory of mind		
		identity development		

Children learn by watching adults. Young children often do as parents do instead of as parents say, suggesting that visual models exert a powerful influence on children's actions. In infancy, before language, imitation plays an especially prominent role: It is an avenue for teaching motor skills and also embodies a mutuality and reciprocity that is the essence of communication at the nonverbal level. As apparently simple and commonplace as imitation is, it presents some of the deepest puzzles for theories of infancy. In order to imitate, the child must see the adult's actions, use this visual perception as a basis for an action plan, and execute the motor output. Thus, imitation taps perception, cross-modal coordination, and motor control. If imitation takes place after a significant delay, memory is also involved. The type of memory indexed by imitation is not

merely recognition memory, because the infant is doing more than seeing a pattern as familiar or novel. The infant must generate an action on the basis of a memory, thus illustrating a primitive form of nonverbal recall memory (Mandler, 1990; Meltzoff, 1985, 1988a, 1990b).

The rich psychological web in which imitation is situated—learning, communication, perception–action links, memory, and representation—has made it an enduring topic in developmental psychology (Baldwin, 1906; Piaget, 1962) and an issue in philosophy of mind (Campbell, 1994; Goldman, 1992). Recently, there has been an explosion of interest in how imitation informs models of early cognitive development (Bower, 1989; Meltzoff, Kuhl, & Moore, 1991), “theory of mind” research (Bruner & Feldman, 1993; Meltzoff, 1990a, 1994; Meltzoff & Gopnik, 1993; Perner, 1991; Wellman, 1993), language (Kuhl & Meltzoff, in press; Speidel & Nelson, 1989; Studdert-Kennedy, 1986), and comparative psychology (Tomasello, 1986), and Kruger, & Ratner, 1993; Zentall & Galef, 1988). Within the broad topic of imitation, facial imitation has received special attention (Meltzoff & Moore, 1977, 1993; Piaget, 1962). Facial imitation poses a particularly interesting problem because of the apparent gulf between the target and the matching response. Infants can see the adult's face but cannot see their own faces. They can feel

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their own faces move but have no access to the feelings of self-movement in another. By what mechanism can infants link up the visible movements of others with the invisible (but felt) movements of the self?

Classical developmental theory answered this question by postulating special learning experiences that connected the visible aspects of another person to the invisible aspects of the self. Mirror experience and tactual exploration of self and other figured prominently on the list. Facial imitation was thought to emerge between 8 to 12 months of age (Piaget, 1962), and this fit with the observation that the postulated learning experiences were not ordinarily available much earlier than this. However, it has been found that newborns and young infants in the first half-year can match certain facial movements that they see. Tongue protrusion has been the most commonly reported example, but over the past 15 years, imitation of a wide range of other simple gestures has been documented, including lip, head, and hand movements (Abravanel & DeYong, 1991; Abravanel & Sigafos, 1984; Field et al., 1983; Field, Goldstein, Vaga-Lahr, & Porter, 1986; Field, Woodson, Greenberg, & Cohen, 1982; Fontaine, 1984; Heimann, 1989; Heimann, Nelson, & Schaller, 1989; Heimann & Schaller, 1985; Jacobson, 1979; Kaitz, Meschulach-Sarfaty, Auerbach, & Eidelman, 1988; Legenstein, 1991; Maratos, 1982; Meltzoff & Moore, 1977, 1983, 1989, 1992; Reissland, 1988; Vinter, 1986). These results call into question the psychological processes that were postulated as the mechanism for connecting self and other.

What can we infer from the fact that very young infants can match simple facial acts? It is not likely that any single experiment will define the underlying psychological mechanism; this will only be decided by weighing a large set of converging experiments. Nonetheless, alternative interpretations of early matching have been offered that lie on opposite ends of a continuum. It is helpful for understanding what is at stake to discuss the poles of the debate. Meltzoff and Moore (1977, 1983, 1989, 1992) proposed that early imitation is mediated by active intermodal mapping (AIM). The crux of the AIM hypothesis is that there is a genuine matching to target. Infants are using the cross-modal equivalence between body transforma-

tions that are seen and body transformations that are felt to generate the matching response. At the other end of the continuum is the hypothesis that early imitation is mediated by innate releasing mechanisms (IRMs) (Abravanel & Sigafos, 1984; Bjorklund, 1987; Jacobson, 1979). In this view, there is no real matching to target. When an infant sees tongue protrusion, a preorganized fixed-action pattern is released; the visual target does not guide or mold the response. In the case of the pupillary reflex, a bright light causes the pupil to contract; in the case of a Moro response, a sudden change in postural support triggers a particular motor pattern. The same occurs to tongue protrusion: A sensory pattern automatically triggers a motor response, but it is not critical that the stimulus and response be structurally equivalent. The equivalence does not enter into the motor generation process.

What sort of data can help us decide, or at least shift, the balance from one side of this interpretive continuum to the other? One relevant piece of information concerns how time locked the stimulus-response connection is. On the IRM view, one would expect that the sign stimulus would trigger the response within a relatively small temporal gap. It is notoriously difficult to define "relatively small." However, if infants were shown a gesture on one day and they only produced their imitative response when reintroduced to the situation on the next day, after a 24-hr delay interval, it would be difficult to call this an automatically triggered IRM. Instead, infants would have to be acting from a memory for the absent target.

There has been little work concerning constraints on the temporal gap, though Meltzoff and Moore (1977, Study 2; 1989) reported imitation after delays of a few seconds. One aim of this study was to use 6-week-old infants to test both immediate imitation and imitation after a 24-hr delay interval. A test of memory-based imitation in 6-week-old infants goes beyond the narrow debate about early imitation; it bears more generally on theories of early memory and representation, on the way one thinks about the "sensorimotor" period. To perform *facial* imitation in a *deferred* situation would mean that infants could use a part of their body that they had never seen to match a target that was no longer visible. Such behavior would be far removed from the kind of senso-

ry-based, stimulus-driven behavior often associated with early infancy.

Another kind of data that is relevant both to early imitation and to more general theoretical issues is the motor organization of the imitative response. If the AIM view has merit, one should see some evidence of an active matching to target. This would fit the idea that the visually specified motor act was serving as a target for the infants' own behavior. For example, infants might produce approximate matches to the target and gradually home in on the exact match over successive efforts. Such convergence toward correct matches has been noted previously (Meltzoff & Moore, 1983), but it has not been systematically explored. It has also been observed that there are distinctions between partial and full matches (Abravanel & Sigafos, 1984; Heimann, 1991; Heimann et al., 1989; Jacobson, 1979; Reissland, 1988), but the temporal sequencing of these types of responses has not been investigated. The second aim of this research was to examine the motor organization aspects of the infants' matching to target. Several grades of fidelity to the target were defined, and analyses evaluated whether infants converged toward more accurate responding over successive trials.

Finally, the study tested infants' reactions to a novel facial act. The act was a large tongue protrusion to the side. We did not think that this novel display would elicit high-fidelity matches on first try; the principal purpose of using this novel display was to examine whether infants' responses to the target converged over time. If the AIM hypothesis is correct and infants are actively matching their motor behavior to external targets, their behavior should converge towards this unusual motor pattern. The IRM viewpoint, on the other hand, predicted that either this nontypical display would not release tonguing, or if some form of tonguing occurred, there would not be a modification of the response to match the novel display.

The overarching goals of this study were to explore both the psychological mechanism that mediates early imitation and the role it plays in infants' understanding and communication with persons. The study was designed to investigate two more specific questions: (a) imitation from memory—do 6-week-old infants imitate absent gestures after a 24-hr retention

interval, or is imitation confined to the trials in which the gestures are perceptually present? and (b) organization of response—do 6-week-old infants converge towards more accurate matches of the target over successive trials, especially in the case of novel facial displays?

## METHOD

### Subjects

The subjects were 40 normal 6-week-old infants. Subjects were recruited from the University of Washington's computerized subject pool. Preestablished subject characteristics for admission into the study were:  $\pm 3$  days of 6 weeks old, normal birthweight (2.5–4.5 kg), normal length of gestation by maternal report ( $40 \pm 3$  weeks), and no history of visual or motor problems. The specifics of the sample were as follows:  $M$  age = 5.96 weeks ( $SD = 0.23$ , range = 5.58–6.43);  $M$  birthweight = 3.58 kg ( $SD = 0.44$ , range = 2.84–4.48);  $M$  length of gestation = 40.20 weeks ( $SD = 1.38$ , range = 37.29–42.43). Half the subjects were male, and half were female. The ethnic breakdown of the sample was 35 Caucasian, 4 Asian, and 1 Hispanic. Mothers were asked to describe the facial games played at home with their infants and were observed in the waiting room (approximately 20 min) before the test sessions. Because a goal of the study was to assess reactions to a novel facial movement, 3 potential subjects were excluded from the study because parent and child had a tongue game that resembled a tongue-protrusion-to-the-side gesture; for the rest, this gesture was presumed to be an unfamiliar display. Twenty-nine additional infants were dropped due to failure to return for all three test sessions ( $n = 3$ ), fussing ( $n = 14$ ), hiccoughing, spitting up, or choking uncontrollably ( $n = 9$ ), sleeping ( $n = 2$ ), or having a bowel movement during the test ( $n = 1$ ). This rate of subject loss is common in studies of young infants involving multitrial tests spread over several days (e.g., Stephens & Banks, 1987).

### Test Environment and Apparatus

The study took place within a large two-room suite. One room was a waiting area in which parents could feed and change their infants; the other contained a three-sided cubicle that provided a homogeneous visual environment for the test. The cubicle was lined with gray paper and the room ceiling was covered with the same material. The infant sat in the open end of the cubicle facing the rear wall which was 2.6 m away. The videotaping was done through a small hole in the rear wall of the cubicle. A light located above (25 cm) and behind (15 cm) the infant was used to spotlight the experimenter's face, which was presented at a distance of 30–35 cm from the subjects' eyes. The luminances of the experimenter's face and of the gray background (measured at 2.5 cm to the right of the experimenter's face) were approximately  $1.04 \log \text{ cd/m}^2$  and  $1.01 \log \text{ cd/m}^2$ , respectively. The video camera was focused on the infant's oral region, and the complete image was a close-up shot of the infant that only extended from the top of the infants' head to about 5 cm below the chin. The experiment was electronically timed by a character generator, the output of which was digitally displayed in a box

located directly above the infant's head and also fed into the video recorder. The elapsed time (0.10-s increments) was a permanent part of the video record for scoring purposes.

### Stimuli and Procedure

Each subject was randomly assigned to one of four independent treatment groups, with the constraint that there were equal numbers of males and females within each of the four groups. The treatments consisted of having the experimenter demonstrate either no oral movement (NOM), mouth opening (MO), tongue protrusion at midline (TP<sub>mid</sub>), or tongue protrusion to the side (TP<sub>side</sub>). Each infant was exposed to the same treatment on 3 consecutive days; for example, infants assigned to the MO group saw the experimenter demonstrate MO on the 3 days and were not shown any TP gestures. Across the 3 days, there were five 90-s test periods, as depicted in Table 1. The NOM group served as a control and on each day was exposed to a neutral facial expression with lips held gently in the closed position; the MO group was shown a full mouth opening/closing with the tongue body on the floor of the mouth; the TP<sub>mid</sub> group was shown a fully extended/retracted tongue at midline; the TP<sub>side</sub> group was shown a tongue protrusion that was a fully extended/retracted tongue at approximately 45° off midline such that it was protruded and withdrawn at the right corner of the mouth. Previous work suggested that infant attention and responsivity to facial models was maximized if a short interval of gesturing was alternated with a short pause, the "burst-pause" stimulus-presentation technique (Meltzoff & Moore, 1983, 1989). Accordingly, the MO, TP<sub>mid</sub>, and TP<sub>side</sub> modeling consisted of a repetitive alternation between 15 s of gesturing and 15 s of a neutral face for the full 90-s test period. Each individual gestural act

was 2.25 s with an interstimulus interval of 2.0 s, thus, there were four repetitions (e.g., four mouth openings) in a 15-s interval.

Day 1 proceeded as follows: When in a quiet, alert state, infants were placed in a padded chair inclined 30° off the horizontal and allowed to acclimate for 3 min. Acclimation consisted of a 1.5-min exposure to the empty cubicle followed by 1.5 min to the stranger-experimenter (during which time the experimenter simply sat with a neutral face). The gestural treatment (NOM, MO, TP<sub>mid</sub>, TP<sub>side</sub>) was then administered according to the previously described format. The experiment was electronically timed, and there were no breaks or pauses during the test session. Days 2 and 3 followed the same general procedure as Day 1 except that the acclimation period was omitted when infants returned on these subsequent days. To avoid having the parents practice the experiment with their infants between test sessions, parents were kept naive both to the experimental hypothesis and to the infant's treatment group (they left the subject with the experimenter for the test and did not see the gesturing; see "Specialized procedural steps" section). Parents were told the experiment involved videotaping infants' reactions to an unfamiliar person and testing for any changes in reactions that might occur over the 3 days as the person became more familiar. They were debriefed at the end of the study.

As shown in Table 1, three trials (1, 3, and 5) were termed the immediate imitation trials, because the adult demonstrated the facial gestures (MO, TP<sub>mid</sub>, TP<sub>side</sub>) during these times. The other two trials (2 and 4) were termed the memory trials, because they followed the immediate tests after 24-hr delays. In the memory trials, the adult maintained a neutral passive face in all treatment groups. Thus, in the memory trials, the stimulus shown to all infants was identical; any systematic differences that emerged as a function of treatment group were attributable

TABLE 1  
Design of the Experiment

Stimulus Information	Trials				
	1	2	3	4	5
Treatment group (adult display) <sup>a</sup>					
NOM ( <i>n</i> = 10)	PF	PF	PF	PF	PF
MO ( <i>n</i> = 10)	MO	PF	MO	PF	MO
TP <sub>mid</sub> ( <i>n</i> = 10)	TP <sub>mid</sub>	PF	TP <sub>mid</sub>	PF	TP <sub>mid</sub>
TP <sub>side</sub> ( <i>n</i> = 10)	TP <sub>side</sub>	PF	TP <sub>side</sub>	PF	TP <sub>side</sub>
Trial duration (in seconds)	90	90	90	90	90
Day of test	1	2	2	3	3
Trial type <sup>b</sup>	Immediate imitation	Memory	Immediate imitation	Memory	Immediate imitation

Note. NOM = no oral movement; MO = adult mouth opening; TP<sub>mid</sub> = adult tongue protrusion at midline of mouth; TP<sub>side</sub> = adult tongue protrusion from side of mouth; PF = adult passive face.

<sup>a</sup>The adult displays shown to each group are specified by reading across the line.

<sup>b</sup>Trials 1, 3, and 5 were termed immediate imitation trials because these trials contained the different adult demonstrations. Trials 2 and 4 were termed memory trials because they occurred after a 24-hr delay and the adult maintained a neutral passive face during the 90-s trial. There was a 24-hr delay interval between Day 1 and Day 2 and another 24-hr delay interval between Day 2 and Day 3. Within a particular day, the trials occurred sequentially without any delay.

to information that had been presented 24 hrs earlier, not to differences in present perception.<sup>1</sup>

**Specialized Procedural Steps.** Certain conditions seem to be more effective in eliciting early imitation than others. There is not, as yet, a principled list of the factors involved, but Meltzoff and Moore (1992) found that imitation is dampened if infants have competing expectations about the experimenter or his or her actions. Several steps were aimed at lessening such confusions. First, care was taken to distinguish the featural characteristics of the experimenter from the mother. The experimenter was the opposite gender from the mother, wore glasses if the mother typically did not wear them, and adopted a different hairline than the mother (wearing a fitted knit cap if she had bushy hair that stood out from the skull line). The factors of gender, hairline, and glasses have been found to be salient cues for facial discrimination and recognition in studies ranging from neonates to adults (Bushnell, 1982; Carey & Diamond, 1977; Fagan & Singer, 1979; Haith, Bergman, & Moore, 1977).

Second, the procedure ensured that the infants visually tracked the mother's exit from the test cubicle after she initially put the infant in the chair. Poor control over maternal leave-taking and the entrance of the experimenter was reported to dampen imitative responding in previous work with 6-week-olds (Meltzoff & Moore, 1992). The current procedure was standardized by having the adults sit on a small wheeled stool (a pediatrician's stool), which held them about face height, so the infant could see them. After comfortably positioning their infant in the chair, the mothers attracted the infant's attention by gently shaking a rattle or calling the infant's name and then moved out of the test cubicle. Before the experimenter entered the test cubicle, he too attracted the infants' attention and approached on a path in the opposite direction of the mother's exit (randomized across infants). The adults moved only as quickly as allowed by the infant: If the infant seemed to lose sight of the adults, they temporarily stopped and regained the infant's attention before continuing the path into or out of the cubicle.

Finally, the infant was prevented from interacting with the experimenter (the experimental stimulus) before or between test sessions. A research assistant greeted the parents at the door and answered any queries they had as they filled out forms.

### Coding Scheme and Behavioral Definitions

The videotapes of the subjects consisted of close-up images of the infants' faces with no picture or record of the adult's display. The videotapes were divided into 120 segments (40 subjects  $\times$  3 days each) and scored in a random order by a scorer who was kept blind to the gestures shown to the subjects and uninformed about the specific hypotheses under test. The coder's task was to use paper and pencil to record the infant behaviors and to note the time at which

they occurred. The coder viewed the videos in real time, slow motion, and frame-by-frame at her choosing. The operational definitions of the mouth and tongue behaviors were adapted from Meltzoff and Moore's (1983, 1989, 1992) coding scheme but extended to include subclassifications relevant to the TP<sub>side</sub> model.

A mouth opening was operationally defined by four characteristics: (a) initiated by an abrupt drop of the mandible; (b) lips opened along the entire width including the corners of the mouth so that space (in the form of a black region on the video monitor) could clearly be seen; (c) executed in a unitary motion so that the lip separation was greater than or equal to the width of the lower lip; and (d) fulfilled the foregoing criteria in silence and more than 1.5 s before a vocalization was produced (such acts look like a separate behavioral unit and not simply a concomitant of vocalizing or cooing). The termination of a mouth opening was defined by the end of the closing movement of the lips or the initiation of another criterial mouth opening.

The operational definition of a tongue protrusion was a clear forward thrust of the tongue that visibly crossed the back edge of the lower lip. For those cases in which the tongue was being retracted, but was not yet behind the lip when a second tongue thrust occurred, the first tongue protrusion was terminated with the initiation of the second. Tongue protrusions were further subclassified according to the form of the act, taking into account the maximum extent and direction (straight vs. lateral) of the protrusion. The subclassifications were mutually exclusive, such that the sum of the subclassifications was the total number of tongue protrusions: (a) "small tongues" (ST)—a tongue thrust that does not clearly exceed the outer edge of the lip and no directional component can be definitively classified; (b) "small nonmidline tongue protrusions" (NMT)—small tongue protrusion that emerges from the corner of the mouth after pushing out the corners or cheek; (c) "small tongue protrusions to the side" (STS)—small tongue protrusion that is followed by a clearly visible and definite lateral movement of the tongue before withdrawal is completed; (d) "large tongue protrusions" (LTP)—a tongue protrusion that is clearly thrust farther than the outermost edge of the lower lip; and (e) "large tongue protrusions to the side" (LTPS)—a large tongue protrusion that emerges and retracts at a corner of the mouth or manifests a visible and definitive lateral movement while outside the mouth by sliding across lips. Any infant oral behavior that occurred during yawning, sneezing, choking, spitting, or swallowing was not coded by the scorer, who bracketed it as physiological activity.

The principal dependent measures used in the analyses were the frequency of infant tongue protrusions and the frequency and duration of mouth openings. The onset time of each different type of tongue protrusion was recorded, but no attempt was made to have the coder also quantify how long each tongue movement lasted, because many were quick flicks, and accurate durations would have been difficult to obtain. (In Sackett's, 1978, and Bakeman & Gottman's, 1986, terms, a tongue protrusion is a "momentary event" in which one is interested in how often the event occurs and not how long it lasts.) For mouth opening, both frequency and duration were measured: Onsets and offsets of each act were coded at the 0.1-s level, and then the durations of the individual acts were summed to yield a

<sup>1</sup>There were three immediate-imitation trials and two imitation-from-memory trials because the infant must start off by seeing the display that is to be remembered. The first trial cannot be a memory trial. Thus, over a 3-day experiment with 1-day delays, there will be three immediate and two memory trials, as depicted in Table 1.

total duration per trial. In a different experiment with 6-week-olds, Meltzoff and Moore (1992) found that total duration of mouth opening was a more sensitive measure of imitation than frequency in infants of this age. The mouth opening and tongue protrusion behaviors were coded on separate passes through the videos, which allowed the coder to concentrate on each in microanalytic detail.

### Scoring Agreement

Assessments of both intra- and interobserver agreement were based on a rescoring of 20 trials (10% of the data record). Several conventional assessments were conducted, all of which indicated good coding agreement. First, agreement on infant mouth openings was evaluated by means of correlational statistics. The Pearson correlations between Observer 1 and Observer 2 for the frequency of mouth opening per trial were .97 for the intraobserver and .96 for the interobserver comparisons. The corresponding coefficients for the duration of mouth opening were .96 and .91. A fine-grained examination of the point-by-point agreement for the mouth opening code was also undertaken, although this was more rigorous than the subsequent statistical analyses required. Bakeman and Gottman's (1986) approach was adopted for evaluating point-by-point agreement for a continuously scored behavioral stream. The coding record of each observer was cast in terms of whether it had mouth opening ("code") or no mouth opening ("no-code") in each sequential 1-s interval. A 2 (Observer 1/Observer 2)  $\times$  2 (code/no-code) matrix was then constructed and evaluated using Cohen's kappa, which corrects for chance level agreement. A kappa of .75 or greater is considered to be excellent agreement (Fleiss, 1981). The intra- and interobserver kappas were .87 and .84. For the tongue protrusion coding, the agreement was also good. The correlations between Observer 1 and Observer 2 on the frequency of tongue protrusions yielded .97 for the intraobserver and .95 for the interobserver comparisons. Point-by-point agreement was evaluated using a multicategory confusion matrix (five different types of tongue protrusion and a no-code category). A disagreement between Observers 1 and 2 was tallied if there was a discrepancy in whether a behavior occurred (e.g., one observer scored a tongue but the other did not within a given 1-s interval—an error of "omission") or a discrepancy about the exact quality of behavior (e.g., a confusion of ST with LTP at a particular time point—an error of "commission"). Kappa can be used to evaluate observer agreement for a multicategory confusion matrix of this type. The obtained intra- and interobserver values were .80 and .75, respectively.

### RESULTS

The infants were randomly assigned to one of four treatment groups. In all groups the infants were presented with the same face, at the same distance, in the same test setting, for the same overall length of time. The groups differed only according to the experimental treatment, which consisted of the type of adult facial demonstration shown. If infants respond differ-

entially as a function of group, this can be attributed to the nature of the adult display. Table 2 provides the means and standard deviations for three infant response measures as a function of experimental group.

### Overall Test

The analyses in this section all pertain to the data from the total test, the sum of all five trials for each subject (Table 2, Total Test column). For the tongue protrusion response measure, the prediction from a hypothesis of infant imitation is that infants will produce more tongue protrusion in response to seeing adult tongue protrusion demonstrations (Groups TP<sub>mid</sub> and TP<sub>side</sub>) than in response to seeing other adult demonstrations (Groups NOM and MO). The data conform to this prediction. Table 2 (top panel) shows that infants produced about 1.5 times more tongue protrusions in response to the TP displays (TP<sub>mid</sub>:  $M = 56.80$ ,  $SD = 29.94$ ; TP<sub>side</sub>:  $M = 58.60$ ,  $SD = 24.05$ ) than in response to the other adult demonstrations (NOM:  $M = 36.30$ ,  $SD = 20.83$ ; MO:  $M = 31.90$ ,  $SD = 12.31$ ). A planned comparison directly contrasting the two tongue (TP<sub>mid</sub> and TP<sub>side</sub>) versus nontongue treatment groups (NOM and MO) was significant,  $t(36) = 3.29$ ,  $p < .005$ . Other orthogonal contrasts showed that there was neither a significant difference between the two tongue displays (TP<sub>mid</sub> vs. TP<sub>side</sub>) nor between the two nontongue displays (NOM vs. MO;  $ps > .50$ ).<sup>2</sup>

For the mouth opening response measure, the prediction from a hypothesis of infant imitation is that infants will produce more mouth openings in response to the adult mouth opening display (MO) than to the other displays (NOM, TP<sub>mid</sub>, TP<sub>side</sub>). The data are in accord with this, although the duration of infant mouth opening was found to be a more sensitive measure of treatment effects than the frequency of infant mouth opening, as also reported in previous research (Meltzoff & Moore, 1992). For the duration measure (middle panel), infant

<sup>2</sup>These data and those reported in the next section were also reanalyzed by applying a square root transformation to the raw data before conducting the planned comparisons and also by using nonparametric statistics (Mann-Whitney  $U$  tests) with the untransformed scores; the pattern of results remained the same regardless of the statistical approach used.

TABLE 2  
Means and Standard Deviations of Infant Behaviors as a  
Function of Treatment Group and Trials

Treatment Group (Adult Display)	Individual Trials					Grouped Trials		
	1	2	3	4	5	Total Test ( $\Sigma$ Trials 1-5)	Immediate ( $\Sigma$ Trials 1 + 3 + 5)	Memory ( $\Sigma$ Trials 2 + 4)
Infant Tongue Protrusion (frequency)								
NOM								
M	8.40	5.30	7.40	6.80	8.40	36.30	24.20	12.10
SD	5.93	5.12	5.76	5.27	6.38	20.83	13.56	8.82
MO								
M	8.70	4.60	7.40	5.60	5.60	31.90	21.70	10.20
SD	5.62	3.03	6.17	3.31	4.03	12.31	10.85	3.99
TP <sub>mid</sub>								
M	9.40	10.40	16.20	8.10	12.70	56.80	38.30	18.50
SD	9.20	7.68	9.40	6.23	6.57	29.94	20.21	11.21
TP <sub>side</sub>								
M	11.10	11.50	11.90	10.80	13.30	58.60	36.30	22.30
SD	5.02	6.93	10.39	3.94	6.40	24.05	17.11	9.60
Infant Mouth Opening (duration in s)								
NOM								
M	3.59	3.25	2.80	5.22	5.71	20.57	12.10	8.47
SD	6.46	3.92	2.86	6.08	5.76	18.59	12.18	8.85
MO								
M	7.74	5.22	9.52	9.28	7.67	39.43	24.93	14.50
SD	7.47	3.94	8.85	9.76	6.22	23.11	15.42	11.64
TP <sub>mid</sub>								
M	3.77	3.36	5.00	5.01	2.09	19.23	10.86	8.37
SD	3.36	4.46	5.25	6.47	1.96	10.84	6.15	7.96
TP <sub>side</sub>								
M	2.49	3.56	1.76	3.06	5.56	16.43	9.81	6.62
SD	4.00	4.44	2.41	3.76	5.27	10.63	7.28	7.30
Infant Mouth Opening (frequency)								
NOM								
M	1.90	1.60	1.00	2.40	2.70	9.60	5.60	4.00
SD	2.64	2.01	.94	2.76	2.87	9.06	5.10	4.59
MO								
M	2.60	1.80	3.50	2.90	2.90	13.70	9.00	4.70
SD	2.32	1.62	2.59	3.67	2.60	7.75	5.68	4.16
TP <sub>mid</sub>								
M	1.60	2.00	2.30	2.10	1.40	9.40	5.30	4.10
SD	0.97	2.31	2.36	2.47	1.07	4.84	3.30	2.88
TP <sub>side</sub>								
M	1.00	1.60	1.20	1.60	2.60	8.00	4.80	3.20
SD	1.25	1.96	1.48	1.65	2.12	5.06	2.70	3.26

Note. NOM = no oral movement; MO = mouth opening; TP<sub>mid</sub> = tongue protrusion at midline; TP<sub>side</sub> = tongue protrusion to the side.

mouth opening was approximately twice as long in response to the adult mouth opening display ( $M = 39.43$ ,  $SD = 23.11$ ) than to the nonmouth opening displays, which were tightly clustered (NOM:  $M = 20.57$ ,  $SD = 18.59$ ; TP<sub>mid</sub>:  $M = 19.23$ ,  $SD = 10.84$ ; TP<sub>side</sub>:  $M = 16.43$ ,  $SD = 10.63$ ). A planned comparison

showed that this difference was highly significant,  $t(36) = 3.40$ ,  $p < .005$ . For the frequency of infant mouth opening (bottom panel), the means were in the predicted direction, with infants producing more mouth openings in response to the adult mouth opening display ( $M = 13.70$ ,  $SD = 7.75$ ) than to nonmouth opening

displays (NOM:  $M = 9.60$ ,  $SD = 9.06$ ; TP<sub>mid</sub>:  $M = 9.40$ ,  $SD = 4.84$ ; TP<sub>side</sub>:  $M = 8.00$ ,  $SD = 5.06$ ), but the result was equivocal,  $t(36) = 1.86$ ,  $p = .07$ .

#### Imitation From Memory

It is of interest to theory to examine the strength of the matching effects during two mnemonically different aspects of the test: immediate imitation and memory. The data from the whole test were broken down into these subdivisions to examine this issue in detail (Table 2).

First, consider the data from the immediate imitation test alone, the trials in which the adult was actually demonstrating the facial displays (Trials 1, 3, and 5). The relevant means are displayed in Table 2's Immediate column. The results supported the hypothesis of imitation. As shown in the top panel, infants produced more tongue protrusions in response to seeing the adult tongue protrusion displays (TP<sub>mid</sub>:  $M = 38.30$ ,  $SD = 20.21$ ; TP<sub>side</sub>:  $M = 36.30$ ,  $SD = 17.11$ ) than to the nontongue displays (NOM:  $M = 24.20$ ,  $SD = 13.56$ ; MO:  $M = 21.70$ ,  $SD = 10.85$ ),  $t(36) = 2.87$ ,  $p < .01$ . For the mouth opening duration measure (middle panel), infants produced significantly longer mouth opening in response to seeing the adult mouth opening display (MO:  $M = 24.93$ ,  $SD = 15.42$ ) than to the nonmouth opening displays (NOM:  $M = 12.10$ ,  $SD = 12.18$ ; TP<sub>mid</sub>:  $M = 10.86$ ,  $SD = 6.15$ ; TP<sub>side</sub>:  $M = 9.81$ ,  $SD = 7.28$ ),  $t(36) = 2.72$ ,  $p < .05$ . For the mouth opening frequency measure (bottom panel), infants also produced more mouth opening in response to seeing the adult mouth opening display (MO:  $M = 9.00$ ,  $SD = 5.68$ ) than to the nonmouth opening displays (NOM:  $M = 5.60$ ,  $SD = 5.10$ ; TP<sub>mid</sub>:  $M = 5.30$ ,  $SD = 3.30$ ; TP<sub>side</sub>:  $M = 4.80$ ,  $SD = 2.70$ ),  $t(36) = 2.36$ ,  $p < .05$ .

Next consider the memory test alone, the trials that followed the adult demonstrations after a 24-hr retention interval (Trials 2 and 4). In the memory test, the stimulus that was *perceptually present* was identical for all infants. The identical neutral face stimulus was used, and infants differed only according to what they had seen 1 day earlier (see Table 1). The relevant means for assessing imitation from memory are displayed in Table 2's Memory column. As shown in the top panel, infants who were viewing a neutral face, but who had seen that

adult showing tongue protrusions the day before, produced significantly more tongue protrusions (TP<sub>mid</sub>:  $M = 18.50$ ,  $SD = 11.21$ ; TP<sub>side</sub>:  $M = 22.30$ ,  $SD = 9.60$ ) than infants who had not seen the tongue protrusions (NOM:  $M = 12.10$ ,  $SD = 8.82$ ; MO:  $M = 10.20$ ,  $SD = 3.99$ ),  $t(36) = 3.31$ ,  $p < .005$ . Similarly, as shown in the middle panel, infants who had seen the adult showing mouth openings the day before devoted more time to mouth opening (MO:  $M = 14.50$ ,  $SD = 11.64$ ) than those who had not seen the mouth openings (NOM:  $M = 8.47$ ,  $SD = 8.85$ ; TP<sub>mid</sub>:  $M = 8.37$ ,  $SD = 7.96$ ; TP<sub>side</sub>:  $M = 6.62$ ,  $SD = 7.30$ ),  $t(36) = 2.01$ ,  $p = .05$ . Though the means were in the predicted direction, the frequency measure of infant mouth opening (bottom panel) did not yield significant differences.

#### Motor Organization of the Matching Response

Meltzoff and Moore (1983; Meltzoff et al., 1991) suggested that infants converge on an accurate reproduction of the model, and other researchers have also noted distinctions between approximate versus full matches (Abravanel & Sigafos, 1984; Heimann et al. 1989; Jacobson, 1979; Reissland, 1988). This study provided an ideal opportunity to assess such convergence, because it seemed highly unlikely, by anyone's theory, that the unusual behavior of TP<sub>side</sub> could be a preorganized motor packet that was simply released by the sight of that gesture. According to the AIM view, however, infants might go through steps in constructing a match to the TP<sub>side</sub> display, progressing from less to more accurate matches over successive efforts.<sup>3</sup>

To address this question, we examined the order of emergence of different types of infant tongue protrusions. The coding scheme defined four types of infant tonguing that bore an ordinal relationship with respect to their match to the TP<sub>side</sub> display. They were (a) small non-midline tongue protrusions (NMT), (b) small

<sup>3</sup>No attempt was made to assess convergence in the ordinary tongue protrusion group (TP<sub>mid</sub>) for two reasons: (a) The scoring system did not make distinctions between many different levels of exclusively midline tongue protrusions, and therefore, it simply could not be tested using the current coding subdivisions; and (b) such convergence has already been noted for ordinary tongue protrusion in neonates (Meltzoff & Moore, 1983).



tongue protrusions to the side (STS), (c) large tongue protrusions (LTP), and (d) large tongue protrusions to the side (LTPS).<sup>4</sup> If infants are correcting their responses, infants in the TP<sub>side</sub> group might begin by producing small behaviors approximately matched to the model and converge towards producing large tongue protrusions to the side. In other words, there should be a progression of behavior levels from NMT to LTPS over successive trials. The first question is whether any such progression is evident in the data. If so, the next question is whether it is related specifically to the adult display of TP<sub>side</sub>. The general psychological principle being drawn upon is that organisms that are aiming to hit a target (whether this be a spatial location, behavioral form, etc.) will not behave in a random way but, rather, will show a systematic progression in the accuracy of their behaviors over successive efforts.

The statistical evaluation of this order of emergence was provided by the statistic *S* (Ferguson, 1965, 1981). *S* provides a simple and straightforward measure of how well a set of numbers conforms to a predicted order (it is also the numerator in the Kendall rank-correlation coefficient, tau). A brief example, adapted from Ferguson (1981), will make the principle clear. Suppose that there are four qualitatively different behaviors. The top row shows the expected rank order of four behaviors and the bottom row shows the obtained order.

<i>Expected:</i>	1	2	3	4
<i>Observed:</i>	1	2	4	3

To calculate *S*, every rank in the observed data is compared with each other (all pairwise comparisons) and a value of +1 is assigned for each pair that is in the correct order and -1 for each pair in the inverse order. The five comparisons would be: 1 versus 2, 1 versus 4, 1 versus 3, 2 versus 4, 2 versus 3, and 4 versus 3. The

values would be +1, +1, +1, +1, +1, and -1. *S* is the sum of these values, or 4. A positive value of *S* means that the obtained behaviors tend to be ordered in the predicted sequence, an *S* value of 0 means that the behaviors are in disarray, and negative value of *S* means that the behaviors tend to be ordered in the inverse of the predicted sequence. (In certain cases, no *S* value can be assigned because no ordering evaluation can be made; for example, if an infant produces no behavior at all or only produces one type of behavior in all trials, then no *S* value can be determined for that subject.) One particularly useful feature of *S* is that it is obtained for each individual subject. This provides information about how many individual infants exhibit the predicted order.

For this analysis, if infants produced their maximum number of NMT behaviors in Trial 1, they were assigned a value of "1" for NMT behavior. If they produced their maximum number of STS behavior in Trial 2, they were assigned a value of 2 for STS behavior, and so on. In this example, NMT and STS behaviors would be correctly ordered with respect to each other (NMT behavior emerged before STS behavior). The empirical questions under test were whether infants in the TP<sub>side</sub> group tended to obtain *S* scores with positive values and, if so, whether they did so to a greater degree than the other groups.

Table 3 shows that, in the TP<sub>side</sub> group, 8 infants obtained positive *S* scores as opposed to only 1 who obtained a negative score ( $p < .05$  by a sign test). This shows that there was a systematic order of emergence of the tongue protrusion behaviors among infants in the TP<sub>side</sub> group. In other words, infants were not emitting the different types of tongue protrusion in a random order. Ferguson (1965, 1981) provided a formula for analyzing multiple subjects with *S* scores (a nonparametric monotonic trend test). The results show a significant ordering at the group level ( $z = 2.23, p < .05$ ).

In the comparison groups (NOM, MO, TP<sub>mid</sub>), infants saw the same adult over the same number of trials as infants in the TP<sub>side</sub> group. The only difference was that they were not presented the same gestural target. These groups can be used to examine whether or not the obtained ordering in the emergence of behaviors was specific to the TP<sub>side</sub> group. The results showed that infants in the comparison

<sup>4</sup>The fact that these behaviors can be organized along an ordinal scale has reasonable face validity, and extensive pilot work with the TP<sub>side</sub> display also had suggested this particular empirical ordering. No claim to an interval scale can be made, but the requirements of an ordinal scale are met. From a psychological perspective, the prediction is also at the ordinal level: that infants will progress from less accurate to more accurate matches. The use of ordinal statistics honors this, because individual infants may skip a step, as long as they exhibit the predicted ordering towards greater accuracy.

TABLE 3  
Convergence on TP<sub>side</sub> Behavior:  
Number of Subjects With Different S-Score  
Signs as a Function of Group

Treatment Group (Adult display)	S Score		
	+	0	-
NOM	2	2	2
MO	1	2	1
TP <sub>mid</sub>	3	1	2
TP <sub>side</sub>	8	0	1

Note. NOM = no oral movement; MO = mouth opening;  
TP<sub>mid</sub> = tongue protrusion at midline; TP<sub>side</sub> = tongue  
protrusion to the side.

groups did not tend to exhibit the same ordering as those exposed to the TP<sub>side</sub> target. The raw distribution of positive, negative, and zero *S* values is probably sufficient to make the point (Table 3); but these data can also be statistically analyzed using a 2 × 2 matrix contrasting the TP<sub>side</sub> versus non-TP<sub>side</sub> groups for the number of positive versus nonpositive *S* scores (Fisher exact test,  $p < .025$ ).<sup>5</sup> Ferguson's monotonic trend test confirmed that neither the TP<sub>mid</sub> group considered by itself, nor the pooled data from the three control groups, exhibited the behavioral ordering shown by TP<sub>side</sub> ( $z_s < .50$ ,  $p_s > .30$ ).<sup>6</sup> It is of interest that the profile exhibited by the TP<sub>side</sub> group is quite specific: It is not even exhibited when a

different type of tongue protrusion is demonstrated by the adult.

The issue of response convergence was also examined for the duration of mouth opening. The duration of mouth opening demonstrated by the adult was 2.25 s (see Stimuli section). The question was whether infants converged on this target duration after a preliminary period of under- and overshooting the target.

Different durations of mouth opening were categorized according to how well they matched the model. A linear time scale with increments of  $\pm 0.5$  s was constructed around the target value of 2.25 s. The most accurate level consisted of behaviors that fell within an absolute value of 0.5 s of the target, behaviors between 1.8 to 2.7 s in duration. The scale then proceeded in 0.5-s steps. For example, the second grade of mouth opening consisted of behaviors that were 0.6 to 1.0 s different in absolute value from the 2.25 target, and so on. This scheme yielded five grades of infant mouth opening that were objectively ordered for how well they matched the target mouth opening. The statistic *S* was again used in the same manner as just described. Table 4 shows that, in the MO group, 7 individual infants obtained positive *S* scores as opposed to 2 who obtained nonpositive scores. The monotonic trend test showed that the behavior of the infants in this group was ordered ( $z = 2.05$ ,  $p < .05$ ). Infants in the control groups (NOM, TP<sub>mid</sub>, TP<sub>side</sub>) did not exhibit this ordering: 14 individuals showed positive *S* scores and 13 showed nonpositive scores, and the monotonic

<sup>5</sup>The proportion of subjects who could not be assigned an *S* score is higher in the control groups than for the TP<sub>side</sub> group because subjects tended not to produce TP<sub>side</sub> relevant behaviors (which makes sense because they were not modeled for them). For completeness, the data were also reanalyzed using the full sample of 10 subjects per treatment group by assigning  $S = 0$  for those cases in which an infant exhibited no TP<sub>side</sub> relevant behaviors and no ordering could be evaluated. The results were strengthened (Fisher exact test,  $p = .001$ ). The numbers that correspond to the rows of Table 3 are: NOM, 2, 6, 2; MO, 1, 8, 1; TP<sub>mid</sub>, 3, 5, 2; and TP<sub>side</sub>, 8, 1, 1.

<sup>6</sup>In the text, the trial of maximum incidence was used to define the emergence of a particular behavior type. Another measure is the first trial in which infants show each of the particular behaviors. The pattern of results is the same if one adopts this slightly different measure. The predicted ordering is exhibited in the TP<sub>side</sub> group ( $z = 1.68$ ,  $p < .05$ ), and again, the ordering is not obtained in the controls ( $z = .33$ ,  $p > .35$ ).

**TABLE 4**  
**Convergence on Mouth Opening Target**  
**Duration: Number of Subjects With Different**  
**S-Score Signs as a Function of Group**

Treatment Group (Adult display)	S Score		
	+	0	-
NOM	4	0	4
MO	7	0	2
TP <sub>mid</sub>	5	2	2
TP <sub>side</sub>	5	1	4

Note. NOM = no oral movement; MO = mouth opening;  
 TP<sub>mid</sub> = tongue protrusion at midline; TP<sub>side</sub> = tongue  
 protrusion to the side.

trend failed to approach significance ( $z = .64$ ,  $p > .25$ ).

#### Subsidiary Analysis:

##### Imitation of Novelty

Infants' reaction to the TP<sub>side</sub> display is of special interest because it is a novel gesture. The fact that infants converged toward the TP<sub>side</sub> target over trials suggested a supplementary analysis. For this analysis, just the last day of testing was isolated, which allowed infants the maximum time to organize their response to this target. Did infants imitate this unusual display? Table 5 displays the number of subjects who produced the high-fidelity large-tongue-protrusion-to-the-side behavior (LTPS).

As can be seen, only 13 of the 40 infants produced this behavior, as might be expected because it is an unusual infant behavior. However, this behavior was significantly

more likely to be produced by infants who had seen this display than those who had not: In the TP<sub>side</sub> group, 7 of 10 infants produced this behavior as compared to 6 of 30 infants in the other groups ( $p = .007$ , Fisher exact test). Inspection of the table also shows that this novel behavior is quite specifically tied to those infants who saw the TP<sub>side</sub> display: It was not associated with infants who saw the other kind of tongue protrusion (TP<sub>mid</sub>). These and the convergence data indicate that infants were imitating the TP<sub>side</sub> display, although they required several trials before they accurately matched this novel display.

#### DISCUSSION

This study provides new data concerning imitation from memory, the organization and typology of the imitative response, and the imitation of novel acts by young infants. These empirical findings are considered in relation to three broad theoretical issues: (a) memory, representation, and developmental change; (b) perceptual-motor mapping and coordination in infancy; and (c) the functions of imitation, particularly its role in the understanding of "persons."

##### Memory, Representation, and Developmental Change in Imitation

There have been no previous tests of imitation after a significant delay in young infants. This study examined immediate and delayed imitation. The findings indicated that infants imitated in the immediate trials, which is in

**TABLE 5**  
**Number of Subjects Who Produced (Yes/No) a**  
**Large-Tongue-Protrusion-to-the-Side Behavior on**  
**Day 3 of the Test**

Treatment Group (Adult display)	Yes	No
NOM	2	8
MO	1	9
TP <sub>mid</sub>	3	7
TP <sub>side</sub>	7	3

Note. NOM = no oral movement; MO = mouth opening; TP<sub>mid</sub> = tongue protrusion at midline; TP<sub>side</sub> = tongue protrusion to the side.

accord with past literature. They also showed that 6-week-olds imitated from memory after a 24-hr delay, which is new.

A common assumption about early imitation is that it is tightly bound temporally to the stimulus movement that elicits it. This assumption figures prominently in the reflexive or IRM view. The idea is that the adult's gesture automatically triggers the infant's matching response. The new results indicate, however, that infants imitate in the absence of the putative sign-stimulus after a significant delay. In the memory trials, infants in all groups were watching the same neutral face expression. Why should this same passive face act as a sign-stimulus for mouth opening for some children and as a sign-stimulus for tongue protrusion for others? The IRM model cannot explain these data. The information on which such imitation is based is not in the perceptual stimulus: It is represented in the infant's mind.

These findings of memory-based imitation in 6-week-old infants are compatible with other recent findings of deferred imitation. Meltzoff (1985, 1990b), and independently, Bauer and Mandler (1992), have shown that deferred imitation does not first emerge at 18 months of age, as postulated in classical developmental theory (Piaget, 1962). The data have shown that 14-month-olds can imitate novel acts from memory after a 1-week delay (Meltzoff, 1988a) and also after a delay coupled with a change in situational context (Hanna & Meltzoff, 1993), that 11- to 13-month-olds can retain information about event sequences (Bauer & Mandler, 1992), and that even 9-month-olds can perform deferred imitation over a 24-hr delay (Meltzoff, 1988b). The age at which infants begin to perform deferred imitation has been dropping in recent studies. We suggest a further downward revision from 9 months to 6 weeks of age.

The findings here are also in line with recent work with toddlers in a deeper way. Meltzoff (1988b) found no significant difference in the strength of immediate imitation and deferred imitation after a 24-hr retention interval in 9-month-olds, a point also noted by Abravanel (1991) in 13- to 20-month-olds. A similar pattern emerged here with much younger infants. The conclusion one draws is different from what would have been expected on classic developmental accounts. The suggestion is that memory—in the sense of bridging a significant

temporal gap between the perception of the target and the execution of the matching response—is not a critical constraint on infant imitation.

This does not mean that there is no development in imitation, but the classic progression from stimulus-bound, reflexively triggered response to representationally based deferred imitation (at 18 months) does not, in our view, accurately describe imitative development or fit with recent data. There are developmental changes in imitation, but we suggest that these are best viewed as developments in social cognition and the understanding of persons. For example, Meltzoff and Moore (1992) documented changes in facial imitation between the neonatal period and 2 to 3 months of age. We found that older infants had developed social expectations about people, their games, and expressive behaviors that were not present in the newborn and 6-week-old, and this influenced the deployment of imitation. Infants at this age tried out routinized social behavior (smiling, greeting, cooing), which superseded strict imitation. The capacity to imitate was not lost, however. There was no "drop out," inasmuch as imitation was elicited quite readily when it was made the focus of the social encounter (Meltzoff & Moore, 1992). By 9 months of age, infants begin to use people as sources of information about things in the environment. They imitate more than pure body movements. They copy people's actions on objects (Meltzoff, 1988b), suggesting that the unit for imitation, as it were, has now expanded to a person-thing relation, rather than solely body movements themselves. The development of object-directed imitation dovetails with the emergence of other behaviors at about this age, which also use people's actions to "refer" to attributes and affordances of objects (Butterworth, 1991; Tomasello et al., 1993; Trevarthen & Hubley, 1978), particularly the phenomenon of "social referencing" (Campos & Stenberg, 1981). By 18 months of age, it has been found that infants will imitate not only an adult's actual actions but the actions he or she intends or tries to produce, even if they are not fully realized; at this age, infants can now read below the surface behavior of the adult and reenact the goals, aims, or intentions of the adult (Meltzoff, 1994). At the end of infancy and in early childhood, children duplicate

social roles: Behaving "as if" they were mommy, acting from a mommy-like perspective, and expressing mommy-like desires and beliefs, even if they are not the child's own. Thus, we think there is significant development in imitation. Imitation develops beyond the level of specific behaviors to the reenactment of intentions, roles, and perspectives that underlie and predict behavior.

Our intention is not to collapse the differences between 6-week-old and 24-month-old children, but to elucidate the basic "primitives" from which development proceeds. In our view, the capacity to organize actions based on a stored representation of perceptually absent events is a starting point in infancy, not its culmination. This (innate) capacity to represent the invisible—to act off stored representations of the perceptually unavailable—is made manifest by early imitation from memory but applies more broadly than imitation (cf. Bailargeon, 1993; Bower, 1982; Spelke, Breinlinger, Macomber, & Jacobson, 1992). The double significance of early imitation is that it is not only a marker of such a representational capacity, but is itself an important engine in infants' developing understanding of persons.

#### Motor Organization and Imitation of Novelty

A finding of particular relevance for the mechanisms of early imitation is that infants zero-in on the high-fidelity matches to unfamiliar targets. We think of imitative acts as being composed of two components, the "organ" or body part and the action or transformation: imitative act = body part + transformation. Infants seem to have a primitive body scheme that allows them to map a delimited set of body parts: tongue to tongue, lips to lips. We have not observed young infants confusing tongue protrusion with finger protrusion, for example. When tongue protrusion is presented, infants activate the tongue quite quickly, as if the first level of analysis is a kind of organ identification. However, infants do not necessarily realize the correct action with this body part on first try. This makes sense because infants cannot have hard-wired motor templates for each of the numerous transformations these body parts may be put through. For example, it seems implausible to us that there is a prewired template for the TP<sub>side</sub> behavior. Infants did

not immediately produce accurate imitations of this novel behavior, they needed to correct their behavior to achieve it.

These findings of infants homing-in on the presented target are in line with the mechanism for early imitation suggested by Meltzoff and Moore (1977, 1983, 1989). We proposed that infant imitation depends on a process of active intermodal mapping (AIM). The central notion is that imitation, even early imitation, is a matching-to-target process. The goal or behavioral target is specified visually. Infants' self-produced movements provide proprioceptive information that is compared to the visually specified target. Thus, AIM hypothesizes that the perception and production of human acts can be represented within a common framework, that infants are not limited to modality-specific information about body movements in space. The AIM hypothesis highlights the possibility of using proprioceptive information about one's own unseen movements, but AIM does not rule out visual-motor mapping of elementary acts on "first try," without the need for feedback. The crux of the hypothesis is that the adult act serves as a genuine target for the infant's behavior. There may be a delimited set of primary acts (ordinary tongue protrusion?) that are achieved with little need of feedback, whereas other more complex acts involve modifications of these primitives (e.g., TP<sub>side</sub>) and proportionately more proprioceptive monitoring.<sup>7</sup>

The AIM hypothesis of imitation is compatible with what is being learned about perceptual-motor coordination in other domains. It is particularly fruitful to draw parallels between the perceptual-motor aspects of early imitation and reaching. In imitation, infants "fit" their bodies to a pattern that is visually perceived. Infant reaching also involves fitting a body part to a visually perceived target: The fit may be spatial location, form, or orientation of the

<sup>7</sup>Students of motor control traditionally distinguished between "closed loop" (feedback mechanisms) and "open loop" (preprogrammed action) motor behavior. However, it is increasingly apparent that it is difficult to classify most purposive human behavior within a rigid dichotomy of this sort (Bernstein, 1967; Reed, 1982; Savelsbergh, 1993; Schmidt, 1982; Sporns & Edelman, 1993; Thelen, 1989; Thelen & Fogel, 1989; von Hofsten, 1989). Early imitation is another example of a coordination between perception and action that resists such a rigid dichotomization.

object to be grasped (Bower, 1982; von Hofsten, 1982; von Hofsten & Fazel-Zandy, 1984; von Hofsten & Rönqvist, 1988), but in both reaching and imitation there is a molding of the body to a visually perceived external target. The response modifications infants make in successive reaches as they home in on a target are analogous to the modifications we here report in imitation. However, in the normal case, infants can see both their own hands and the visual target and, therefore, can use visual comparisons to bring their hand and target into correspondence. In facial imitation, such visual guidance is impossible because they cannot see their own faces. Reaching can be more closely equated to facial imitation in the special cases in which the hand is obscured from the infant's view during reaching (Bower, 1982; Butterworth & Hopkins, 1988; Clifton, Muir, Ashmead, & Clarkson, 1993; Lasky, 1977; Rochat, Blass, & Hoffmeyer, 1988). There are particularly interesting parallels between memory-based facial imitation and reaching in the dark to a remembered object (Bower & Wishart, 1972; Clifton, Rochat, Litovsky, & Perris, 1991). In such studies, hand position cannot be monitored by vision (as in the case of facial movements), and infants must move an unseen body part to a remembered and currently invisible target (which makes it more parallel to the deferred imitation case). We are aware that reaching and imitation can be "split" as well as "lumped," but the key point is that facial imitation is not unique in infant development: There is independent, converging evidence that young infants are capable of using proprioceptive information about their *unseen body parts* to modify their behavior in accord with the visually specified input.

#### Imitation and the Identity of Persons:

##### A Theory

A full understanding of early imitation must go beyond the consideration of memory and perceptual-motor coordination. The findings also raise issues about the psychological functions imitation subserves in social encounters. What would motivate an infant to imitate yesterday's observed behavior? Our theory is that imitation serves an *identity* function. Infants use imitation as a way of reidentifying and communicating with persons they see before them.

Imitation is multiply determined, but we

suggest that a chief reason infants deploy imitation is to probe whether this is a *reencounter* with a familiar person or an encounter with a stranger. In the case of deferred imitation, the infant has seen a person show a tongue protrusion gesture. Twenty-four hours later, a person who looks the same appears in the same place with a neutral face. We believe that one of the salient issues raised by this social encounter for the 6-week-old is one of the identity of the person and the continuance of the games they play. Is this the self-same person acting differently, or a different person who merely looks the same?

Infants use imitation to help resolve this question; thus, situations posing a question about person identity will be ones that are especially effective in motivating imitation. In what way does imitation serve this function?<sup>8</sup> Here we are building from the Piagetian-Wernerian insight that young infants come to "know" things, in part, through acting on them. We wish to extend this line of argument to people, not just things. Inanimate things may be known primarily through physical actions, but people are known through interaction and the distinctive behaviors they manifest. When infants reencounter a bottle or rattle, they probe whether this "is the one that is suckable/rattleable" as part of making sense of their world. This discovery is principally owed to Piaget. What we are suggesting is that when infants reencounter people, they similarly take action to test the identity of the person before them. Imitation is to understanding people as physical manipulation is to understanding things.

This view makes some sense of the deferred imitation data reported here. This study was designed so that the experimenter played one, and only one, game with the infant. For some infants, it was a mouth opening gesture; for

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<sup>8</sup>There are actually two logically separable functions here that seem to be intertwined at this early developmental stage. One concerns what philosophers call particular, or numerical, identity (Strawson, 1959) and we have called unique identity (Meltzoff & Moore, 1992, 1993; Moore & Meltzoff, 1978). This concerns the reidentification of a particular person as the same one as seen before the break in perceptual contact. The other concerns the maintenance of social games. Infants may remember that they played a game with the adult in this same context and be reinstituting "the game," which is more social-communicative. We believe that both play a role in early imitation.

others, it was a tongue protrusion, and so on. When they saw the person the next day with a neutral facial expression, we believe infants recognized the person as potentially the same as the previous encounter and used nonverbal behavior as a way of verifying this connection. In other words, infants were motivated to imitate yesterday's act, in part, because seeing today's adult posed an identity question.

This way of thinking about the motivation and function of early imitation is also compatible with the previous reports that having a person stay in sight and continuously repeat a gesture is not a very effective elicitor of imitation. As long as the adult continuously and repetitively shows tongue protrusion, no identity problem arises—and neither does much imitation. It also helps explain why having adults switch from one type of gesture to another can dampen imitation effects (Meltzoff & Moore, 1992). In such a case, infants would have competing hypotheses about the person's game. In this study, the adult's actions were consistent and distinctive: This adult always played one specific facial game in this context. The social identity question that was prompted by the reintroduction of the experimenter's face after the delay motivated imitation of only one act, hence the strong effects.

The broader idea being suggested here is that the actions of young infants are only partly governed by the stimulus that is present in perception. Infants act to bring their perceptual and representational worlds into register, to "give meaning to" what they perceive. This is one of the chief motivations and psychological functions of the early imitation of people.

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