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CHAPTER

23 Imitation: Social, Cognitive, and Theoretical Perspectives

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Abstract

Human beings are the most imitative creatures in the animal kingdom. Imitation has both cognitive and social aspects and is a powerful mechanism for learning about and from people. Imitation raises theoretical questions about perception–action coupling, memory, representation, social cognition, and social affinities toward others "like me." Childhood imitation is attracting attention both within and outside of developmental psychology. Modern studies of imitative development are bringing to bear the techniques of cognitive neuroscience, machine learning, education, and cognitive-developmental science. By using neuroscience tools and cognitive modeling, scientists are uncovering the mechanisms that underlie imitation. Evolutionary biologists are using imitation to investigate social learning in other species and to compare this to the abilities of human infants. Engineers are designing robots that can learn like babies—imitating the skilled actions of experts in an unsupervised manner. Educational psychologists are increasingly attending to how children learn through observation, role-modeling, and apprenticeship in informal settings and using this to revise pedagogical practices in formal educational settings. This chapter provides an analysis of the development of children's imitative ability, the mechanisms that underlie it, and the functions it serves in social, cognitive, and cultural learning from infancy to early childhood.

Key Words: imitation; cognitive development; social cognition; social learning; goals; intentions; theory of mind; culture; neural mirroring mechanisms, robotics, autism

Key Points

1. Imitation is foundational in four key areas of child development: cultural propagation, causal learning, social-emotional interaction, and developing a theory of mind.
2. Imitation arises early in ontogeny and can be exploited as a key mechanism for social learning prior to language.
3. The active intermodal mapping (AIM) hypothesis proposes that neonatal facial imitation involves the ability to process one's own acts and the acts of others in a common, cross-modal framework. Self and other are represented in commensurate terms starting from birth.
4. Discoveries about deferred imitation contribute to our understanding of infants' recall memory. It is of theoretical interest to analyze the relationship between deferred imitation and object permanence search behavior, because both entail representing (and acting on) information that is currently absent from the perceptual field.
5. In addition to imitating adults, children imitate peers and behaviors they see on television and other media.

6. New investigations have expanded the scope of imitation by showing that children learn about cause-and-effect and abstract rules from watching others' behaviors.

7. Infants regulate their imitation. Children's imitation is not fixed, rote, and automatic, but rather interpretive and goal-directed. Children vary who, what, and when they imitate depending on their own understanding and prior experiences as well as the emotional reactions of others.

8. The behavioral reenactment procedure shows that infants can infer unfulfilled goals from intentional, human action. In some cases, infants imitate what an adult meant to do, not what the adult actually did do as surface behavior.

9. Infant imitation promotes an understanding of others as "like me." This recognition of shared similarity is a building block for the development of a mature folk psychology, including an understanding of "mentalizing" or "theory of mind."

10. Imitation research is at the center of a new science of learning that combines developmental psychology, social psychology, neuroscience, robotics, animal behavior, and education to understand and apply humans' remarkable abilities for social learning.

Imagine yourself at a dinner party seated next to the college president. Dinner is served, and you find yourself confronting a formal place setting with three forks, two knives, and multiple spoons. What to do? Chances are that you will sneak a peek at what the presidential host is doing. Children also watch and imitate the behaviors of others in their culture. One of the favorite playthings of infants is a toy telephone. They hold it to their ear and talk into it. There is no innate tendency to treat hunks of plastic in this way: age-matched peers in a culture without telephones might bang it or chew on it, but would not put it to their ear and talk to absent people. Nor is this behavior the product of operant conditioning: parents do not shape their children to act in this way and often discourage infants from playing with the real mobile telephone. Other examples include children's desire to play with mom's forbidden lipstick and to peck on her (even more forbidden) computer keyboard. These are not accidental behaviors. Nor are they the product of individual discovery and invention on the child's part. They illustrate the power of imitative learning in the human child and its role in everyday cultural life.

Four Functions of Imitation

Imitation serves four essential functions in child development.

Cultural Propagation

The evolutionary biologist Sir Peter Medawar (1960) described two types of evolution that operate in human beings—Darwinian evolution which he termed "endosomatic," and cultural evolution which he called "exosomatic." Endosomatic evolution occurs in all species; the mechanism of transmission is DNA. In contrast, exosomatic evolution is not common across species, and is most sophisticated in *Homo sapiens*. A key mechanism in endosomatic evolution is imitation. Imitative learning fulfills the Lamarkian role of transmitting acquired behaviors from one generation to the next. Without it, the knowledge of how to manufacture stone tools or build a fire would have been lost after each generation, endlessly contingent upon independent rediscovery. Imitation contributes to cultural differences in human beings. The children in one culture shake hands to greet others, and those in a different culture bow; some use chopsticks to eat, and others use spoons and forks. Part of the observed cultural diversity among *Homo sapiens* derives from formal schooling and reward/punishment regimes; but far more is learned without explicit pedagogy as "background knowledge" through imitation.

Instrumental and Causal Learning from Observing Social Agents

Imitation multiplies learning opportunities and accelerates learning. Children do not have to wait to learn by doing. Children can use observational experiences to create first-person knowledge. This is useful for learning about fundamental aspects of the physical world such as cause-effect relations. Instead of having to work the causal relations of how x causes y, children can learn from watching experts. Popper famously said that the value of scientific theories is that "they can die in our stead" (Popper & Eccles, 1977, p. 138). This too is the value of observational learning and imitation. The behavioral explorations of others serve as a proxy for our own. Other people act and fail; others can struggle to figure out a solution to a problem through trial and error or through insight. We learn from watching both their successes and failures. Their behavior can die instead of our own.

Social-Emotional Communication and Affinity

Imitative interactions serve a social-communicative and emotional role in human development.

Imitation is interpreted as an aspect of communication and affinity by human observers. In one social psychological experiment, waitresses were randomly assigned to either act normally or to produce specific imitations of their customers. Tips were significantly higher from the tables at which the waitresses imitated, all other things being controlled, although the tippers were unaware of the experimental manipulation (van Baaren, Holland, Steenaert, & van Knippenberg, 2003). Scientific research on psychotherapy has shown that postural congruence and motor imitation occurs at a significantly higher rate in successful therapist–patient interactions (Ogden, 1982; Racker, 1968). Finally, in a controlled laboratory study using infants, Meltzoff (2007a) found that 14-month-old infants smile more at adults who were randomly assigned to imitate their particular actions (an emotional tip?) versus adults who performed mismatching acts. Imitative responding is perceptually and emotionally salient to human observers. It is a sign of "communing" or "being with" someone else and forges a feeling of affinity between observer and imitator.

Theory of Mind

Imitation is an early building block in the development of "theory of mind" (ToM) or "mentalizing"—the realization that others have beliefs, desires, emotions, and intentions similar to oneself. This is not settled ground, of course. Some theorists argue that ToM in humans is a module that matures or is triggered rather than sculpted from experience (e.g., Fodor, 1987). But others have suggested that imitation is causally related to ToM as an ontogenetic precursor (e.g., Meltzoff & Gopnik, 1993; Meltzoff, Gopnik, & Repacholi, 1999). Meltzoff (2007b, in press) argues that children realize the equivalence between themselves and others at the level of motor behavior and that this provides crucial experience that promotes understanding that adults are "like me" in other deeper ways as well—in terms of the mental states that underlie the similar behavior.

Historical Perspectives

The imitative prowess of human children sets them apart from other animals, including our closest living evolutionary relative, the chimpanzee (e.g., Tomasello & Call, 1997; Whiten, 2002, 2005). Although chimpanzees imitate a few select behaviors under constrained conditions (usually in order to obtain food), the human child imitates a range of behaviors often without extrinsic reinforcement, including vocalizations, manual and facial actions, novel actions on objects, tool use, and cause-and-effect relations learned from watching others. The laboratory work of modern developmental science supports Aristotle's observation that

> Imitation is natural to man from childhood. One of his advantages over the lower animals being this, that he is the most imitative creature in the world, and learns at first by imitation. (Aristotle, 1941, p. 448b)

Most developmental psychologists would agree with two of Aristotle's points—that humans are the most imitative creatures in the world and that this accords humans several advantages. Four essential "advantages" were discussed in the foregoing section. What about Aristotle's third point, that imitation is "natural" to man? If we take this to mean that young infants are highly proficient imitators, or more literally that there is an innate capacity to imitate, classical developmental theory was at odds with Aristotle. According to most classical views of childhood imitation (e.g., Bandura, 1986; Gewirtz, 1969; Piaget, 1962; Uzgiris & Hunt, 1975), young infants are not particularly good imitators. This view has been revised, but before turning to the modern findings it is worth reviewing the classical claims.

Piaget's Stages of Imitative Development

Piaget's (1962) developmental theory has been the most widely accepted and influential view of imitation development. Piaget's theory was influenced by an earlier philosopher-psychologist, James Mark Baldwin (1906), who wrote abstractly about the role of imitation in children's social and intellectual development. Piaget built on this foundation and added theoretical and empirical work on children's imitative behavior, the latter taking the form of detailed observational records of his own children as he posed clinical experiments to them. The central idea in the Piagetian framework is that there are cognitive constraints delimiting infant imitation. Infants progress through different stages of imitation.

Piaget's theory postulates six stages of imitative development between 0 and 24 months of age. For ease of summary, we have grouped these stages into three broader levels. In Level 1 (0 to 12 months, encompassing stages 1 through 3), infants are thought to be restricted to imitating simple vocal and manual maneuvers. Piaget reports numerous instances of vocal and manual imitation (hand opening or finger movements) during the first year. The key, according to Piaget, is that for these kinds of imitation infants can perceive both the model's and their own responses through the same perceptual modality. For example, infants can see both an adult's hand movements and their own. By comparing the sight of their own motor productions to that of the model, infants can alter their motor performance to converge to the adult's. A similar matching process can underlie vocal imitation. Again an intramodal process, albeit in this case auditorally guided, underlies the imitation of sounds (for experiments on the development of vocal imitation, see Kuhl & Meltzoff, 1996).

In Level 2 (12 to 18 months, encompassing stages 4 and 5), infants go beyond within-modality comparisons. The landmark development in Level 2 is the onset of imitation of facial gestures, such as tongue protrusion. Although an infant can see the adult's face, she cannot see her own face—visual–visual matching is ruled out. Piaget calls this "invisible imitation," also referred to as "opaque imitation." He predicted that infants under about 1 year of age could not perform invisible imitation. (Piaget's theory is concerned only with spontaneous, untrained responses. The theory does not deny that young infants could be trained to imitate earlier, for example through a regime of operant conditioning or associative learning. Piaget was interested in imitation that went beyond those learning procedures.) Interestingly, Piaget saw a deep kinship between invisible imitation and the onset of infants' search for invisible objects. The infant in both cases needed to use a cue from the *visible* world as in "index" pointing to something invisible. Piaget reported a close synchrony at 8 to 12 months of age (sensorimotor stage 4) in the onset of facial imitation and the onset of search behavior in object permanence tasks. He offered an explanation for this cross-domain synchrony (Piaget, 1952, 1954, 1962; see Meltzoff & Moore, 1998, for analysis in light of modern research on object permanence and imitation).

In Level 3 (18 to 24 months, encompassing stage 6), infants first become capable of "deferred imitation"—that is, imitation after the target has disappeared from view. Piaget's observations revealed no trace of deferred imitation until about 1.5 years of age, although younger infants could duplicate acts immediately or with a short delay. Again, general cognitive constraints were thought to restrict such imitative performance at younger ages. Piagetian theory held that deferred imitation emerged in synchrony with other complex cognitive abilities including (a) symbolic play, (b) the use of insight in means–ends problem solving, and (c) high-level object permanence ("invisible displacements," such as moving an object under a cup from one location to another). Piaget called this tight cross-domain coupling a psychological "*structure d'ensemble*." The *structure d'ensemble* constitutes what Piaget termed stage 6, the last purely sensorimotor stage of infancy, which prepares the infant for symbolic thought and the emergence of language.

Piaget disagrees with Aristotle. Imitation is not "natural" to man. Although infants may have the Aristotelian motivation to imitate, they lack the technique or capacity for imitating certain classes of acts. Infants' capacity for imitation fundamentally transforms as they develop, which is part and parcel of domain-general cognitive growth. The theory postulates a progression in imitation from behaviors that can be directly compared within the same perceptual modality (vocal and manual imitation), to behaviors that cannot (facial imitation), to imitation that cannot be directly compared or guided through perception because the model was perceptually absent altogether (deferred imitation).

One virtue of Piaget's stage model is that it makes strong predictions. Stage 1 infants do not have the cognitive wherewithal to imitate Stage 4 behaviors. Piaget was prepared to stand behind clear predictions:

> [Before 8 to 12 months in stage 4] the intellectual mechanism of the child will not allow him to imitate movements he sees made by others when the corresponding movements of his own body are known to him only tactually or kinesthetically, and not visually (as, for instance, putting out his tongue). To be able to make the connection between his own body and those of others, the child would require mobile indices, which are not yet at his disposal. Thus since the child cannot see his own face, there will be no imitation of movements of the face at this stage, provided that training, and therefore pseudo-imitation, is avoided. (Piaget, 1962, p. 19)

Piaget made similar strong predictions about deferred imitation first appearing at 18 months of age, and not earlier, and its close coupling to language, symbolic play, and the understanding of invisible displacements in object permanence.

Foundations: Neonatal Facial Imitation

Piaget's theory of cognitive development, including his theory of imitation, dominated developmental science for 50 years, from the 1920s to the 1970s when an explosion of research on imitation was designed to test his predictions.

The first piece of evidence against Piaget's stage-developmental theory of imitation came from experiments with neonates. Meltzoff and Moore (1977) reported that 12- to 21-day-old neonates, far before Stage 4, were able to imitate facial gestures. In the experiment, an adult poked out his tongue, opened his mouth, pursed his lips, and performed a distinctive finger movement. Contrary to Piagetian theory, infants imitated each of the four gestures. Replications of these findings of neonatal imitation have been reported in more than 24 studies from more than 12 independent laboratories from several cultures (see Meltzoff & Moore, 1997, for review).

One response to these surprising findings was that the infants might have learned how to imitate in the first 2 weeks of life, and therefore we were observing the results of training—either through operant conditioning or associative learning. To test this interpretation, Meltzoff and Moore conducted two studies using newborns. The mean age of the participants in these studies was 36 hours old; the youngest was only 42 minutes old. In one study successful mouth-opening and tongue-protrusion imitation was documented (Meltzoff & Moore, 1983); in the other, infant imitation of a new non-oral gesture, head movements, was found (Meltzoff & Moore, 1989). The neuroscientific and evolutionary roots of facial matching is currently being explored, and reports are emerging of imitation in neonates from other primate species (Bard, 2007; Ferrari et al., 2006, 2012; Myowa, 1996), although fewer experimental control conditions have been run than in the human case.

Crucial controls were included in the human neonatal imitation work to rule out lower-level explanations for the matching behaviors. One concern initially raised by Meltzoff and Moore (1977) is that infants might simply be more aroused when they see an adult act, and therefore increase their general movement activity, including their facial movements, at the sight of a moving face. However, studies have shown that the specificity of the responses rules out this explanation (see Meltzoff & Moore, 1997 for a review). Infants respond differentially when the same face, at the same distance from the infant, and moving at the same rate, makes two closely matched gestures (e.g., tongue protrusion vs. lip protrusion). An arousal interpretation cannot account for such specificity. Moreover, young infants differently imitate a tongue that is protruded straight from the center of the mouth versus one that is protruded off-center from the corner of the mouth (Meltzoff & Moore, 1994, 1997). This specificity and fidelity cannot be accounted for by a simple arousal interpretation (and it also strains an associative learning or conditioning viewpoint).

A fundamental question concerns the neural and psychological processes linking the observation and execution of matching acts. Before addressing this issue, it is relevant to review three relevant discoveries about the nature of facial imitation in humans, one showing temporal flexibility, a second revealing that infants correct their imitative responses, and a third showing imitation of a range of acts, suggesting a generative mechanism.

Temporal Flexibility

Neonates are not limited simply to resonating with the adult's gestures, like little tuning forks. A particular experimental manipulation was designed to test this idea. In Meltzoff and Moore's (1977) study 2, neonates had a pacifier in their mouths while observing an adult produce the facial expression. The adult stopped gesturing, assumed a passive face, and only then removed the pacifier. The infants had to wait until the pacifier was removed—while they were viewing the passive face—to initiate the movements. Even under these conditions, infants succeeded in imitating. In a subsequent study, an adult showed 6-week-old infants a gesture, and then the infants were sent home for a 24-hour memory delay. The next day the infants were presented with the same adult sitting with a neutral facial expression (Meltzoff & Moore, 1994). If the adult had shown mouth opening the day before, the infants initiated that gesture from memory; if the adult had shown tongue protrusion, infants responded by poking out their tongues. Infants' imitative response can be initiated after a delay. Any comprehensive theory of infant imitation will need to take these data into account.

Correction of the Response

The imitative response does not emerge fully formed. Rather, infants converge on the match over successive efforts arriving at closer and closer matches to the modeled gesture. The morphology of the imitative response is informative for theory. The 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 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 crucial point is that the tongue, rather than the lips or fingers, is moved before the high-fidelity matching action is isolated (Meltzoff & Moore, 1997). Young infants identify *what* part of their body to move before choosing *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 with humans is emerging in neuroscience (Buccino et al., 2001). These new neuroscience findings are compatible with our findings of the accurate activation of a body part by neonates. The neural representation of specific body parts could serve as a foundation for imitation in infants.

Range of Gestures

Another clue to the mechanism underlying imitation comes from the range of gestures that infants imitate. Published studies document imitation of a variety of acts, including mouth opening, tongue protrusion, lip pursing, head movements, hand movements, and emotional expressions. The range of gestures imitated weighs against an earlier hypothesis that "only tongue protrusion" is matched (Anisfeld, 1996). This claim confuses "tongue protrusion is most popularly tested" with "tongue protrusion is the only gesture imitated." Tongue protrusion is undoubtedly the most popular gesture tested, but this is because it is such a visible and dramatic response, which makes it easy for investigators to score. However, the imitation of other gestures has also been replicated across many laboratories (see Meltzoff, 2002, pp. 11–12, for a review), so there is no evidence of "tongue only" imitation—indeed infants differentially imitate two types of tongue protrusions (Meltzoff & Moore, 1994), which shows both the range and fidelity of the matching response.

Mechanism Underlying Imitation: The AIM Hypothesis

If Piagetian theory cannot account for early imitation, and if it is not due to early conditioning, associative learning, or general arousal, what mechanism underlies this behavior? Meltzoff and Moore (1977, 1997) proposed that imitation is based on active intermodal mapping (AIM). Figure 23.1 provides a conceptual schematic of the AIM hypothesis. The fundamental idea is that infant imitation is rooted in infants' capacity to register equivalences between the body transformations they see performed and

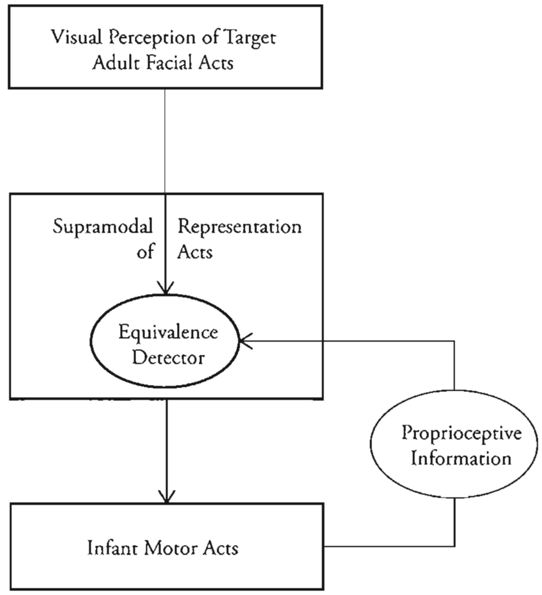

Figure 23.1. A schematic of the active intermodal mapping hypothesis (AIM). (Reprinted with permission from Meltzoff & Moore, 1997.)

the body transformations they only feel themselves make. On this account, facial imitation involves cross-modal matching. Infants can, at some primitive level, recognize an equivalence between action perception and action production. There appears to be a primitive and foundational "body scheme" that allows the infant to unify the seen acts of others and their own felt acts into one common framework. The infant's own facial gestures are invisible to them, but they are not unperceived. The acts of the self are monitored by proprioception. In 1977 Meltzoff and Moore postulated that human infants link observation and execution through a common "supramodal" coding of human acts. This supramodal code allows infants to correct their imitative movements, and it is also why they can imitate from memory. Infants store a representation of the adult's act, and it is the target against which they compare their own acts. Imitation is a goal-directed activity.

Prenatal Experience: The Role of "Body Babbling"

Meltzoff and Moore (1997) also hypothesized that infants' own prior motor experience may play a role in early postnatal facial imitation. Films of fetal behavior reveal that they make repeated lip, tongue, and hand movements *in utero* (de Vries, Visser, & Prechtl, 1985; Hooker, 1952; Humphrey, 1971; Patrick, Campbell, Carmichael, Natale, & Richardson, 1982; Zoia, Blason, D'Ottavio, Bulgheroni, Pezzetta, Scabar, & Castiello, 2007), and this self-generated activity continues after birth. Meltzoff and Moore (1997) proposed the concept of "body babbling" and analyzed the role it has in postnatal imitation.

Body babbling, even prenatally, provides infants with dynamic experience with how their own body moves. The range of experienced movements sets up an "act space" of possible actions of the body. This would be an analogy to how vocal babbling and cooing is used to construct an auditory-articulatory map in speech development (e.g., Kuhl & Meltzoff, 1996). Experience with body babbling allows infants to assimilate seen movements to their own act space. Tongues move in certain ways, and these ways are very different from the action patterns of hinged joints such as in fingers and elbows. Based on self-experience with the felt movements of one's own body, the kinetic signatures of tongue protrusion/withdrawal (or mouth opening/closing, or finger flexing) could be recognized as cross-modally equivalent to those produced by oneself.[1] A more detailed analysis of the cross-modal mapping mechanism involved in imitation is provided elsewhere (Meltzoff & Moore, 1997).

Deferred Imitation and Infant Recall Memory

Piagetian theory also underestimated infants' deferred imitation—that is, the reproduction of behaviors that are no longer perceptually present. For Piaget, the infant prior to 18 months is a sensorimotor creature who lacks the capacity for deferred imitation. Piaget put great stock in the synchronous emergence of deferred imitation, symbolic play, language, and high-level object permanence. He argued that this *structure d'ensemble* was a significant cognitive milestone that occurred as the child transitioned out of the purely sensorimotor period into one that involved representation prior to (and sometimes independent of) action.

Memory for Object-Directed Acts

Naturalistic observations led many researchers to concur with Piaget that deferred imitation first emerged at about 1.5 years of age (e.g., Uzgiris & Hunt, 1975). However, inspired by the finding that neonates could perform facial imitation ahead of the Piagetian schedule, researchers conducted controlled laboratory experiments to examine the emergence of this behavior.

The first demonstration of deferred imitation before 18 months of age was reported in a series of studies by Meltzoff (1985, 1988b, 1988c), which tested 9- and 14-month-olds using delays ranging from 1 day to 1 week. The results showed deferred imitation even in 9-month-olds. Crucially, Meltzoff used a stringent, "observation-only" design. In this design infants are confined purely to watching the adult's display. They are not allowed to interact with the objects, or to imitate the action before the delay is imposed. Thus their memory cannot be for a habit or well-practiced motor procedure. Moreover, no verbal narrative describing the actions is provided to the child.

In one experiment, 14-month-old infants saw an adult perform six acts, each on a different object. The behaviors that the adult used were distinctive. One of the acts, for example, was bending at the waist and touching a light panel with the head, causing the light to turn on. The children were not allowed to touch the objects during this session. Instead, the adult simply showed each of the six novel actions in sequence as the child sat quietly and observed. After this observation the infants were sent home for a 1-week memory delay. In Piagetian terms one might say that the infants had been blocked from building up any purely sensorimotor scheme with the objects. If they had been allowed to perform immediate imitation, then when they returned after the delay they could be remembering their own past actions (a kind of sensorimotor memory). The "observation-only" procedure rules out this possibility.

Control groups were used to zero in on imitation rather than other mechanisms. Control group 1 was a baseline group. For this group, the adult simply played a warm-up game with the infants and did not expose them to the adult modeling of the first session. These infants were then sent home for the 1-week delay. Meltzoff (1988b) argued that a rigorous test of imitation requires more than a simple baseline control. Infants in the imitation condition see the experimenter manipulate the test objects; they also see that the objects have properties and affordances—that they light up when touched, and so forth. It is possible that seeing the adult handle the test objects and/or that simple exposure to the special properties of the objects motivates infants to manipulate the objects when they are subsequently presented. Such manipulation might attract infants to the object (stimulus enhancement) which in turn could increase the probability that the infants produce the target actions by chance, not through imitation.

Therefore, the Meltzoff (1988b) study of deferred imitation incorporated a control group 2, called the "adult-manipulation" control. The infants were exposed to a series of six stimulus-presentation periods. For each presentation the experimenter reached out and manipulated the test object for the same length of time as he had in the experimental condition. Each control display mimicked distinctive results of the experimental display. For example, for the light panel, the experimenter touched his hands to the sides of the box and illuminated the panel (via a foot switch), so that the identical effect or outcome was achieved as when the experimenter touched it with his forehead.

Thus, the baseline and adult-manipulation conditions provide complementary controls. The baseline condition assesses the chance probability that subjects will produce the target behavior on their own without previously having been exposed to the toys or actions modeled. The adult-manipulation control assesses the degree to which infants are induced to perform the actions for nonimitative reasons—that is, merely because interest was increased as a result of seeing the adult touch the test stimuli and/or because they witnessed the interesting properties and affordances of the test objects, or the outcomes/effects produced (often referred to as stimulus enhancement and goal emulation, respectively).

The Meltzoff (1988b) study incorporated these controls. Infants were randomly assigned to each of three conditions (baseline, adult-manipulation, and target demonstration). A 1-week delay was interposed between the first and second sessions. Infants in all three conditions were treated identically on the second visit: The test objects were placed on the table one by one, and the infants' behavior with them was video recorded (for subsequent blind scoring) for a fixed-duration response period.

The results established deferred imitation after a 1-week delay under controlled laboratory conditions. Infants in the imitation group produced significantly more target behaviors than did infants in either of the controls, which did not differ from one another. Moreover, there was strong evidence for deferred imitation of the novel act of head-touch. Fully 67% of the infants produced this act in the group who had seen the demonstration, in contrast to none of the infants producing it in either of the control groups. Follow-up studies established that infants of this age are able to defer their imitation over a 4-month period (Meltzoff, 1995b). Other work demonstrated that statistical models combining deferred imitation and measures of visual-recognition memory and turn-taking can significantly predict language development in infant longitudinal studies (Heiman et al. 2006).

Infants are not restricted to copying single acts on objects. They can also imitate sequences of behaviors over delays (e.g., Barr, Dowden, & Hayne, 1996; Bauer & Shore, 1987; Esseily, Nadel, & Fagard, 2010; Elsner, Hauf, & Aschersleben, 2007; Hayne, Boniface, & Barr, 2000; Mandler & McDonough, 1995). Bauer and colleagues have measured infants' imitation of sequences of behaviors using an elicited imitation procedure (Bauer, Wenner, Dropik, Wewerka, & Howe, 2000). The elicited imitation procedure differs critically from Meltzoff's observation-only design. Infants typically have an initial opportunity to interact with the materials before the delay, and in many cases the infant is allowed to perform immediate imitation before the delay. Moreover, in the elicited imitation procedure a verbal narrative is typically used during encoding ("Here is what I do with this. I am shaking this.") and then a verbal prompt is used in the response period ("Do you remember what to do with this?").

Using this elicited imitation procedure, Bauer and others have traced infants' capacity to imitate a sequence of acts. Some of the sequences are enabling—the steps need to be performed in a certain sequence to complete an outcome. An example of an enabling sequence is to place a ball into a cup, seal the cup, and shake it to create a rattling sound. Other sequences are arbitrary (e.g., placing different animals into a toy truck)—the steps can be performed in any order. By 13 months of age, infants can recall a sequence of behaviors in the correct temporal order over a delay of a month (Bauer et al., 2000), and imitation is found to be enhanced when the series of acts is enabling versus arbitrary (e.g., Barr & Hayne, 1996; Bauer, Hertsgaard, & Wewerka, 1995; Bauer & Mandler, 1989). Reminders and additional exposures to a demonstration improve imitation of a sequence of acts after a delay (Bauer, Wiebe, Waters, & Bangston, 2001; Hayne, Barr, & Herbert, 2003; Hayne & Herbert, 2004). Providing a verbal description of a series of acts (Hayne & Herbert, 2004) or using a shorter sequence (Kressley-Mba, Lurg, & Knopf, 2005) has also been shown to improve infants' abilities to imitate it.

Scientists have begun to link infants' deferred imitation with neural correlates of long-term memory. Studies combining event-related potential (ERP) techniques and infant imitation reveal correlations between brain activity and imitation after a delay (Carver, Bauer, & Nelson, 2000; Heimann, Nordqvist, Johansson, & Lindgren, 2010). Researchers have also identified neural measures of encoding that predict whether individual infants will successfully imitate after a month-long delay (Bauer, Wiebe, Carver, Waters, & Nelson, 2003; Bauer et al., 2006). This combination of behavioral and neuroscience measures of imitation provides useful information about the development of infants' long-term memory and its neural correlates.

Generalization Across Object Properties and Context Change

Other studies assess infants' ability to generalize and imitate across changes in context. In a study with 14-month-olds, Barnat, Klein, and Meltzoff (1996) manipulated salient object properties between the demonstration and recall periods. After observing the adult's demonstration with one set of objects, infants were presented with objects that had different features. During the test period, they were given objects of different sizes and colors than those that were used in the adult's demonstration, but ones that were the same shape. Despite these changes, infants generalized and used the novel objects to reenact the behavior they had seen the adult do with the old objects.

One study established that 18-month-olds generalize and imitate after changes in color and shape over longer delays than 12-month-olds (Hayne, MacDonald, & Barr, 1997). Changes in the shape of an object, in particular, seem to disrupt 12-month-olds' abilities to generalize and imitate (Jones & Herbert, 2008); however, certain cues can help (Herbert, 2011; Jones & Herbert, 2008). For example, narrating the actions produced on an object during the demonstration phase and giving a shared linguistic label to the objects used during demonstration and test (e.g., "It's a puppet") improve 12-month-olds' imitation of acts across objects of different shapes (Herbert, 2011).

Another line of studies involved manipulating environmental context by changing the physical location in which the children observed and then reproduced the adult's behaviors. The lab room in which the adult demonstrated the target acts was covered to create a large, orange polka-dot tent. After a delay, the children were subsequently tested in an ordinary room, creating a different context in which to perform the behaviors (Barnat, et al., 1996; Klein & Meltzoff, 1999). Infants as young as 12 to 14 months old were able to perform deferred imitation over these dramatic changes in context (Fig. 23.2A). Klein and Meltzoff (1999) systematically tested how context change and memory interact by evaluating imitation in 12-month-olds

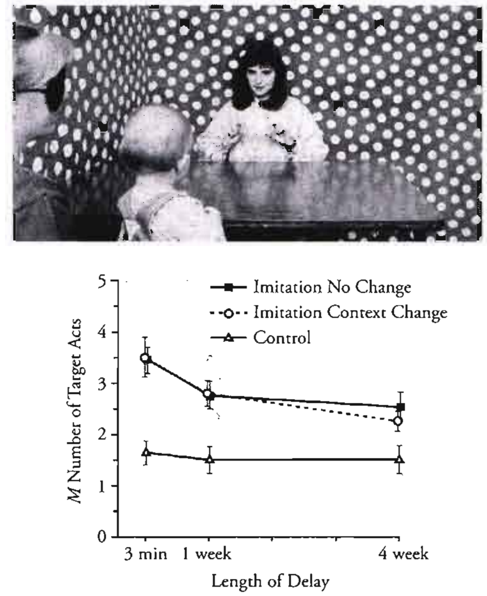

Figure 23.2. Deferred imitation across context change. **A.** The polka-dot tent used to assess imitative generalization across context change. **B.** Infants remembered and imitated even after the 4-week delay. (Reprinted with permission from Klein & Meltzoff, 1999.)

for delays ranging from immediate to 4 weeks. The results document robust deferred imitation and provide a systematic forgetting function, showing that deferred imitation is an excellent tool for investigating the properties of infant recall memory. Other work suggests that context change is particularly disruptive for deferred imitation in children under 12 months of age (Hayne et al., 2000). The theoretical and empirical connections between deferred imitation (reproducing absent acts) and object permanence (searching for absent objects) has been addressed, including how generalization across context and object properties differentially influences these constructs (Meltzoff & Moore, 1998; Moore & Meltzoff, 2004).

Infant Memory Theory

Three standard methods used to assess infant memory in humans are (a) novelty preference after delays (e.g., Fagan, 1990), (b) conditioning (mobile conjugate reinforcement) (e.g., Rovee-Collier & Hayne, 1987), and (c) deferred imitation (e.g., Meltzoff, 1988b, 1988c). All three techniques are useful, but deferred imitation using the observation-only design provides a window into infant memory that is particularly decisive for developmental theory, especially for understanding the nature of infant representational capacities and how these exceed classical Piagetian theory.

Novelty preference procedures test whether infants perceive a pattern as different from one to which they have been previously exposed. In deferred imitation, the infant must do more than visually recognize a target as being familiar or novel; he or she must generate a motor act on the basis of memory. Imitating an act from memory entails recall memory, not simply recognition memory.

Both mobile conjugate reinforcement procedures and deferred imitation involve motor production. However, deferred imitation differs from the conditioning procedure in two ways. First, the target behavior is not shaped, learned, or practiced over a series of trials but rather is picked up by observation after a brief one-time display. Second, there is no reinforcement for pairing the visual stimulus with the response, because the infant is not allowed to generate the response during the memory encoding session. Although the memory demonstrated by conditioning procedures has been characterized by some theorists as habit learning or procedural memory (Howe & Courage, 1993; and for a rebuttal see Rovee-Collier, Hayne, & Colombo, 2001; Rovee-Collier & Cuevas, 2009), deferred imitation cannot be reduced to habit learning. There is no habit established to begin with: no learning trials are allowed, no practice is given—infants only observe the adult on day 1.

Such deferred imitation raises the idea that infants are capable of nonverbal declarative memory, and this is exactly the type of nonsensorimotor memory that Piagetian theory denied to them. This idea is buttressed by a report that adult amnesiacs, who do not have an intact declarative memory system (Squire, 1987), fail on infant-like deferred imitation tasks even though they succeed on tasks involving procedural memory (McDonough, Mandler, McKee, & Squire, 1995). If saying that infants are capable of declarative memory seems too strong, one could be more conservative and say that they are capable of *non*procedural or *non*habit recall memory to underscore that they are capable of more than sensorimotor schemes or habits. The findings from deferred imitation using the observation-only design allow us to make these claims (see also Meltzoff & Moore, 1998).

Peer Imitation

The ecology of child rearing is changing in Western societies. With the increase of women in the workforce, young children are spending increasingly more time with peers in daycare settings. Do young children learn from and imitate their peers in daycare centers and other sites? In all of the previous experiments discussed in this chapter, adults were used as models. Several observational studies report peer imitation. Nadel-Brulfert and Baudonniere (1982), for example, found that groups of 2-year-olds often tended to play with the same types of objects. Subsequent work with 2- and 3-year-olds observed that the children not only chose the same object, but also imitated the way the object was used (Nadel, 2002).

Experimental studies using controlled procedures and random assignment established that even younger infants will imitate novel behaviors after observing a peer's example. Hanna and Meltzoff (1993) trained an "expert infant" to manipulate five toys in distinctive, novel ways. Fourteen-month-old "naïve infants" were then brought into the laboratory to observe as the peer demonstrated how to act with the objects. After watching the tutor, the observer infants left the test room for a 5-minute memory delay. They then returned and were presented with the test objects in the absence of the peer (Fig. 23.3). The results showed imitation.

A second study adapted this procedure for use in a daycare setting (Hanna & Meltzoff, 1993). The expert peer was put into a car seat and driven to a variety of daycare sites. As the naïve infants sat around a table or on the floor sucking their thumbs, the expert infant picked up and acted on novel toys in particular ways. The naïve infants were not allowed to approach or touch the toys, following Meltzoff's observation-only procedure. After a 2-day delay, a new experimenter (not the one who had accompanied the expert infant) brought a bag of objects to the infants' homes and laid them out on a convenient table and videotaped the responses. Neither the parent nor this new experimenter had been present in the daycare center 2 days earlier. The only person who knew what actions had been demonstrated was the student infant. The results showed significant imitation. The implication is that imitation may play a role beyond the laboratory. Evidently even prelinguistic infants are influenced by their peer groups at school. In some circumstances, young children prefer imitating the actions of a peer versus an adult (Marshall, Bouquet, Thomas, & Shipley, 2010; Zmyj, Aschersleben, Prinz, & Daum, 2012; Zmyj, Daum, Prinz, Nielsen, & Aschersleben, 2012).

Studies using techniques borrowed from the animal literature have simulated the role that peer-to-peer tutoring and imitation can play in the transmission of behaviors across generations of learners. A novel tool-use behavior was initially taught to a 3- or 5-year-old child, who then served

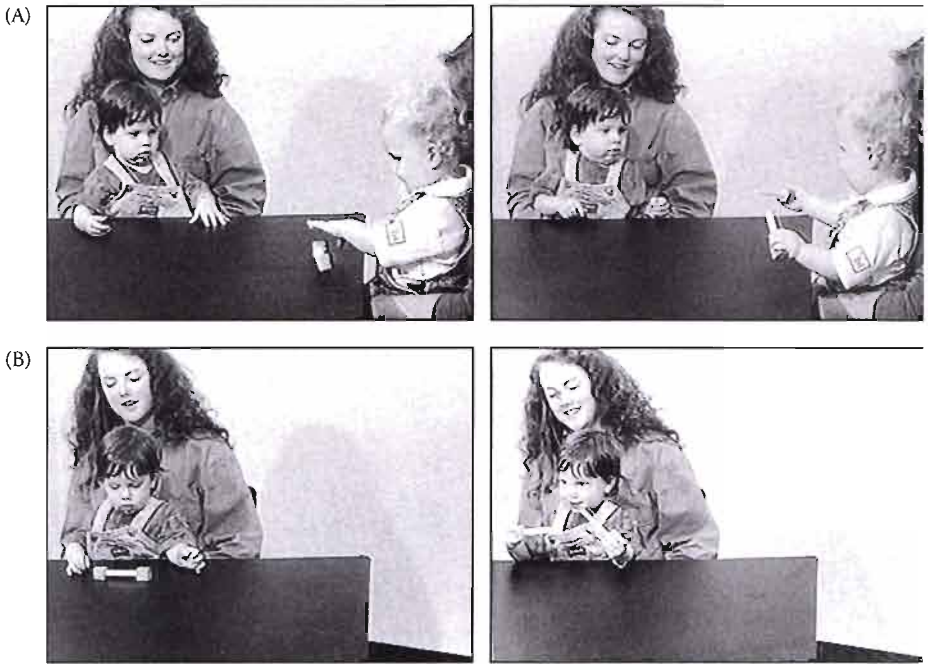

Figure 23.3. **A.** Peer imitation. An "expert peer" demonstrates how to pull apart a novel toy. **B.** After a delay, the observer infant imitates the expert's action from memory. Both infants are 14 months old.

as a tutor to a second child, and so on, through five children. Children who participated in such peer-to-peer learning chains showed consistency in how they manipulated the tools (Flynn & Whiten, 2008; Horner, Whiten, Flynn, & de Waal, 2006; McGuigan & Graham, 2010). Taken together with the earlier studies, we can conclude that imitation is a useful means for transmitting information from one young child to the next over delays outside of laboratory settings.

Imitation from Television and Media

In American homes, 99% have at least one TV set, and the average 2- to 5-year-old views more than 25 hours of television per week (Rideout & Hamel, 2006). The amount of time younger children, even infants (0 to 2 years old), spend in front of television is also significant. A survey of 1,009 parents revealed that by 3 months of age about 40% of children regularly watch television (broadcast TV, DVD, or videos) and that this number rose to 90% by 24 months of age (Zimmerman, Christakis, & Meltzoff, 2007). The average viewing time rose from about 7 hours a week for infants under 12 months to more than 10 hours a week by 24 months of age.

Reports from a naturalistic study of language development hint at the potential impact of TV on infant learning (Lemish & Rice, 1986). Researchers recorded how children used language in everyday interactions in the home. When a commercial came on the television, a 23-month-old suddenly began to croon, "Coke is it, Coke is it." Another repeated "Diet Pepsi, one less calorie." This suggests that infants may pick up the audio-track of TV, but it does not show that the visual images similarly influence their behavior. From an acoustic standpoint there is little difference between "real" and "TV" speech, but not so with the visual modality. Television pictures present a miniaturized, two-dimensional (2D) depiction of reality. Can infants relate the activities they see on a miniature, 2D screen to the real, 3D world? To answer this question it is not enough to know that infants are visually riveted by TV or stay oriented to the TV. They may be attracted to the visually changing mosaic of colors, but visual attention does not mean that they "understand" or can "decode" what they see.

Studies using imitation paradigms clarify this issue. One study tested imitation from TV in 120 infants at two ages, 14 and 24 months (Meltzoff, 1988a). In an immediate imitation condition, infants watched an adult's action on TV and were allowed to copy with little delay. In the deferred imitation condition, infants watched the action on TV but were not presented with the real toy until they returned to the lab after a 24-hour delay.

The results showed significant imitation at both ages in both the immediate and deferred conditions. Importantly, the real objects were not in the infant's perceptual field during the televised display, so infants did not have the opportunity of looking back and forth between the TV depiction and the real objects. No linguistic support was used to name the objects or the actions during the encoding or memory test. Nonetheless, the results showed that infants used their memory of the TV display to imitate successfully when they saw the 3D object for the first time after a 24-hour delay. Infants can understand the actions they see on TV and map them to the real 3D world.

Although infants can learn from televised displays, they show lower rates of imitation than when behaviors are presented by live models (e.g., Barr & Hayne, 1999; Barr, Muentener, & Garcia, 2007; Barr, Muentener, Garcia, Fujimoto, & Chávez, 2007; Hayne, Herbert, & Simcock, 2003; Klein, Hauf, & Aschersleben, 2006; McCall, Parke, & Kavanaugh, 1977). Scientists are currently investigating the basis for this so-called "video-deficit effect" (Anderson & Pempek, 2005).

One possible account is the perceptual difference between 2D and 3D objects. Perhaps infants have difficulty using the 2D depiction as a guide for what to do in the real world. This was explored in a study using 15-month-old infants and a novel touch-screen technology (Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009; Zack, Gerhardstein, Meltzoff, & Barr, in press) (Fig. 23.4). In one cross-dimension manipulation, the infants were first shown how to activate a toy via a TV presentation and then given the chance to reenact this on a 3D version. This is the standard type of test. In a novel cross-dimension manipulation, infants were shown how to activate a toy by pushing a button on a real (3D) object and subsequently were tested using a TV representation of the toy with a sensitive touch-screen button. All possible combinations of information transfer were tested (3D to 3D, 2D to 2D, 2D to 3D, and 3D to 2D). The infants exhibited significantly higher levels of imitation on the within-dimension tests (3D to 3D or 2D to 2D) than on the cross-dimension tests (2D to 3D or 3D to 2D). This suggests that one reason infants show poor performance on the standard TV imitation tasks is that they require infants to cross dimensions.

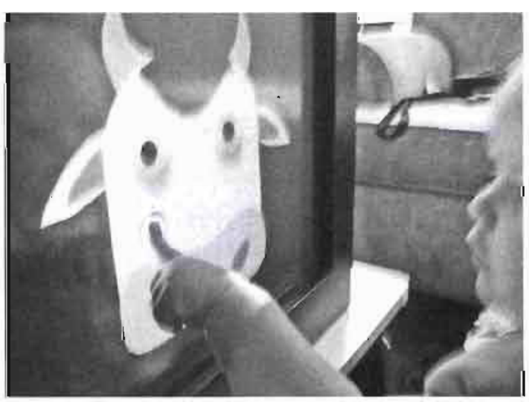

Figure 23.4. Imitation from television. Infant imitating the target action on the 2D touch-screen image. (Reprinted with permission from Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009.)

A second likely contributor to the video-deficit effect is the lack of social interaction involved in many studies using televised displays (this is not a necessary limitation of TV, which can be interactive). Nielsen, Simcock, and Jenkins, (2008) used a closed-circuit system to allow an adult viewed on television to act contingently with 24-month-olds. The toddlers in this study were more likely to imitate these interactive displays than a traditional noncontingent video model.

Regardless of the outcome of this ongoing work on the video-deficit effect (e.g., Barr, Wyss, & Somanader, 2009), it is clear that infant learning from TV and other electronic media will be a topic of growing importance as software programs are aimed at ever-younger children, including infants. It will also be interesting to compare infants' responses to TV with more traditional 2D media, such as picture books, which often support a rich joint engagement and social experience when presenting information to children (Brito, Barr, McIntyre, & Simcock, 2012; Simcock, Garrity, & Barr, 2011). The value added by research on imitation is that it is a way of exploring what the infant or child understands about 2D media presentations and how media affects children's subsequent behavior on real-world objects.

Causal Learning and Tool Use

In the developmental and animal psychology literatures, one of the most celebrated examples of causal learning is the case of tool use. We know a lot about chimpanzees' use of tools—starting from Köhler's (1927) observations of Sultan moving crates below an overhead banana to Jane Goodall's (1968) reports of termite fishing on the Gombe Stream Reserve. Although it was once argued that tool use was uniquely human, it is now acknowledged that other animals are successful tool users, including the "gold standard" of wielding a freestanding stick to obtain an out-of-reach target. Scientists interested in imitation examine the ability to learn about tool use through observations of others (instead of through trial and error or insight). There is a debate about how well nonhuman primates can learn to use novel tools from observation (for reviews of the controversy see, for example, Limongelli, Boysen, & Visalberghi, 1995; Povinelli, 2000; Tomasello & Call, 1997; Visalberghi & Limongelli, 1994; Whiten, 2002, 2005).

The literature concerning human infants is also not fully settled. Infants certainly learn to use sticks as tools when left to their own devices (Bates, Carlson-Luden, & Bretherton, 1980; Piaget, 1954), but much sparser evidence exists concerning learning tool use from observing others. Of course, adults and older children learn how to use tools by watching experts; the debate concerns the age at which such learning starts. Much of the extant work with infants involves simple tools for which the degrees of freedom are highly constrained, such as a toy on a support and other simplified arrangements (Goubet, Rochat, Marie-Leblond, & Poss, 2006; Meltzoff, 1995a; Nielsen, 2006; Provasi, Dubon, & Bloch, 2001; Sommerville, Hildebrand, & Crane, 2008).

Learning to Use Tools by Observing Others

There have been few well-controlled tests of infants' observational learning of how to use complex tools such as freestanding sticks and rakes to obtain distant objects. The use of a rake as a tool presents infants with formidable motor control problems, inasmuch as the tines of the rake must be oriented downward, and the pull must be executed in a particular manner to be successful. Infants must resist lunging directly for the distant goal-object and use an intermediary tool in the right manner to achieve the goal. Nagell, Olguin, and Tomasello (1993) performed a relevant experiment. They reported that 18-month-old children failed to learn how to use a rake from observation but that 24-month-olds could do so.

Meltzoff (2007b) tested younger infants. The sample consisted of 120 infants, 30 at each age of 16, 18, 20, and 22 months. Within each age group, infants were randomly assigned to one of three test conditions: (a) Imitation—the adult modeled the correct use of the stick to obtain the out-of-reach goal, (b) Control 1 (Baseline)—infants saw no modeling and were simply given the stick, and (c) Control 2 (Stimulus Enhancement)—infants saw the adult use the stick to touch the goal, thereby drawing attention to the stick and also to the fact that it could make spatial contact with the goal (correct use of the stick was not shown).

The stick was a long rakelike object. In the response period it was placed horizontally in front of the infant, with approximately a 2.5-foot spatial gap between it and the goal object. Preliminary studies had suggested that infants performed better when they observed the model from a first-person perspective—that is, when the adult and infant were side by side rather than facing each other across the table. This methodological point may be important because previous studies indicating that infants were poor at imitating tool use modeled it only from across the table (e.g., in the Nagell et al. study). Viewing the goal-directed act of the model from the same perspective as one's own may facilitate learning from observation (see Jackson, Meltzoff, & Decety, 2006, for relevant neuroscience work on imitation from a first-person perspective).

There was little tool use in either of the control groups. Only 7.5% of them solved the problem spontaneously in the two control conditions, whereas significantly more of the infants (50%) succeeded after they saw the adult show them how to use the tool. The 20- and 24-month-olds seemed to profit more from observation than did the younger infants (16- and 18-month-olds), and Meltzoff (2007b) argued that infants "on the cusp" of solving the problem themselves may be better able to interpret and use the adult's technique. The important point is that infants can learn how to use a novel tool (a freestanding stick) in a causally effective manner by observation. Recent work has replicated these general developmental effects and is uncovering strategies for boosting infants' use of tools through highlighting the goals of the act (Esseily, Rat-Fischer, O'Regan, & Fagard, in press). Related work shows ways in which infants use imitation for acquiring other novel skilled actions (Esseily et al., 2010; Fagard & Lockman, 2010; Gardiner, Bjorklund, Greif, & Gray, 2012).

The tool-use literature also indicates that children profit from watching other people's tool-use *errors*. Want and Harris (2001) showed 3-year-olds a task in which a stick was used to push a desired object out of a tube. Children who saw adults push in the wrong direction first and then correct themselves were more likely to imitate the correct solution than if they saw only the successful act. It is as if the error helped highlight what was important about the adult's display and isolated what to imitate. Nielsen (2006) and Király (2009) found related effects using a simpler tool-use task in younger children.

Other research shows that children also make inferences about an object after watching another person use it as a tool. For example, seeing another person use a tool effectively leads preschool-aged children to selectively choose the same one from an array of equally appropriate objects when later presented with the task (Casler & Kelemen, 2005; see also Casler & Kelemen, 2007). Children also take their own understanding of the causal relations into account when deciding which tool to select. When an adult chose an object that was clearly ineffective for completing a task, 2- to 4-year-olds were significantly less likely to copy that object choice (DiYanni & Kelemen, 2008). This was true even when the adult explicitly rejected the effective tool in favor of the ineffective tool. If an adult chose a soft, plastic sponge instead of a hard, handled object to use for crushing a cookie, children still used their understanding of the task to guide their selection of the malletlike object. Young children seamlessly combine their own causal understanding with their imitation of others.

Imitation and Causal Learning: The Role of Social Agents and Statistical Learning

Infants intermingle imitation and their own causal understanding of the world in several interesting ways. Young children are more likely to imitate behaviors that lead to physical outcomes than those that do not (Bauer, 1992; Brugger, Lariviere, Mumme, & Bushnell, 2007; Elsner, 2007; Hauf, Elsner, & Aschersleben, 2004). For example, Brugger and colleagues (2007) found that 15-month-olds were more likely to remove a barrier when doing so cleared a path for a ball to pass versus when it was inconsequential to the outcome (e.g., the barrier did not block a path).

Schulz, Hoopell, and Jenkins (2008) discovered that children use probability information about the outcome to choose when to use high-fidelity versus ballpark imitation. An adult moved a sliding object to a particular position on a continuum to produce the effect of turning on a light. When the slider placement deterministically produced the result, 18-month-olds and 4-year-olds were more precise in their imitation of the placement of the switch than when it did so probabilistically. In the latter case, they explored other positions on the continuum as if to use the adult's act but to go beyond it and test the underlying causal structure of "what makes this light work." Buchsbaum, Gopnik, Griffiths, and Shafto (2011) pushed this one step farther and found that young children can use patterns of statistical data to determine which combinations or sequences of actions cause a result. The children then selectively reenact the causally necessary sequence to bring the result about.

Studies investigating causal learning have also discovered that the social aspects of imitation deeply influence infants' construal of causal events. For example, Meltzoff (2007b, experiment 3) found that infants systematically vary their imitation depending on whether or not they understand that a person is involved in producing an outcome. The study showed that infants are more likely to reenact the event if they think that a person has caused an outcome versus when the same event/outcome ocurred by itself with no human intervention.

Meltzoff, Waismeyer, and Gopnik (2012) reported a series of four experiments investigating how infants use observation of the goal-directed acts of others to learn about cause-effect relations. In a two-choice procedure, 2- to 4-year-old children saw two objects (potential causes). The adult demonstrated the same action on both objects, but doing the action on one object caused a spatially remote effect to turn on, and acting on the same way on the other did not. The experimental question was whether the children could learn what to do and which object to intervene on simply from watching—termed *observational causal learning*. The experiment showed that children did so. They selectively intervened on the causal object and even predictively looked towards the remote effect before it occurred, suggesting that they had learned the cause-effect relations. The youngest children (24- to 36-month-olds) were more likely to make such causal inferences when the outcomes were the result of human interventions than when they were not (see also, Bonawitz, Ferranti, Saxe, Gopnik, Meltzoff, Woodward, & Shulz, 2010).

This new work on causality suggests a powerful learning process at play in infancy and early childhood—one that uses the social world to teach children about the physical world. Observational causal learning may be a fundamental learning mechanism that enables infants to abstract the causal structure of the world so quickly and effortlessly even before language. Young children learn about cause and effect not simply by doing things themselves but by watching the actions of others and studying the causal consequences that follow from those actions. Children are thus accelerated in their learning about causal relations—especially about those that matter in their culture—by watching the causal consequences of the acts of others, prior to and often without taking action themselves.

Abstract Imitation: Learning Rules and Strategies from Observing Others

We have so far reviewed studies showing that infants and children imitate a wide range of concrete behaviors. However, adults learn more abstract things from observing other people. Adults also pick up particular strategies and "rules of the game" from watching the behavior of others. For example, an intern may shadow the chief dermatologist and learn to diagnose skin rashes based on their color and pattern. A graduate student may use a professor's talk as a guide or template when later developing her own talk. Although the student does not copy the content, she might apply the professor's organization or presentation style to her own talk. This is imitation, although it is certainly more abstract than mimicking particular behaviors. Arguably, such abstract copying of rules and strategies undergirds much apprenticeship learning and mentoring that happens in informal settings, outside of formal schooling. The student is not expected to imitate the literal behavior of the expert, but to pick up certain principles from "watching how the expert does it." Researchers have investigated whether young children are able to identify and imitate abstract strategies and rules, not simply concrete behaviors. This is crucial for cultural learning.

Sequence Learning

In some cases, adults execute behaviors according to a fixed temporal order. For example, when typing a password to log into an account, the necessary characters must be pressed in an exact order. One series of experiments tested whether children can learn such a sequence from watching someone execute the behaviors. In this procedure, several different pictures are displayed on a touch-screen monitor (Subiaul, Cantlon, Holloway, & Terrace, 2004; Subiaul, Lurie, Romansky, Klein, Holmes, & Terrace, 2007; Subiaul, Romansky, Cantlon, Klein, & Terrace, 2007). The children watch as a model touches the pictures in a particular sequence and then receives a reward. The experimenter may touch the pictures of a pyramid, a tree, and then a dolphin and then be rewarded with an entertaining video clip. After watching the adult execute the series, the children are given a chance to act on the computer display. The spatial location of the pictures on the monitor changes on each trial during the test period. This ensures that the children cannot simply duplicate the experimenter's actions *per se*: they must learn the abstract temporal sequence in order to obtain the reward, even though the spatial location of the targets has been altered. The results with 2- through 4-year-olds show that they can learn the sequence (independent of spatial position) and reenact it themselves to obtain the reward. Children who see the adult's demonstration need fewer trials to input the correct sequence compared to children who never see the demonstration and learn through trial and error.

Hierarchical Order

A hierarchical organization can often make completing a process more streamlined and efficient. Whiten and colleagues (Flynn & Whiten, 2008; Whiten et al., 2006) conducted studies investigating whether children represent and imitate the hierarchical organization embodied in an adult's demonstration.

To test different hierarchical organizations, the researchers designed a task that involved a multistep sequence of acts. Children had to build a number of keys and then use them to unlock and open a container. Three- and 5-year-old children were shown two different organizations. One group of children saw an adult assemble and use each key in turn. The second group saw the adult complete one step of the assembly sequence with all of the keys before moving on and completing the second step with all of the keys. Children were then given the locked object and the materials. Children who saw either demonstration were better at opening the container than were children in a baseline comparison. The children were more likely to employ the organization they saw the model use compared to the alternate organization. The children in these studies learned more than the concrete actions needed to unlock the box; they also learned a hierarchical organization for those behaviors from watching another person's example.

Rules and Strategies

Another type of organization that can be used to guide a person's behavior is a categorization rule. People often sort or group materials based on their properties. For example, based on their color, a gardener may divide strawberries into two groups: ones ripe enough to eat and those that they must let ripen. Categorization strategies have the potential to be applied across situations. Can children learn categorization strategies simply from watching the sorting behavior of others?

A series of studies was recently designed to answer this question (Williamson, Jaswal, & Meltzoff, 2010). In these studies, 36-month-old children saw an adult sort a heap of objects into two distinct piles according to either a visible property (color) or a nonobvious property (sounds made when shaken). For example, an adult was given a heap of eight objects (four of one shape and four of another shape; two of each shape were one color and two a different color). The adult proceeded to sort the objects into two piles of four green and four pink objects, putting four of one color into the left bowl and four of the other into the right bowl. There was no verbal narrative and no mention of color, just the adult's sorting behavior. After watching this demonstration, the children were presented with a heap of the same eight objects and given a chance to manipulate them. Children's behavior was scored to determine whether they sorted the objects by the target dimension (color in this case, thus ignoring shape).

To isolate the role of imitation, three relevant control groups were used, following Meltzoff's observation-only procedure. In the Baseline Control, children saw no demonstration. This assessed whether children spontaneously sorted by shape or color without observing a demonstration. In the Presort Control, the experimenter presented children with the eight objects from a particular set, as in the Sorting group. However, the objects were presented already sorted in the two bowls by color. This condition controlled for the possibility that children would sort the objects into two groups based merely on seeing the outcome/results of the sorting process—the two-category configuration. In the Presort + Manipulation Control, the experimenter also presented children with the eight objects already sorted by color; and this control was even more rigorous inasmuch as the experimenter also manipulated the objects. She lifted and returned each object one at a time from the right-hand bowl, and then did the same for each object in the left-hand bowl. This controls for the possibility that children will sort the objects into groups based on seeing the end-state configuration *plus* a person actively handling the objects in each of the bowls.

Children in the experimental group sorted the objects by color significantly more often than did the children in the controls. Moreover, children generalized the sorting rule. They were presented with a new set of eight objects, composed of two kinds of shapes and two colors. The adult never sorted the second set of objects. The children in the experimental group, but not the controls, sorted them by color.

The findings of these experiments show that children can learn a new sorting strategy through observation; children who saw the sorting demonstration were more likely to group the objects by the target dimension than were controls, even though the children in one of the control groups saw the adult model make similar movements and saw the same end-state arrangement (i.e., the objects sorted by color). Seeing the adult's sorting behavior itself seems to be critical for the acquisition of this rule. Children also generalized their newly learned sorting strategy, applying it to a novel set of objects.

These findings were replicated in Experiment 2 using a different dimension of sorting, in this case an invisible dimension. Four identical objects were used. The adult picked them up, one at a time, shook them, and sorted the objects into two piles based on their invisible acoustic properties. The end result was two piles of visually identical objects, but sorted by their invisible properties. The 36-month-olds also succeeded on this task simply from watching and listening to the adult's display.

Summary

Imitation is not limited to copying body movements, acts on objects, or outcomes and end states; children also learn abstract rules and strategies by observing the behaviors of the people around them. The cognitive concepts discussed here are only a subset of the strategies that are learned and imitated by children. The significance of this research is that it underscores the power of imitative learning in young human children and what they learn from experts in their culture. Children can learn abstract rules, strategies, and the "gist" of cultural rituals and routines from watching the behavior of others.

Top-Down Control of Imitation

Young children do not imitate all the time. Children garner information from other people but do not imitate compulsively or blindly. Laboratory work has uncovered four factors that influence top-down control of when, what, and whom to imitate.

Social Context

Reproducing others' behaviors is a social exchange, and studies with adults suggest that even unconscious mimicking of subtle behaviors (such as touching one's own face) may promote affiliation among individuals (e.g., Lakin & Chartrand, 2003). Over and Carpenter (2009) extended these investigations of affiliation to children by examining its role in 5-year-olds' overt imitation. The children first watched short videos of moving geometric shapes (as in Heider & Simmel, 1944). Half of the children saw videos in which one of the shapes was ostracized; for example, a circular "ball" was not passed to one triangle in the display. The other half of the children saw videos that were neutral. The children then participated in an imitation task in which they saw an adult perform a sequence of actions leading to turning on a light. The 5-year-olds who saw the social exclusion were more likely to reproduce the specific manner and means the adult used in turning on the light. The authors use these results to highlight the social role of imitation.

The social style of the one-on-one imitative interactions also influences children's imitation. Infants are more likely to imitate a model that engages them socially. In an experiment by Brugger et al. (2007) an adult varied the cues she gave to 15-month-olds by modifying her posture, attention, and vocalizations. For one group of children the model looked at and spoke to the child before demonstrating the target behavior. For the other group, she did not engage the children, but instead looked off at a wall while speaking. The results showed that the infants were less likely to reproduce the demonstrated behaviors when the adult did not look at or speak directly to them. Similarly, Nielsen (2006) found that 18-month-olds showed more faithful imitation when an experimenter engaged with them versus acting aloof.

Csibra and Gergely (2006) suggested that human demonstrations for teaching typically involve multiple cues, including mutual eye-gaze, "motherese," and purposeful actions that set up an expectation that there will be a pedagogical exchange. Such social engagement and an intentional production of a behavior may be one cue, among others (Beisert, Zmyj, Liepelt, Jung, Prinz, & Daum, 2012; Gergely, Bekkering, & Király, 2002; Paulus, Hunnius, Vissers, & Bekkering, 2011), that the act should be duplicated. Aspects of the social display may serve to bring attention to and segment the key elements of the display making imitation more likely. Recall too that at the most basic level, young infants are specially attuned to imitate when they see another person involved: Meltzoff (2007b) showed that 14-month-old infants vary their imitation depending on whether they think a person produced an outcome. They are more likely to reenact the event if they think a person has instigated a result as opposed to the same event just happening by itself with no human intervention (see also, Bonawitz et al., 2010; Hopper, Flynn, Wood, & Whiten, 2010; Meltzoff et al., 2012; Thompson & Russell, 2004).

Goals

Bekkering, Wohlschläger, and Gattis (2000) proposed that children view others' behaviors as organized in a hierarchy of goals. When presented with a difficult series of actions, 3- and 5-year-old children reproduce those that are most important and highest in the hierarchy. In these studies children saw an adult reach either contralaterally (across the body) or ipsilaterally (with the arm on the same side of the body). When the reach was directed at a tangible goal, such as a spot on the table (Wohlschläger, Gattis, & Bekkering, 2003) or the model's ear (Gleissner, Meltzoff, & Bekkering, &, 2000), children often disregarded the type of reach used and simply reached directly for the appropriate endpoint during their own imitation. However, when there was no obvious goal (when the same hand movement was made but there was no spot on the table or the adult reached to an empty place in space next to the ear), children were more likely to reproduce the exact type of reach used, i.e., they imitated the manner or means with higher fidelity. Thus, children will vary what aspect of the display they imitate depending on what they identify to be the primary goal of a behavior.

Adults' memory for action is organized according to a hierarchy of goals, even to the degree that adults sometimes distort their recollection of events according to goals they impute to the actor. Little previous research has examined whether goal information is privileged over veridical sequential order information in young children. In a recent experiment using imitation as an outcome measure 3-year-old children's memory for naturally occurring action sequences was investigated (Loucks & Meltzoff, in press). The children were presented with sequences in which an actor switched between actions for achieving *two distinct goals*, as might occur when a multitasking caretaker is making a cup of tea while also folding the laundry. In the real world, one does not always complete one series of action steps before engaging in the next set of steps headed toward a different goal—rather the actions are co-mingled. Can young child make sense of this jumble?

In the Loucks and Meltzoff (in press) work the adult showed a three-step sequence of putting a doll to bed intermixed with a three-step sequence of feeding a doll. The question was whether children would imitate what they actually saw, or whether they would transform what they saw—imitating the steps involving one goal and then the next goal—in effect "cleaning up" and chunking the adult's messy series into two goal-directed efforts. This tests whether children's action representations prioritize a goal interpretation over veridical sequential information. Children's memory for the action events was assessed by deferred imitation. The results indicated that children's memory prioritizes goals over veridical sequential order—even to the extent that the actual sequential order was distorted in deferred imitation—thus underscoring the role of goals in organizing action representations and imitative productions.

Carpenter, Call, and Tomasello (2005) also argue that younger children (12- and 18-month-olds) use their understanding of a model's goal to guide what parts of a demonstration they will imitate. In an adaptation of the Bekkering and colleagues' (2000) original procedure, infants were shown to be more likely to imitate distinctive sounds and acts on a toy mouse when a person moved it to a general location that had no clear external goal versus when the person moved it into a house. In the latter case, they simply copied the endpoint but did not necessarily use the adult's distinctive means. In another study, Carpenter, Call, and Tomasello (2002) showed 24-month-olds an adult using a multistep series of acts to open a box and retrieve a reward. Children who knew the model's intended outcome before observing the demonstration (e.g., those who saw the box already open) were better able to reproduce the behaviors necessary to attain it.

Williamson and Markman (2006) propose that without a clear understanding of an overall goal it would be beneficial for children to imitate in precise detail. To test this hypothesis, 3-year-olds saw an adult place an object using unusual means (e.g., turning a cup over and rotating it in a two-handed grip). When no reason was given for this placement, children were more likely to reproduce the model's precise actions with great fidelity; when a context provided the reason for the placement (e.g., the cup was a nose in a face configuration), children duplicated the end-state placement but often ignored the precise movements by which the adult put the object there.

Exactly how children determine the primary goal of a behavior is not yet clear. Some researchers have argued that certain aspects of a behavior, such as the outcome of an action, are more likely to be imitated (e.g., Bekkering et al., 2000; Elsner, 2007; Gattis, Bekkering, & Wohlschläger, 2002). In line with the primacy of outcomes, Hauf et al., (2004) found that 12- and 18-month-olds were more likely to imitate acts and to do so more quickly when the acts elicited an outcome (produced a sound) versus when they did not. Additionally, by 15 months of age, children expect their own actions to have the same outcomes as those of others (Elsner & Aschersleben, 2003). Other researchers have argued that what is most likely to be imitated from a series of behaviors may not be fixed; instead, children may imitate means instead of outcomes if those means are highlighted (e.g., with a color light) (Bird, Brindley, Leighton, & Heyes, 2007) or suggested by features of the event (Wagner, Yocom, & Greene-Havas, 2008).

This body of empirical work does not have a settled interpretation, but we can offer a synthetic suggestion that cuts across various studies. Children use a mental trade-off between duplicating the goal/end state versus the particular acts the adult used to achieve it. If they lack a clear understanding of an overall goal or how to achieve it, it is beneficial for children to imitate in precise detail. If you imitate the details of the act with your own body, then the result in the world often comes for free. They may implicitly follow the maxim: "when in doubt, imitate what the expert is doing and how he or she does it." This may at least partially explain why human children are sometimes found to "over-imitate," that is to reproduce unnecessary actions that are not needed (from the adult's viewpoint) to reach an end (e.g., Horner & Whiten, 2005; Lyons, Damrosch, Lin, Macris, & Keil, 2011; Lyons, Young, & Keil, 2007; McGuigan, Whiten, Flynn, & Horner, 2007).

Prior Self-Experience and Success of the Model

Children's own prior experiences have also been shown to influence their imitation (Pinkham & Jaswal, 2011; Williamson, Meltzoff, & Markman, 2008). Williamson, Meltzoff, and Markman (2008) tested 36-month-old children to see if they were more likely to imitate another person's technique if the child had a prior experience of difficulty with a task. Children were randomly assigned to two independent groups: one group had an easy experience and the other a difficult experience in achieving an outcome. For the children randomly assigned to the difficult experience, a drawer was surreptitiously held shut by a resistance device. Then the model demonstrated a distinctive technique for opening the drawer (pressing a button on the side of the box). The same distinctive technique was demonstrated to children regardless of whether they had been assigned to have a prior easy or prior difficult experience. Children were significantly more likely to imitate the adult's distinctive act if the child had a prior difficult experience with the task. These results fit together well with work in educational psychology showing that some prior experience confronting difficulties with a problem (often called "hands-on experience") can help the student be more ready to learn from an expert—as was also shown here with much younger participants.

Children are also sensitive to others' experiences with a task when imitating. Three-year-olds are more likely to imitate a successful versus an unsuccessful actor's specific means for accomplishing a task (Williamson et al., 2008). Similarly, children as young as 12- to 14 months old have been shown to be more likely to take up an unusual successful strategy after first witnessing the adult demonstrate an unsuccessful alternate strategy (Király, 2009; Nielsen, 2006; Want & Harris, 2001). The actor does not even have to be unsuccessful versus successful: children also respond to the efficacy of an adult's demonstration. Williamson and Meltzoff (2011) found that 36-month-olds were more likely to imitate a second adult's strategy for opening a drawer after first witnessing another adult struggle versus easily complete the task. In both cases the adult was successful, but children wisely chose to imitate the particular act when it was more efficacious.

Children will also use an individual's general past reliability to guide their imitation. Thus, infants are less likely to imitate an adult's unusual means for completing a task when that adult has previously given misleading emotional information about the contents of containers (Poulin-Dubois, Brooker, & Polonia, 2011) or used familiar objects in incorrect ways (Zmyj, Buttelmann, Carpenter, & Daum, 2010). Overall, these results suggest that children are not blind or rote imitators, and instead flexibly vary their imitation depending on their own experiences with the task and their assessment of the actors involved in the task. We might say that children are "picky imitators" and not slavish copiers.

Emotions and Attention

Emotions also play a role in regulating imitation. As adults we often monitor the reaction that others have to the performance of an action. Let's return to the college president's dinner party with formal place settings. If someone picks up the wrong fork and the president scowls, you are unlikely to imitate that behavior. As adults, we regulate what we imitate according to the social-emotional reactions of others.

Repacholi and Meltzoff (2007; Repacholi, Meltzoff, & Olsen, 2008) investigated this phenomenon in infants using what was called an "emotional eavesdropping" procedure. This work evaluated how two factors regulate imitation: (a) the emotional consequences of actions, and (b) whether the children are being observed. The infants sat at the table and observed as two adults interacted. When one adult performed a seemingly innocent act, the second adult had an angry outburst (saying, "*That* is so irritating!"). The experiment involved manipulating the emotional response of the adult and also whether or not that adult was looking when the child had a chance to play with the objects. The results showed that children were loath to imitate an act that caused the adult's anger if the previously angry adult was currently watching the child. If the currently angry adult left the room and could no longer see the child's response, the child would imitate.

Repacholi and colleagues (2008) examined the role of adult gaze in more detail. The work followed the same procedure as the previous study, but in the critical new control conditions the previously angry Emoter either (a) stayed facing the child but closed her eyes (thus not looking at the child) or (b) stayed facing the child but picked up a magazine to read (and thus not looking at the child). Children were significantly more likely to imitate the demonstrator's act in these conditions than when the previously angry Emoter watched the child's response. (In all cases the adult adopted a neutral face during the response period.)

This research shows regulation of imitation. Toddlers regulate their actions based on the emotional exchanges between two other people—emotional eavesdropping. These effects cannot be explained by emotional contagion, because the child had the chance to "catch" the adult's emotion equally well in all the conditions in which the Emoter became angry. If the children simply caught the adult's angry emotion and were frozen, they would not have imitated in any of the angry conditions. However, they were motivated to imitate in the conditions where the adult had been angry but then left the room, when she turned her back, when she was facing toward them with eyes closed, or even if she was facing them with eyes open but was distracted by reading a magazine. Children's actions were influenced by their memory of the adult's past emotions and varied as a function of whether that previously angry adult was currently looking at them. Toddlers regulate their behavior based on whether or not the previously angry person now has *visual access* to their own actions. The work is significant because it shows that children do not blindly and automatically imitate. Rather, children choose whether and when to imitate. This is an example of top-down regulation of imitative responding.

Social Consequences of Being Imitated: Emotional Reactions to Others "Like Me"

An observation in the social-developmental literature is that parent–infant games are often reciprocally imitative in nature. Infants shake a rattle and parents shake back; infants vocalize and parents do likewise. The turn-taking aspect of these games, the "rhythmic dance" between mother and child, is of theoretical interest because it shows the social aspects of contingency detection (Beebe, Sorter, Rustin, & Knoblauch, 2003; Bruner, 1983; Stern, 1985). Most social developmental theories, however, have overlooked the importance of the *form* of the participants' behavior. Mutual imitative games provide infants with special information that they are like another person and that the other is "like me."

The social-emotional consequences of such structural congruences was tested in a series of studies with 14-month-olds (Meltzoff, 2007a). Infants may like people who are acting "just *like* they act" (structural congruence) or they may like when others do something "just *when* they act" (temporal contingency) regardless of whether or not it is matching behavior. To investigate this empirically, Meltzoff (2007a) conducted a study with 2 adult experimenters in which both adults' actions were contingent on the infant's. Both adults sat passively until the infant performed a target action on a predetermined list, and then both experimenters began to act in unison. One of the adults matched the infant, while the other performed a mismatching response. The results showed that the infants looked and smiled more at the matching adult. These effects were replicated and extended in a developmental study of mutual imitation (Agnetta & Rochat, 2004). Taken together, the work suggests that infants like adults who imitate them. This is manifest not only by infants paying greater attention to adults when they imitate (the visual measure) but also by the fact that infants smiled more at the imitator than the nonimitator, and smiling is an pro-social, emotional response.

Saby, Marshall, and Meltzoff (2012) applied infant neuroscience techniques to further investigate the consequences of being imitated. They used an event-related electroencephalographic (EEG) procedure with 14-month-old infants. The results revealed specific neural signatures for being imitated by another person. Under experimental conditions, infants showed greater desynchronization of the EEG mu rhythm (6–9 Hz frequency band) when they saw their action being matched versus mismatched by an adult partner. This significant change in the mu rhythm was exquisitely timed with respect to seeing the matching action performed by the other person.

Decety, Chaminade, Grèzes, and Meltzoff (2002) conducted a related brain-imaging study investigating adults' recognition of being imitated by another person. The participants either imitated or was imitated while they received a PET scan, which could help localize changes in brain activity. The results indicated that the right inferior parietal lobe was specifically activated when the subjects performed an action and were imitated. Our hypothesis, consistent with other adult neuroscience work, is 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?" Taken together, the brain and behavioral work supports the idea that infants recognize the structural congruence between the acts of self and other.

Meltzoff (2007a, in press) argues that the mechanisms that underlie imitation are bidirectional. The machinery that takes visual input and generates a matching motor response can also run in reverse and recognize when the self's own actions are being mirrored. This bidirectionality is consistent with the AIM hypothesis discussed earlier in the chapter. The exciting recent additions are that: (a) being matched has deep emotional consequences, sparking positive emotions (smiling) and preferences (longer looking at the imitator) and (b) the neural correlates of being imitated are measurable using neuroscience techniques, allowing us to integrate brain, behavior, and emotions in infant social neuroscience work.

Imitation, Intentions, and Foundations for Theory of Mind

In the mature adult social cognition, others not only act "like me," they also are understood to have mental states, including beliefs, desires, and intentions that are like my own. When do preverbal infants begin to ascribe such intentionality to human movement patterns? The behavioral reenactment procedure was designed to provide a nonverbal approach for exploring intention reading in preverbal infants (Meltzoff, 1995a). The procedure capitalizes on children's natural tendency to imitate, but uses it in a more abstract way to investigate whether they can read below the literal surface behavior to the goals or intentions of the actor.

The experimental procedure involves showing infants an unsuccessful act. For example, the adult accidentally under- or over-shoots a target, or he tries to pull apart a barbell-shaped toy but his hand slips off the ends and he is unsuccessful. Thus, the goal state is not achieved. To an adult, it is easy to read the actor's intentions, although he never fulfills them. The experimental question is whether children read through the literal body movements to the underlying goal or intention of the act. The measure of how they interpreted the event is what they choose to reenact, in particular whether they choose to ignore what the adult literally did and instead produce the intended act despite the fact that it was never present to the senses.

The study compared infants' tendency to perform the target act in several situations: (a) after they saw the full target act demonstrated, (b) after they saw the unsuccessful attempt to perform the act, and (c) after it was neither shown nor attempted. The results showed that 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, toddlers can understand our goals even if we fail to fulfill them.

Age Changes

At what age does this understanding of the intention of unsuccessful acts of others emerge? Results suggest that it develops between 9 and 15 months of age. For example, Meltzoff (2007b) found that 15-month-olds behaved much like the 18-month-olds in the original 1995a study, but 9-month-olds did not respond above baseline levels to the unsuccessful-attempt demonstrations. Importantly, control conditions indicated that 9-month-olds succeeded if the adult demonstrated successful acts. Thus, the 9-month-olds imitated visible acts on objects, but gave no evidence of inferring intentions beyond the visible behavior itself. This finding of a developmental change in infants' understanding of others' goals and intentions has been reported in other studies as well (Bellagamba & Tomasello, 1999; Tomasello, Carpenter, Call, Behne, & Moll, 2005), so there is converging evidence for an important developmental change between 9 and 15 months. It is also worth noting that not all goals and intentions are the same. The acts tested in the Meltzoff studies were not only unsuccessful acts, but ones that could not be inferred simply by "extending" the direction of goal-directed movements that were visible (e.g., Hamlin, Hallinan, & Woodward, 2008). For example, when the adult's hand slips off one end of the barbell, the correct response for the infant is not to slip in the same direction, or slip further or faster, but rather to do something completely different. It is to wrap their fingers around the barbell more tightly and to take action of a *different* form than that shown by the adult, who was unsuccessful in reaching the goal (Meltzoff, 1995a, p. 846; Meltzoff, 2007b, p. 33).

Differences Between Behavioral Reenactment and Other Techniques for Assessing Goal Reading

The foregoing focuses on the behavioral reenactment procedure, but for completeness, it is worth noting that this is not the only technique used in assessing goal reading in the preverbal period. Other researchers have used the visual familiarization/habituation procedure to investigate infants' understanding of goal-directed actions (e.g., Brandone & Wellman, 2009; Gergely, 2002; Woodward et al., 2001). This procedure differs from the behavioral reenactment procedure in a couple of interesting ways. First, it does not measure infant recreations of events in *action*; it tests whether they choose to *look* longer at one display or another. Second, the familiarization/habituation procedure addresses slightly different questions. For example, Woodward (1998, 1999) showed infants an adult grasping an object that appeared in either of two locations. The question was whether infants treated the object as the "goal of the reach." Note that the "goal" of the reach is the *seen physical object* (a toy ball or bear). This differs from the reenactment procedure in which the goal is an *unseen* act the adult was trying to achieve. In the behavioral reenactment procedure the goal is not visible; it has to be inferred. In Woodward's technique, the goal is an object that is quite visible to the infant, the thing that the adult is tending toward.

Tomasello and colleagues investigated goal reading using an action approach that is also distinguishable from the behavioral reenactment procedure (Carpenter, Akhtar, & Tomasello, 1998; Tomasello, 1999; Tomasello & Barton, 1994). In these studies, infants saw an adult perform intentional acts versus accidental acts, which were marked linguistically by saying "Whoops!" The results showed that infants choose to imitate the former. In these studies, infants imitate what they see in front of their eyes, and the question is which of two acts they see they selectively choose to copy.

These methodological and theoretical differences are productive for the field because they provide independent tests of infants' understanding using different techniques. We can be more confident that infants understand goals and intentions before language, because results from different paradigms converge towards the same conclusion.

What Constitutes a Social Agent Worthy of Imitating: Examining Boundary Conditions

Are there constraints on the types of entities that are interpreted to act in a goal-directed, intentional fashion? In the adult framework, only certain types of entities are ascribed intention. Chairs rock and boulders roll, but their motions are not seen as intentional. What do infants think?

To begin to examine this, Meltzoff (1995a) tested how 18-month-olds responded to a mechanical device that mimicked the same movements as the actor in the unsuccessful-attempt condition (Fig. 23.5). An inanimate device was constructed that had poles for arms and mechanical pincers for hands. It did not look human but it could move very similarly to the human. For the test, the pincers grasped the barbell at the two ends just as the human hands did. One mechanical arm was then moved outward, just as in the human case, and its pincer slipped off the end of the barbell just as the human hand did. The movement patterns of machine and man were matched from a purely spatiotemporal description of movements in space.

Infants did not attribute a goal or intention to the movements of the inanimate device. Although they were not frightened by the device and looked at it as long as at the human display, they did not see the sequence of actions as implying a goal. Infants readily touched the object, but the likelihood that they would pull apart the toy after seeing the unsuccessful attempts of the inanimate device were the same as in baseline conditions (when they saw nothing), and significantly less than when they saw the unsuccessful attempts of a person trying to do so (see also Slaughter & Corbett, 2007).

Of course, it is possible to create displays that fool infants, just as adults can be presented entities that are difficult to categorize: Is a computer intentional? What about a thermostat with a feedback loop, or a goal-seeking robot? We do not know the necessary and sufficient conditions for young children's ascription of intentionality. However, research indicates that in certain circumstances (and using certain response measures) infants see goals in the actions of pretend humans (e.g., stuffed animals and puppets; Johnson, Booth, & O'Hearn, 2001) and in visual displays that may be ambiguous as to agency (e.g., 2D spots that leap and move spontaneously on a TV screen; Gergely, Nádasdy, Csibra, & Bíró, 1995). The inanimate 3D object (pincers) used by Meltzoff (1995a) gives a lower boundary (infants fail) and real people give an upper boundary (infants succeed). There is a lot of room in between, current research using humanoid robots with infants is investigating who and what infants imitate and under what conditions (e.g., Itakura, Ishida, Kanda, Shimada, Ishiguro, & Lee, 2008; Meltzoff, Kuhl, Movellan, & Sejnowski, 2009; Meltzoff, Brooks, Shon, & Rao, 2010).

Theory

There are three fundamental contributions of the work on imitation to theories of developmental psychology. The first concerns Piagetian stage-developmental theory. The second pertains to

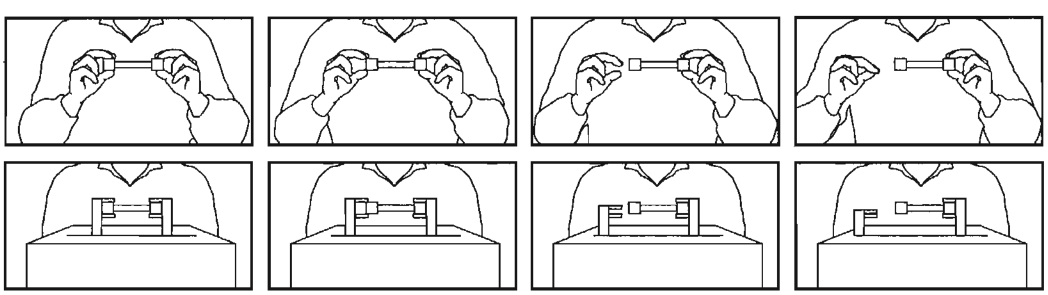

Figure 23.5. Intention reading. Human demonstrator (*top panel*) and inanimate device performing the same movements (*bottom panel*). Infants reenact the goal of the act for the human but not inanimate device demonstration. (Reprinted with permission from Meltzoff, 1995.)

theories of action representation and its neuroscientific underpinnings. The third concerns the origins of understanding of other minds.

Piagetian Theory

The discovery of robust deferred imitation before 18 months of age forces a deep revision in classical views of developmental psychology. Piaget's (1952, 1954) developmental theory was premised on the idea that there was a "sensorimotor" stage of infancy, properly so called. The Piagetian infant is one who develops ever-more-elaborate habits, procedures, and adaptive actions on the world but lacks mental representations that exist prior to action (see also Thelen & Smith, 1994, who argue for a position that is similar to Piaget's in this respect). Although Piaget could account for much of infant behavior while resisting the notion that infants were capable of storing internal representations, the findings of deferred imitation using the observation-only technique makes such resistance futile. Infants are able to form a mental representation of an adult's display simply from observation and can use this stored representation to guide their subsequent actions after a temporal and spatial detachment from the site of initial encoding.

There are theoretical implications of this shift. First, it indicates that infants are not restricted to being "sensorimotor" creatures at all. *They never go through a purely sensorimotor period in which they operate solely with habit knowledge.* Contrary to Piaget, the ability to act on the basis of a stored representation of a perceptually absent stimulus is the foundation that makes infant cognitive development possible. It is the origin rather than the outcome of development.

There have been other challenges to Piagetian theory of infancy, of course, including reports of early object permanence using looking-time measures (e.g., Baillargeon, 1993; Spelke, 1998), and there is debate as to whether the looking-time assessments measure the "same thing" as the action-based object search measures that Piaget used (see Haith, 1998; Kagan, 2008; Meltzoff & Moore, 1998; Newcombe & Huttenlocher, 2006). The value of the work on deferred imitation is that it uses an action measure. There is no paradox—as there is in the object permanence literature—of infants seemingly reacting to the absent object (as measured by looking time) but failing to act on this information (as measured by search behavior). Deferred imitation shows that infants can store representations of absent objects and events *and that they can act on this stored information.* Infants perform exactly the type of deferred imitation that Piaget denied, and this has prompted a theory revision.[2]

Action Representation and Neural Mirroring Mechanisms

Imitation informs us about action representation and the mapping between perception and production. To imitate, children must use visual input to organize and drive their motor plans. According to the AIM hypothesis, infants map information about human acts into a common *supramodal* framework (Meltzoff & Moore, 1977, 1997). The supramodal representation of action allows them to imitate facial gestures even though they cannot visually monitor their own behavior. Infants can correct their facial behavior because there is a cross-modal feedback loop that connects their own facial actions (monitored through proprioception) with the facial actions they see performed by others. That infants can recognize the equivalence between the actions of self and other is also demonstrated in imitation recognition studies, in which infants are presented with two adults who are sitting side by side, one an imitator and the other not. Infants preferentially look and smile at the adult who is imitating their own acts—recognizing when someone else is acting "like me" (Meltzoff, 2007a).

There is increased attention being devoted to the neural bases of imitation. Researchers using single-cell recordings with monkeys discovered cells that respond both at the observation and execution of certain behaviors and dubbed them "mirror neurons" (e.g., Gallese, 2003; Rizzolatti, Fogassi, & Gallese, 2001). In adult humans, neuroscientists using noninvasive brain-imaging techniques (fMRI, MEG) have found evidence for shared neural circuitry for the observation and execution of actions (e.g., Hari & Kujala, 2009; Iacoboni, 2005; Jackson et al., 2006; Rizzolatti, Fadiga, Fogassi, & Gallese, 2002). In a new line of work, developmental neuroscience work has begun to analyze neural mirroring mechanisms in preverbal infants using EEG techniques, particularly recording changes in mu rhythm when infants observe, execute, and imitate actions (for a review, see Marshall & Meltzoff, 2011).

Nonetheless, it is clear that mirror neurons alone cannot account for the phenomenon of imitation. Monkeys have mirror neurons, but they have limited imitation abilities, so something more is needed to motivate and perform imitation. There are five aspects of human imitation that outstrip canonical mirror neurons *per se* and suggest that interconnected neural systems are at play. Human infants: (a) imitate from *memory*, often overriding what they currently see (rather than resonating with it); (b) *actively correct* their behavior rather than directly duplicating the model; (c) reenact *goals* and intentions even when the goals have to be inferred from unsuccessful acts; (d) imitate *novel* acts; and (e) *selectively imitate and regulate* their imitative actions, indicating top-down control and flexibility. Imitation is an ideal phenomenon for uniting developmental scientists and cognitive neuroscientists in investigating the neural underpinnings of action representation and perception–action coupling (e.g., Meltzoff et al., 2009).

Roots of Social Cognition and Theory of Mind

Piaget (1952, 1954) claimed that the child is born a "solipsist" and "radically egocentric," unable to connect self and other. The work in modern developmental psychology, on the contrary, shows that humans do not begin life as social isolates. We reviewed evidence that infants imitate, and that imitation is underwritten by a supramodal coding of human acts that connects self and other.

The application of infants' action representation system as a basis for understanding others has been called the "Like-Me" developmental framework (Meltzoff, 2007a, in press) (Fig. 23.6). The "Like-Me" framework proposes that self-experience is used as an engine for promoting developmental change. Two examples serve to illustrate this view. First, when infants want something, they reach out and grasp it. They also experience their own internal desires and the concomitant bodily movements (hand extension, finger movements, etc.). This experience of grasping objects to satisfy their desires gives infants grounds for interpreting the grasping behavior of others. When a child sees another person reaching for an object, she sees the person extending his hand *in the same way*, complete with finger curling, that she herself does when in a state of desire. It is crucial that infants can recognize the "sameness" between the acts of self and other, and the work on imitation proves they do. Object-directed grasping movements can thus be imbued with felt meaning, based on the child's own experience with these same acts (see also Sommerville & Woodward, 2005a, 2005b; Sommerville et al., 2005).

Second, consider the goal-directed "striving" and "try and try again" behavior used in Meltzoff's (1995a) behavioral reenactment studies. How do infants make sense of this activity? A key developmental foundation may be infants' own self-experiences. Infants have goals and act intentionally. They have experienced their own failed plans and unfulfilled intentions. Indeed, in the second half-year of life, infants become obsessed with the success and failure of their plans (Gopnik & Meltzoff, 1997). During episodes of testing plans and assessing why they failed, infants often vary the means and try and try again. When infants see another act *in this same way as they have acted*, their self-experience could suggest that there is a goal, plan, or intention beyond the surface behavior. Thus infants would come to read the adult's unsuccessful attempts, and the behavioral envelope in which they occur, as a pattern of strivings "like my own" rather than ends in themselves.

The crux of the "Like-Me" developmental framework is that the fundamental similarity between self and other at the level of actions allows infants to realize other deeper similarities as well, including that others have goals, intentions, perceptions, and emotions that underlie their behaviors (Meltzoff & Brooks, 2008). On this view, "mentalizing" and "theory of mind" start

Action representation
Intrinsic connection between the perception and production of acts, as embodied by infant imitation

↓

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'

Figure 23.6. "Like-Me" developmental framework. (Adapted with permission from Meltzoff, 2007b.)

from more primitive beginnings—the recognition of equivalence between the acts of self and other, as is first manifest in action imitation. Through social interaction and mutual imitation with other intentional agents who are viewed as "like me," infants develop a richer social cognition (see also the chapter by Astington & Hughes in this handbook volume).

At a more theoretical level, Meltzoff (in press) has suggested that infants' representation of others as "like me" may be a developmental foundation for the emergence of empathy and positive ingroup attitudes. Infants begin life with the capacity to recognize that others are "like me" in *motor acts*. On the one hand, this primordial link supports infants' realization that others are like me in deeper ways, such as *emotionally*, engendering empathic concern for others who are like the self (Jackson, Brunet, Meltzoff, & Decety, 2006; Jackson, Meltzoff, & Decety, 2005). On the other hand, infants' joy in playing mutual imitative games with caretakers who act "like me" can be generalized. The earliest ingroup may be the caretaker-child dyad engaged in mutual imitation games; these games cofirm mutual likeness and commonality at the level of acts and results in infant feelings of positive affect, as we demonstrated empirically. With development, the ingroup goes beyond this dyad and includes others who not only behave like the self but share visual features, interests, and goals with the self. People's positive attitudes towards this broader class of "like me" individuals, the ingroup, is a focus of social psychology; recent empirical work has established that even preschoolers feel a sense of affinity, belongingness, and positivity toward the ingroup (e.g., Cvencek, Greenwald, & Meltzoff, 2011; Dunham, Baron, & Carey, 2011; Over & Carpenter, 2012). The speculation is that infants' basic sense of "like-me-ness" to other individuals lays the foundation for their sense of belonging and positivity to "like me" groups in early childhood.

Imitation and an Interdisciplinary Science of Learning

The idea that action representation and self–other equivalence are basic building blocks for developing social cognition is proving to be useful in studies of autism, robotics, and educational psychology (Meltzoff et al., 2009). For example, deficiencies in the like-me comparisons may help illuminate the puzzling pattern of impairments exhibited by children with autism spectrum disorders (ASD). These individuals have specific deficits in imitation, gaze following, and emotion understanding (e.g., Dawson, Meltzoff, Osterling, & Rinaldi, 1998; Hobson & Meyer, 2005; Mundy, 2009; Mundy & Newell, 2007; Nadel, 2006; Rogers, 2006; Toth, Munson, Meltzoff, & Dawson, 2006)—all of which are underwritten by the equivalence between self and other. Precisely what piece of the "'like-me" building block is impaired and how its absence alters the trajectory of development in ASD is a grand challenge. But already work on imitation is proving to be useful in two ways: (a) imitation provides a sensitive preverbal measure for identifying children at risk for ASD at increasingly younger ages than more traditional assays and (b) training on imitation seems to provide efficacious treatment that boosts children's understanding of social cognition more generally (Rogers & Williams, 2006).

Imitation research is also influencing the field of robotics and machine learning. Researchers are beginning to design algorithms that enable robots to learn from observing the behavior of others. Instead of laborious programming of a fixed set of behaviors, the robot can be given imitative skills so that it can learn from watching humans. The long-term goal is to construct socially intelligent robots that imitate like a human child—mapping equivalent body parts and actions between self and other and using this as a platform for unsupervised learning (for reviews, see: Demiris & Hayes, 2002; Demiris & Meltzoff, 2008; Nehaniv & Dautenhahn, 2007; Shon, Storz, Meltzoff, & Rao, 2007).

Finally, educators are paying closer attention to how children learn through imitation and apprenticeship learning (e.g., Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003). K–12 educators are now seeking to incorporate these learning processes into school curricula in an attempt to enliven school and capitalize on the natural learning drive we see manifest both in infancy and in children learning outside of school (in museums, clubs, zoos, gaming, on the Internet, which support social and imitative learning, Bell, Lewenstein, Shouse, & Feder, 2009). Within the context of the work summarized in this chapter, it is not surprising that most forms of pedagogy for most of human history have involved a heavy dose of observational and imitative learning by participants in a joint activity, rather than verbal didactic lectures delivered by a "teacher" from the front of a room. In particular, early education stands to profit by incorporating opportunities for young children to use the powerful social learning mechanisms discussed in this chapter (Meltzoff et al., 2009).

Conclusions

Fodor (1987) is correct that solipsism and blank-slate empiricism are too impoverished a starting state for human development. He is correct that there is no known learning mechanism that can generate the richness of adult social cognition from such impoverished beginnings. However, this does not mean that the adult understanding of other minds is present at birth or matures without sculpting from social experience. The evidence from modern developmental psychology suggests that nature designed a baby with powerful social learning mechanisms including imitation. Culture immerses the child in interaction with psychological agents whom the baby can imitate and whose contingent responding and communicative actions are recognized to be "like me" by the child. This supports and enriches the infants' primitive understanding of other minds.

Through studies of imitation and other related work, developmental psychologists have begun to specify the initial state of social cognition and increasingly work is being brought to bear on the mechanisms of change. The goal is a theory that recognizes not only the richness of the innate state, but also humans' remarkable gift for bidirectional social learning—learning about me and the powers and potential of my actions by watching you, and interpreting you in part through my own past self-experience. Without this bidirectional bridge, our species-specific, commonsense psychology would not emerge.

Questions for Future Research

1. What neural systems underlie complex imitation? How does this neural architecture develop within and across primate species?
2. How does infants' causal reasoning influence their imitation, and reciprocally how does the observation of people's goal-directed actions and the outcomes they cause contribute to and accelerate infants' causal learning?
3. What abstract rules, strategies, roles, and cultural rituals do children learn through imitation, and how does imitation contribute to cultural learning?
4. How and why does imitation and being imitated by others prompt prosocial behavior and feelings of affinity with and empathy for others?
5. In what ways does imitative social experience serve as a mechanism of change in the development of human social cognition?

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Notes

1. In this regard it is interesting that young infants are finely attuned to point-light displays and can pick up spatiotemporal patterns from such visual events (e.g., Bertenthal, 1996; Marshall & Shipley, 2009); a related coding of action patterns could well be implicated in infant imitation.

2. A key unresolved issue is whether deferred imitation and object permanence rely on related cognitive machinery. Although both involve the representation of absent objects and events, infants require more than this to succeed on object permanence tasks. Object search requires notions of object identity and permanence in addition to representation of out-of-sight stimuli (Moore & Meltzoff, 2008, 2009), and deferred imitation does not implicate these additional concepts (see Meltzoff & Moore, 1998, for further analysis).

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