The Wiley-Blackwell Handbook of Infant Development

Second Edition

Volume 1

Basic Research

Edited by J. Gavin Bremner and Theodore D. Wachs

WILEY-BLACKWELL
A John Wiley & Sons, Ltd., Publication

2010

Reprinted from: Meltzoff, A. N., & Williamson, R. A. (2010). The importance of imitation for theories of social-cognitive development. In G. Bremner & T. Wachs (Eds.), *Handbook of infant development* (2nd ed., pp. 345-364). Oxford: Wiley-Blackwell.

11

The Importance of Imitation for Theories of Social-Cognitive Development

Andrew N. Meltzoff and Rebecca A. Williamson

Humans are inherently social. We live in complex societies, navigate intricate social interactions, and rapidly learn from those around us. We have a special adaptation that supports this – the ability to learn from observing others. Instead of having to rely on trial and error learning (which can be dangerous) or on independent invention (which can be slow), we profit from others' examples, including their actions, goals, intended efforts, and mistakes. Humans carefully study what others are doing in their transactions with the physical and social world and learn by observing their behavior. Anyone who has visited a foreign culture or attended a dinner party with a formal place setting has felt the need for rapid learning. In such cases we turn to others and imitate what they do. This powerful form of social learning is rare in the animal kingdom. There is a wide consensus among developmental psychologists and primatologists that humans are the most imitative creatures on the planet, imitating more prolifically than other species, including our closest living evolutionary relative, the chimpanzee.

In this chapter we will examine imitation from a developmental perspective, focusing particularly on preverbal imitation. We will show that imitation serves three important functions in infancy: (a) social-communicative, (b) cognitive, and (c) as a foundation for understanding other minds.

Imitation serves a social-communicative function, because copying the actions of others facilitates social engagement. Imitation serves a cognitive function because copying acts on objects helps infants learn how to use tools and cognitive strategies that are used by experts in the culture. Imitation is foundational for children's understanding of other minds because it provides opportunities for mapping the similarities and differences between self and other, what Meltzoff (2007a) calls the "Like-Me" aspect of imitation. A developmental pathway has been described for how infants progress from the

recognition of shared acts to an understanding of shared minds (Meltzoff, 2007b), thereby jumpstarting "mentalizing" and "theory of mind."

Early Bodily Imitation and Social Interaction

There is evidence that even the earliest forms of imitation are connected to infants' social-communicative development. In 1977, Meltzoff and Moore reported that 12- to 21-day-old infants imitate simple body acts. These infants responded to an adult's tongue protrusion by sticking out their own tongues and responded to an adult's mouth opening/closing by duplicating that action themselves. Subsequent studies conducted in a hospital setting (Meltzoff & Moore, 1983, 1989) showed facial imitation in newborns as young as 42 minutes old. Imitation in early infancy has now been replicated in more than two dozen studies across a variety of cultures (for a review see Meltzoff & Moore, 1997), and there is preliminary evidence concerning the evolutionary bases of behavioral matching in other primate species (Bard, 2007; Ferrari et al., 2006; Myowa, 1996).

Importantly, human newborns' responses are specific in ways that have not yet been documented in other primates. Human infants show differential matching responses to two types of lip movements (mouth opening versus lip protrusion), two types of protrusions (lip versus tongue), and they differentially respond to straight tongue protrusions and to tongue protrusions to the side (Meltzoff & Moore, 1977, 1994, 1997). This type of specific mapping has yet to be established in nonhuman primates. The response specificity is important because it indicates that human infants are not merely showing increased activity due to the presence of a social agent or the arousing properties of a dynamic visual display. These results also show that human infants are not restricted to imitating one gesture (for example tongue protrusion and nothing else, as was previously argued by some theorists), but rather have a more general imitative capacity.

Human neonates are not only specific, they are flexible in their imitation. The imitative response can be *temporally decoupled* from the adult demonstration itself. Infant facial imitation does not depend on the dynamic display being in the perceptual field, and thus cannot be explained away as arousal or motor resonance. Young infants will reproduce a behavior after a delay period. In Meltzoff & Moore's (1977) original experiments, the infants had a pacifier in their mouths during the adult's demonstration and later produced the behavior while looking at a passive face. In more recent studies, the adult showed the gesture on one day and returned the next. The infant stared at the same adult who now was showing a passive face, and then reproduced the gesture that the adult had shown the day before. They imitated from memory (Meltzoff & Moore, 1994).

Several researchers have proposed that infant imitation serves as a way to socially engage other people (Carpenter, 2006; Meltzoff, Kuhl, Movellan, & Senjowski, 2009; Meltzoff & Moore, 1995; Nadel-Brulfert & Baudonniere, 1982; Nadel, Guérini, Pezé, & Rivet, 1999; Uzgiris, 1999). There is evidence that the earliest bodily imitation serves a social function. In research by Nagy and Molnar (1994, 2004) newborns were observed while engaging in an imitative exchange with an experimenter. Infants were shown to match the adult's behaviors over several turns and to manifest variations in their heart

rate depending on their current role in the interaction, showing different patterns when initiating a behavior versus when reproducing another's act. The authors argue that both the infants' matching behaviors and their physiological reactions suggest that they were socially engaged during these imitative exchanges.

Meltzoff and Moore presented other evidence that infant imitation serves a communicative function. They found that imitation is connected to identity. Infants use imitation to identify the people around them, as a kind of social-communicative probe. For example, if one adult systematically shows tongue protrusion and a second adult systematically shows mouth opening, 6-week-old infants differentially imitate the facial gestures made by two separate people (Meltzoff & Moore, 1992). However, if the adults surreptitiously switch places – that is if the first adult leaves without the infant tracking him, and a second adult takes his place and shows the opposite gesture – the infants make an interesting error. They carefully stare at the new adult and then produce the previous person's gesture! Without clear spatiotemporal information that the old person left and a new one has entered and taken the old person's place (i.e., without monitoring the identity switch), the infant is uncertain about which person this is. The person looks different (visual appearances) but is in the place of the previous person (spatial location). Given this conflicting information about the person's identity, infants test the individual's behavior. It is as if they are "nonverbally testing" the person and checking which person it is by probing how the person responds in action. This finding supports the theory that infants use imitative interactions to tell people apart or, more technically, as a way of establishing the numerical identity of people (Meltzoff & Moore, 1992, 1995, 1998). In sum, there is evidence that imitation is a social act and it is used as a tool in social cognition starting from the earliest periods of infancy – even young infants are deploying the imitative response flexibly and with a social-communicative purpose. The use of reciprocal imitation games as a powerful force for establishing social rapport has been well documented in older infants and young children (e.g., Nadel et al., 1999; Meltzoff 1999, 2007a).

Instrumental Imitation: Learning and Memory for Object-Directed Acts

Infant imitation consists of more than the duplication of bodily acts. As early as the second half-year of life, they begin to imitate instrumental acts on objects and soon thereafter learn how to use tools through watching others. For example, by 6 months of age, infants begin to duplicate simple acts such as removing a puppet's glove and shaking it to produce a sound (e.g., Barr, Dowden, & Hayne, 1996; Collie & Hayne, 1999). Throughout the next year infants become more adept at storing multiple behaviors over increasing delays (Barr & Hayne, 2000; Meltzoff & Moore, 1998).

One study of 14-month-old infants that investigated imitation of actions on objects had three important features: (a) 14-month-olds were required to remember multiple different demonstrations, (b) novel acts were used, (c) imitation was tested after a 1-week delay (Meltzoff, 1988b). One of the acts, for example, was to bend forward from the waist and touch a panel with one's forehead, which made the panel illuminate. The infants

were not allowed to touch or handle the objects; they were confined purely to watching the adult's behaviors. They were then sent home for a 1-week delay. Upon returning to the laboratory, the infants were presented with the objects to assess imitation.

The details of the control groups are interesting, because they show that the child's manipulation of the objects after the week delay was based on their memory and imitation. Let us examine more closely what these test groups witnessed in session 1, before the delay. In the imitation group, infants were shown six distinct acts on different objects. In a baseline control group, the adult met the infants in session 1 but did not present the test objects. This control assessed the spontaneous likelihood of the infants producing the target acts after the delay. In a second control group, the adult-manipulation control, the adult played with the same objects during session 1 for the same length of time as in the imitation group; but he did so using different movement patterns. For many stimuli, such as the head-touch gesture, the end-state (the panel light turning on) occurred but was activated through different means than were used in the imitation group. All three groups experienced the same delay and then returned to the laboratory where they were presented with the objects and had their behavior videotaped. The results showed significantly more target acts in the imitation group than in each of the controls, providing clear evidence for imitation of thoroughly novel acts from memory.

Subsequent research has demonstrated that 14-month-olds possess an ability to defer their imitation for a period of at least 4 months (Meltzoff, 1995b). Imitation has been used as a cognitive marker to track the development of infants' recall memory (e.g., Barr & Hayne, 2000; Bauer, Wenner, Dropik, Wewerka, & Howe, 2000; Carver & Bauer, 2001; Herbert, Gross, & Hayne, 2006; Meltzoff & Moore, 1998). Researchers have also begun to connect findings of imitation-after-delay to measures of infant neural activity (e.g., Bauer, Wiebe, Carver, Waters, & Nelson, 2003; Carver, Bauer, & Nelson, 2000). Results from both deferred imitation and event-related potential (ERP) measures on the same infants indicate that by about 10 months of age there is a correlation between the memory measured via behavioral imitation and the brain (ERP) measures (e.g., Carver et al., 2000). Factors known to improve adult recall memory have also been shown to improve infants' abilities to imitate after a delay. 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), and hearing a verbal narration of a set of acts has been shown to improve 18-month-olds' later imitation of those behaviors (Hayne & Herbert, 2004).

Whether or not the adult actions have salient, causal effects also appears to influence infants' and young children's imitation of those acts. In a study by Hauf, Elsner, & Aschersleben (2004), 12- and 18-month-olds saw an adult act in different ways on an object (e.g., shake versus place it). The infants were more likely to imitate each of these behaviors when it led to an effect (the production of a sound). Young children are also better able to imitate the steps and sequence of a series of actions when the acts build upon one another to achieve an outcome, such as putting soap on a sponge before washing, so-called "enabling" versus "arbitrary" action sequences (e.g., Barr & Hayne, 1996; Bauer, 1992; Bauer & Mandler, 1989).

In summary, infants have been shown to imitate multiple acts, including novel acts, after lengthy delays. As we will see, this is a cognitive ability that infants deploy in many

social situations. Human parents engage in purposeful pedagogy, often demonstrating a new skill at a time and place far removed from when the infant has an opportunity or reason to imitate. Taken as a whole, the studies on the imitation of object-related acts suggest that infants are well equipped to take advantage of these pedagogical lessons – learning and remembering the observation and deploying the skill at another time.

Imitation from Television

Infants are not limited to imitating live models. They have also been shown to imitate televised acts. In a study by Meltzoff (1988a), 14- and 24-month-olds viewed a video in which an adult demonstrated an action on an object. When given the objects to manipulate after either a brief or a 24-hour delay, the infants reproduced the target act. Even though the infants had never handled the real object before, they were able to remember and transfer what they witnessed in the televised display to govern their own motor plans in the real world with the 3-D object. Repacholi (2009) replicated and extended this finding of infant imitation from TV, finding that infants were less likely to imitate an act if the adult on TV adopted a negative as opposed to a positive or neutral expression upon completing the demonstration.

Although infants can learn from televised displays, they show lower rates of imitation compared to when they observe the behaviors of 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). Scientists are investigating the reasons for this so-called "video-deficit effect."

One possible account of the video-deficit effect may be the transformation between two-dimensional (2D) and three-dimensional (3D), real-world 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 using a novel touch-screen technology (Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009). In one cross-dimension condition, the infants were first shown how to activate a toy via a television presentation and then given the chance to reenact this on a 3D version of what had been shown on the television. This is the standard test. In the novel cross-dimension condition infants were shown how to activate a toy by pushing a button on a real (3D) object and subsequently were tested using a television 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 standard televised imitation tasks is that they require infants to generalize across dimensions. It is not simply that they cannot learn acts from television, because they do well on tests involving a 2D to 2D assessment. Transferring information across dimensions presents them with a special problem.

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 necessarily a concomitant of

television, but it is a correlate if interactive television is not used). Meltzoff et al. (2009) argued that this social interactivity is important for learning and imitation and that this too contributes to the video-deficit effect. Nielsen, Simcock, & 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.

Imitation of Peers

Peers can be important sources of information about how to manipulate objects and interact with others. Many infants spend a great deal of time interacting with other children. Families often have multiple siblings, and increasingly, infants attend day care and socialize with peers. In a recent study, preschoolers have been shown to prefer peers over adults as informants in some situations (VanderBorght & Jaswal, 2009). Studies of imitation suggest that peers' and siblings' acts are also important examples of appropriate social behavior for infants (e.g., Abramovitch & Grusec; 1978; Barr & Hayne, 2003; Hanna & Meltzoff, 1993).

In an experiment by Hanna and Meltzoff (1993) 14-month-old naïve infants observed "tutor infants" who had been previously trained to play with toys in novel ways. After observing the peer play with five objects, the naïve infants left the test room. When they later returned and were presented with the test objects in the absence of the peer, the (previously) naïve infants imitated the actions that had been demonstrated by the peer tutors. Further research extended this investigation to a day-care setting in which the tutor infant played with objects as part of a large group rather than in a one-to-one peer setting. The naïve infants were not allowed to approach or touch the toys in this setting. After a 2-day delay, a new experimenter (not the one who had accompanied the tutor) brought a bag of objects to the infants' homes and presented them to the infant as their behavior was video-recorded. Neither the parent nor the new experimenter had been present in the day-care center 2 days earlier. Correct imitation could only derive from the memory of the once naïve infant. The results showed significant imitation relative to control infants (who had not seen the model's act in the day-care center), providing evidence that infants can learn from peers and transfer the information they have learned across contexts, for example, from daycare to home. Such cross-context generalization is crucial if imitation is to serve important pedagogical functions in infant learning and development.

Recent 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 (Flynn & Whiten, 2008; Horner, Whiten, Flynn, & de Waal, 2006). In these studies, a novel tool-use behavior was initially taught to a 3- or 5-year-old child, who then served as a tutor to a second child, and so on, through five children. Children who participated in the peer-to-peer learning chains showed striking consistency in their manipulation of the tools. Taken together with the earlier studies of infants, we can conclude that imitation is a useful means for transmitting information

from one infant or child to the next over long delays both inside and outside of laboratory settings (for example in day-care centers and preschools).

Regulating Imitation: Social and Causal Information

Infants do not imitate indiscriminately, automatically, or compulsively. Studies show that infants are more likely to imitate a model that engages them socially. In an experiment by Brugger, Lariviere, Mumme, & Bushnell (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 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 them versus acting aloof.

Csibra & Gergely (2006) suggested that human demonstrations involve many cues, including eye-gaze and purposeful actions that set up an expectation of a pedagogical exchange. Such cues allow the adult to indicate to the child that instruction is being given and to isolate what is being taught. The social engagement and intentional production of a behavior may also be a cue for young children that the act is purposeful (e.g., Gergely, Bekkering, & Király, 2002) and causally relevant for completing a task (Lyons, Young, & Keil, 2007) and therefore ought to be copied rather than skipped over.

Studies have isolated important parameters that seem to control imitation. For example, Meltzoff (2007b, experiment 3) discovered that infants vary their imitation depending on whether or not they understand that a person is causally involved in producing an outcome. Infants are more likely to reenact the event if they think that a person has caused an outcome as opposed to the same event happening by itself with no human intervention. This work has been replicated and extended using more complex tests of causal reasoning (Bonawitz, Saxe, Gopnik, Meltzoff, Woodward, & Shulz, 2010). In related work examining particular stimulus conditions that maximize imitation, Slaughter and Corbett (2007) found that 12- and 18-month-old infants produced more target acts after watching a person or human hands, versus hands with mittens or mechanical pincers produce the outcome on an object (see also Meltzoff 1995a for further work on mechanical pincers). However, we also know that under some circumstances infants imitate acts shown by nonhuman agents such as puppets (Johnson, Booth, & O'Hearn, 2001). One active line of research on infant imitation is directed at discovering how animate or human the display must be in order for infants to imitate and infer intention, and what constitutes an "agent" that motivates imitation (Meltzoff, 2007b). A related line of work examines how infants integrate imitation of others with their own independent problem-solving and prior knowledge about the physical outcomes and endpoints (Huang & Charman, 2005; Want & Harris, 2002; Williamson, Meltzoff, & Markman, 2008; Williamson, Jaswal, & Meltzoff, 2010).

Young children will sometimes reproduce behaviors they see even in cases where such precision in copying the model is irrelevant or counterproductive to reaching an instrumental end (Horner & Whiten, 2005; McGuigan, Whiten, Flynn, & Horner, 2007; Nagell, Olguin, & Tomasello, 1993; Nielsen, 2006; Tennie, Call, & Tomasello, 2006; Whiten, Custance, Gomez, Teixidor, & Bard, 1996). For example, Nielsen found that 18- and 24-month-olds (though not 12-month-olds) imitated an act they observed even though it was not, strictly speaking, necessary for achieving the desired outcome. This tendency to reproduce irrelevant behaviors has been shown to persist and even increase through early childhood and is sometimes called "over-imitation" (McGuigan et al., 2007). One hypothesis is that young children are more likely to imitate an irrelevant act or over-imitate if they are unsure about what aspect of the display is causally necessary, or unsure what the adult intends to communicate by acting in the way she does. In such cases of ambiguity children might adopt the strategy of copying "everything the adult does." When children have their own ideas or prior knowledge about how to best reach the outcome, research shows they are less likely to over-imitate (e.g., Williamson et al., 2008).

Regulating Imitation: Emotional Eavesdropping and Beyond the Dyad

It is not necessary for children to be directly involved in an interaction to learn and imitate. They can learn as a bystander – as a third party who is watching the interactions of others. This is adaptive because infants can learn the ways of the culture and the likely emotional consequences of acting in specific ways simply by watching the social dynamics of others. Other people's emotional responses also play a role in regulating imitation.

In an imitation-eavesdropping procedure designed to test infants' learning from watching the emotional interchange between others, 18-month-olds seated at a table observed an interaction between two adults (Repacholi & Meltzoff 2007; Repacholi, Meltzoff, & Olsen, 2008). When one adult performed a seemingly ordinary act, such as pushing a button to make a sound, the second adult responded with an angry outburst saying, "that is so irritating!" while looking at the first adult and speaking in an angry tone of voice. The results showed that infants were less likely to imitate the act that caused the adult's anger if the previously angry adult was watching them; but, interestingly, if that adult left the room, infants were as likely to imitate as when the adult had not displayed anger. The imitation of the act was regulated by a combination of the adult's gaze and her previous emotional reactions.

In a further study, the emoter stayed in the room in all conditions. After her emotional display, the emoter adopted a passive expression and either (a) turned her back so that she was not looking at the child or (b) faced the child with a neutral expression. The infant was then given the object to manipulate. The infants in the anger-back condition displayed significantly higher levels of imitation relative to those in the anger-face group. Repacholi et al. (2008) next zeroed in on the role of adult gaze. The studies followed the same general procedure but in the critical condition the previously angry emoter either:

(a) stayed facing the child but picked up a magazine to read (so not looking at the child); or (b) stayed facing the child but closed her eyes (so not looking at the child). Children were significantly more likely to imitate the demonstrator's act when the emoter could not visually monitor their behavior than in comparison groups that were identical except that the emoter could see them. If the previously angry adult was visually monitoring their behavior, they did not tend to imitate, but as long as the adult was not able to see them (reading a magazine, eyes closed), they quickly grabbed the toy and reproduced the act.

These results are important for theory because they go beyond classical social referencing paradigms (e.g., Feinman, Roberts, Hsieh, Sawyer, & Swanson, 1992) and cannot be explained by emotional contagion. In these eavesdropping studies the child had the chance to "catch" the adult's emotion equally well in all of the conditions in which the emoter became angry. If the children simply caught the adult's angry emotion and were frozen and loathe to imitate, they would not have imitated in any of the angry conditions. That is not what happened. They were perfectly happy to imitate in the conditions where the adult had been angry and then left the room, turned her back, and even when she was facing them but was looking at a magazine or sitting with eyes closed. Children's actions were influenced by their memory of the adult's past emotions. The infants' behavior varied as a function of whether that previously angry adult could see the children's actions.

Taken together this work shows that infants regulate their behavior based on whether or not the previously angry person has *visual access* to their own actions. This contributes to a growing body of research demonstrating that infants and young children do not blindly or automatically imitate others' actions (e.g., Bekkering, Wohlschläger, & Gattis, 2000; Carpenter, Call, & Tomasello, 2005; Gleissner, Meltzoff, & Bekkering, 2000; Schulz, Hooppell, & Jenkins, 2008; Williamson & Markman, 2006; Williamson et al., 2008). Children *regulate* their imitative responses depending on a number of factors, including the emotional reactions of others and whether their acts are being monitored. This establishes that children's imitation is flexible and selective, rather than fixed, automatic, and compulsory. We have learned a great deal about the factors governing when, what, and whom children imitate; this continues as an active line of inquiry, with the aim of utilizing imitation research to address fundamental questions about early emergence of executive functions in toddlerhood.

Imitation, Goals, and Intentions

Infants do not always see successful and well-formed behavior. In the everyday world, people make mistakes. They fail to fulfill their intentions. Adults are able to identify a person's intended goal from unsuccessful behaviors; a batter does not have to hit a ball in order for an adult to recognize that intention. Even these unsuccessful attempts present opportunities for learning. Developmental research suggests that infants also have abilities to understand and utilize the behaviors of others in this sophisticated way; they read into adults' unsuccessful behaviors and reproduce intended outcomes.

Initial demonstrations of infants' abilities to understand the intentions underlying adults' acts used the "behavioral reenactment procedure." In one such study, 18-month-olds saw an adult perform an unsuccessful act (Meltzoff, 1995a, 2007b). For example, the adult pulled on both ends of a barbell-shaped object as if to pull it apart, but one of his hands slipped off the end. The adult repeated the pulling and slipping several times, but the infants never saw the actor complete the underlying goal of separating the toy. The experimental question was what they would take from the adult's demonstration. Would they copy the adult's physical actions and slip their fingers from the toy, or would they infer the intended, but never seen act by separating the pieces of the object?

When given the barbell during the test phase of the experiment, the infants demonstrated their understanding of the adult's intended goal by deliberately pulling the object apart. In fact, their rates of separating the object were comparable to those of a group of infants who saw an adult successfully complete that act and significantly above both those of a baseline group and a second control group who saw the adult manipulate the object but not demonstrate the intention or target act. These results show that toddlers are able to look beyond the surface form of the movements and reproduce what the adult intended to do.

An additional manipulation using the behavioral reenactment procedure further supports the proposal that infants' interpretation of actions is related to their understanding of underlying goals. In this experiment, 18-month-old infants saw a set of mechanical pincers manipulate the barbell-shaped object. The ends of the object were each held in a pincer, and each pincer was mounted on a pole. This contraption did not look human (or even animate), but it closely matched the spatiotemporal movements that adults used when acting on the barbell. The infants watched as the poles moved apart and a pincer slipped off of one end of the object, providing a good match for the spatiotemporal movements made by the adult in the unsuccessful demonstration condition (Meltzoff, 1995a).

In contrast to when the adult was unsuccessful, the infants who saw the inanimate device slip off the end of the barbell rarely pulled the object apart when given an opportunity to act on it. They readily picked up and handled the object, but they were no more likely to complete that target act than a baseline control group of infants who did not see a demonstration at all. The infants did not identify any overarching goal from the movements of this mechanical device. These results suggest that infants make different attributions to people than to clearly inanimate devices.

Using a much simpler type of task, younger infants have also been shown to profit from others' incomplete behaviors. In a simplified case of "act completion" where the target did not have to be mentally created (as in the foregoing work), but rather was an endpoint object in the visual field or at the end of the reach trajectory, infants who saw an adult strain to reach one of two toys are more likely to reach to and choose that specific object to play with versus the other object (Hamlin, Hallinan, & Woodward, 2008; see also Brandone & Wellman, 2009).

Toddlers can also distinguish ill-formed, accidental acts from purposeful action sequences, especially when these are accompanied by verbal markers. Carpenter, Akhtar, and Tomasello (1998) showed that 18-month-olds are more likely to imitate actions that are verbally and behaviorally marked as purposeful ("There!") versus accidental ("Woops!"). Additionally, when an adult fails to complete a behavior using specific means, infants and

young children use that information to guide how they approach the task (Carpenter, Call, & Tomasello, 2002; Nielsen, 2006; Want & Harris, 2001). For example, Nielsen found that 12-month-olds were more likely to use a tool when an adult's failure without the tool suggested that the tool was necessary. Overall, this line of research suggests that infants are adept at learning from others' behaviors, even their unsuccessful acts, which they use as a basis for inferring the adults' underlying goals and intentions.

Enduring Theoretical Questions in Developmental Science

Infant imitation addresses enduring theoretical issues in developmental science and psychology more generally. We here consider five enduring issues: (a) self–other mapping and the sense that others are "Like Me," (b) the equivalence between perception and production, (c) neural mirroring systems, (d) roots of "theory of mind," and (e) the early identification and treatment of autism.

Others "like me"

There is now substantial evidence that infants are able to detect similarities between their own acts and those produced by others, what Meltzoff (2007a) calls the "Like-Me" aspects of imitation. This is demonstrated, for example, by studies in which 14-month-old infants are presented with two adults who are sitting side-by-side and acting on toys. Only one of the adults is imitating the infant's own actions, and the other is performing control actions on a matching toy (Meltzoff, 2007a). The results show that infants systematically choose to look longer and smile more at the adult who is imitating their own acts. They prefer the adult who is acting "Like Me", probably because of a feeling of kinship and rapport with others who act like they do. Reciprocal imitation provides a kind of social bond between the self and like-minded (or at least like-acting) others. It is a key foundation for the development of more sophisticated forms of social cognition, because imitation and reciprocal imitation exchanges "highlight" social agents in the world to which infants direct attention and from whom they learn.

Perception–production equivalence

Studies of infant imitation directly inform theories about perception and action coupling. In order for infants to imitate, they must at some primitive level recognize equivalence between the acts they see others do and the acts they do themselves. Meltzoff and Moore (1997) proposed the AIM (active intermodal mapping) theory to account for facial imitation. According to this idea, infants map information about human acts into a common *supramodal* framework. The representation of others' behavior is used as the model against which infants compare the state of their own body. When there is a mismatch, infants are able to create an action plan to bring the self and other into congruence. Infants are able to observe the act of another, store a representation of it, and to use this internal model to correct and refine their matching acts at a later time. Such correction of the

imitative reactions has been documented in numerous studies (Meltzoff & Moore, 1997), underscoring that the imitative response involves active mapping between self and other. Of course, this does not mean that the infant's sense of self is like the adult's – it is not. It does mean, however, that the infant has a metric of equivalence between perception and production. There is a connection between self and other at the level of *shared acts* right from the earliest periods of infancy. This basic connection to other people, and the capacity to accelerate one's own learning by observing the acts of others, has cascading developmental consequences.

Neural mirroring systems and developmental social-cognitive neuroscience

A third enduring issue is the neural basis of imitation and the representation of action. This topic has garnered increased attention due to the report of "mirror neurons" in the brain of the monkey. Animal researchers using single-cell recording measures with monkeys found 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). Noninvasive brain imaging techniques (fMRI, MEG) have since found evidence for shared neural circuitry for the observation and execution acts in adult humans (e.g., Chaminade, Meltzoff, & Decety, 2005; Hari & Kujala, 2009; Iacoboni, 2005; Iacoboni et al., 1999; Jackson, Meltzoff, & Decety, 2006; Meltzoff & Decety, 2003; Rizzolatti, Fadiga, Fogassi, & Gallese, 2002). To date, the origins of the neural mirroring system is not well understood in any species (Lepage &Théoret, 2007). Neuroscience studies with newborn monkeys would be valuable (equivalent to what has been carried out in human newborn imitation), but this has yet to be done.

At the present time, the behavioral evidence about human infant imitation goes beyond what can be explained by canonical mirror neurons alone. For one thing, monkeys have mirror neurons but are poor imitators, so this immediately suggests that something more is needed to account for the imitative effects in humans. Second, mirror neurons are more compatible with direct resonance than with the details reported about infant imitation. There are five pieces of empirical evidence showing that human infants go beyond direct motor resonance when imitating. Human infants imitate from *memory* often overriding what they currently see; they *actively correct* their behavior rather than immediately resonating with it; they reenact *goals* and intentions (even when the goal goes beyond simple effects of filling in the endpoint); they imitate *novel* acts where prior associations and resonances do not apply; and they *selectively imitate and regulate* their imitative actions indicating control and flexibility. Such effects go beyond a mirror neuron account taken in isolation, and imply a more complex neural system including top-down influences.

The time is ripe for work examining the neural underpinnings of infant imitation and perception–action coupling more generally. Developmental social-cognitive neuroscience work is beginning to emerge using imitation and other tasks to examine infant neural responses. The results show EEG desynchronization (mu rhythm suppression), particularly at central scalp sites, when 9- to 14-month-old infants either watch someone else perform an act or perform the act themselves (e.g., Marshall, Young, & Meltzoff, 2010;

Southgate, Johnson, Osborne, & Csibra, 2009). Such EEG approaches will be useful in examining the neural mechanisms underlying perception–production parity in infancy, and how imitation and neural mirroring systems co-develop.

Roots of "theory of mind"

A fourth enduring issue concerns the developmental origins of understanding others' minds, sometimes called "mentalizing" or "theory of mind." In order to imitate behaviors, infants have to link their own and another's body parts. This seems difficult enough, but the studies on inferring others' goals and intentions go a step further. In this case, the infant must infer the intended act without seeing the outcome. Meltzoff's (2007a, b) "Like-Me" theory proposes that infants can use self-experience as a framework for understanding others, because they recognize the *equivalence* in the acts of self and other.

The "Like-Me" theory provides a mechanism of change in early mentalizing (Meltzoff & Brooks, 2008). For example, infants develop experience with their own bodies and their own wants, goals, and intentions. When they want something, they reach for it. This first-person experience then allows infants to recognize that when another acts "Like Me" that person has the same underlying mental states that the child has when the child acts that way. Infants can act as the other does (imitation) and can also project to others who act like them what they themselves feel when acting that way. The fundamental similarity at the level of acts allows infants to realize other deeper similarities between self and other – including that others have goals, intentions, perceptions, and emotions that underlie their behaviors just like the infant does. In this view, "mentalizing" and "theory of mind" starts from more primitive beginnings – the recognition of *equivalence between the acts* of self and other, as first manifest in action imitation.

Imitation and autism

A fifth enduring issue raised by infant imitation concerns clinical psychology. Making links between self and other is crucial for smooth functioning in our social world (e.g., Beebe, Rustin, Sorter, & Knoblauch, 2003; Beebe, Sorter, Rustin, & Knoblauch, 2003). This is dramatically exemplified by the behavior of individuals with autism. This disorder is characterized by impaired abilities to interact and communicate with others. Autism has been described as a kind of "mind-blindness" (Baron-Cohen, 1995), because individuals with this disorder do not seem to understand others as mental agents. Individuals with the disorder have been shown to have deficits in a cluster of social competencies including imitation, gaze following, and understanding emotions (e.g., Dawson, Meltzoff, Osterling, & Rinaldi, 1998; Hobson & Meyer, 2005; Mundy, 2009; Mundy & Newell, 2007; Nadel, 2006; Rogers, 1999, 2006; Toth, Munson, Meltzoff, & Dawson, 2006). Advances in understanding infant imitation promise to help in two ways. First, imitation provides a sensitive preverbal measure for identifying children with this disorder at earlier ages. Second, training on imitation may provide efficacious treatment that boosts children's understanding of social cognition more generally (Rogers & Williams, 2006).

The Future: Imitation and an Interdisciplinary Science of Learning

Humans are distinguished from other species by their remarkable ability to teach and learn in social situations (Csibra & Gergely, 2006; Meltzoff et al., 2009; Tomasello, 1999). Imitation contributes to these accomplishments in several ways. For one, imitation provides a mechanism for even young infants to socially engage the people around them. Shared body movements allow infants to take turns interacting with and identifying the people around them. Second, through imitation infants can learn the specific behaviors, customs, and practices of their culture, including techniques for using simple tools. Infants learn about these things in a variety of situations, including through overt pedagogy, by overhearing exchanges and, to some extent, from observing the acts of others through cultural artifacts such as television and other media. From the viewpoint of philosophy of mind, however, perhaps the fundamental insight emerging from infant imitation concerns the growth of social cognition and intentionality. Infants' representation of other people's acts as something that *can be imitated* is a key ingredient to their coming to appreciate that they share something deeper with humans: An understanding of shared minds develops from a prior understanding of shared acts. Infant imitation is thus not only a window into infant social-cognitive development it is a mechanism by which infants learn about themselves, other people, and the relationship between the two. Through imitation infants become full-fledged, practicing members of their individual culture.

A number of disciplines are beginning to take advantage of the findings and theories regarding infant imitation. Evolutionary biologists and primatologists are using imitation to investigate the social learning abilities of other species to determine what is or is not uniquely human. Computer scientists and engineers are being inspired by infant imitation to design robots that can learn from observing the skilled actions of experts. Educators are increasingly paying closer attention to how children learn through observation, role-modeling, and informal apprenticeship. These mechanisms, which start in infancy, are highly motivating and emotionally satisfying for children as they learn a wide variety of skills and practices. Educators see the value of capitalizing on the natural power of observational and imitative learning and are beginning to make use of it in learning technologies and designed environments to motivate student learning both inside and outside school (Bell, Lewenstein, Shouse, & Feder, 2009). In summary, imitation is emerging as a topic that unites developmental science, clinical psychology, evolutionary biology, neuroscience, artificial intelligence, and education. Infant imitation is thus playing a key role in galvanizing interdisciplinary research on a "new science of learning" (Meltzoff et al., 2009) connecting brain, development, education, and technology.

Acknowledgments

The order of authorship is alphabetical; the authors shared equally in the writing of this chapter. We gratefully acknowledge financial support from grants from the National Science Foundation LIFE Center (SBE-0354453) and the National Institutes for Health

(HD-22514). The views expressed in this chapter are the authors' and do not necessarily represent those of NSF or NIH. We thank Calle Fisher and Craig Harris for assistance in preparing this chapter, and K. Moore, A. Gopnik, P. Kuhl, and the LIFE Center team for helpful discussions on the issues raised here.

References

Abramovitch, R., & Grusec, J. E. (1978). Peer imitation in a natural setting. *Child Development, 49*, 60–65.

Bard, K. A. (2007). Neonatal imitation in chimpanzees (Pan troglodytes) tested with two paradigms. *Animal Cognition, 10*, 233–242.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind.* Cambridge, MA: MIT Press.

Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behavior & Development, 19*, 159–170.

Barr, R., & Hayne, H. (1996). The effect of event structure on imitation in infancy: Practice makes perfect? *Infant Behavior & Development, 19*, 253–257.

Barr, R., & Hayne, H. (1999). Developmental changes in imitation from television during infancy. *Child Development, 70*, 1067–1081.

Barr, R., & Hayne, H. (2000). Age-related changes in imitation: Implications for memory development. In C. Rovee-Collier, L. P. Lipsitt, & H. Hayne (Eds.), *Progress in infancy research* (Vol. *1*, pp. 21–67). Mahwah, NJ: Erlbaum.

Barr, R., & Hayne, H. (2003). It's not what you know, it's who you know: Older siblings facilitate imitation during infancy. *International Journal of Early Years Education, 11*, 7–21.

Barr, R., Muentener, P., & Garcia, A. (2007). Age-related changes in deferred imitation from television by 6- to 18-month-olds. *Developmental Science, 10*, 910–921.

Barr, R., Muentener, P., Garcia, A., Fujimoto, M., & Chávez, V. (2007). The effect of repetition on imitation from television during infancy. *Developmental Psychobiology, 49*, 196–207.

Bauer, P. J. (1992). Holding it all together: How enabling relations facilitate young children's event recall. *Cognitive Development, 7*, 1–28.

Bauer, P. J., & Mandler, J. M. (1989). One thing follows another: Effects of temporal structure on 1- to 2-year-olds' recall of events. *Developmental Psychology, 25*, 197–206.

Bauer, P. J., Wenner, J. A., Dropik, P. L., Wewerka, S. S., & Howe, M. L. (2000). Parameters of remembering and forgetting in the transition from infancy to early childhood. *Monographs of the Society for Research in Child Development, 65*(4, Serial No. 263), 1–213.

Bauer, P. J., Wiebe, S. A., Carver, L. J., Waters, J. M., & Nelson, C. A. (2003). Developments in long-term explicit memory late in the first year of life: Behavioral and electrophysiological indices. *Psychological Science, 14*, 629–635.

Bauer, P. J., Wiebe, S. A., Waters, J. M., & Bangston, S. K. (2001). Reexposure breeds recall: Effects of experience on 9-month-olds' ordered recall. *Journal of Experimental Child Psychology, 80*, 174–200.

Beebe, B., Rustin, J., Sorter, D., & Knoblauch, S. (2003). An expanded view of intersubjectivity in infancy and its application to psychoanalysis. *Psychoanalytic Dialogues, 13*, 805–841.

Beebe, B., Sorter, D., Rustin, J., & Knoblauch, S. (2003). A comparison of Meltzoff, Trevarthen, and Stern. *Psychoanalytic Dialogues, 13*, 777–804.

Bekkering, H., Wohlschläger, A., & Gattis, M. (2000). Imitation of gestures in children is goal-directed. *The Quarterly Journal of Experimental Psychology, 53A*, 153–164.

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.). (2009). *Learning science in informal environments: People, places and pursuits*. Washington, DC: National Academy Press.

Bonawitz, E. B., Saxe, R., Gopnik, A., Meltzoff, A. N., Woodward, J., & Shulz, L., (2010). Just do it? Investigating the gap between prediction and action in toddlers' causal inferences. *Cognition, 115*, 104–117.

Brandone, A. C., & Wellman, H. M. (2009). You can't always get what you want: Infants understand failed goal-directed actions. *Psychological Science, 20*, 85–91.

Brugger, A., Lariviere, L. A., Mumme, D. L., & Bushnell, E. W. (2007). Doing the right thing: Infants' selection of actions to imitate from observed event sequences. *Child Development, 78*, 806–824.

Carpenter, M. (2006). Instrumental, social, and shared goals and intentions in imitation. In S. J. Rogers & J. H. G. Williams (Eds.), *Imitation and the social mind: Autism and typical development* (pp. 48–70). New York: Guilford.

Carpenter, M., Akhtar, N., & Tomasello, M. (1998). Fourteen- through 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behavior & Development, 21*, 315–330.

Carpenter, M., Call, J., & Tomasello, M. (2002). A new false belief test for 36-month-olds. *British Journal of Developmental Psychology, 20*, 393–420.

Carpenter, M., Call, J., & Tomasello, M. (2005). Twelve- and 18-month-olds copy actions in terms of goals. *Developmental Science, 8*, F13–F20.

Carver, L. J., & Bauer, P. J. (2001). The dawning of a past: The emergence of long-term explicit memory in infancy. *Journal of Experimental Psychology: General, 130*, 726–745.

Carver, L. J., Bauer, P. J., & Nelson, C. A. (2000). Associations between infant brain activity and recall memory. *Developmental Science, 3*, 234–246.

Chaminade, T., Meltzoff, A. N., & Decety, J. (2005). An fMRI study of imitation: Action representation and body schema. *Neuropsychologia, 43*, 115–127.

Collie, R., & Hayne, H. (1999). Deferred imitation by 6- and 9-month-old infants: More evidence for declarative memory. *Developmental Psychobiology, 35*, 83–90.

Csibra, G., & Gergely, G. (2006). Social learning and social cognition: The case for pedagogy. In Y. Munakata &. M. H. Johnson (Eds.), *Processes of change in brain and cognitive development: Attention and performance XXI* (pp. 249–274). New York: Oxford University Press.

Dawson, G., Meltzoff, A. N., Osterling, J., & Rinaldi, J. (1998). Neuropsychological correlates of early symptoms of autism. *Child Development, 69*, 1276–1285.

Feinman, S., Roberts, D., Hsieh, K., Sawyer, D., & Swanson, D. (1992). A critical review of social referencing in infancy. In S. Feinman (Ed.), *Social referencing and the social construction of reality in infancy* (pp. 15–54). New York: Plenum.

Ferrari, P. F., Visalberghi, E., Paukner, A., Fogassi, L., Ruggiero, A., & Suomi, S. J. (2006). Neonatal imitation in rhesus macaques. *PLoS Biology, 4*, 1501–1508.

Flynn, E., & Whiten, A. (2008). Cultural transmission of tool use in young children: A diffusion chain study. *Social Development, 17*, 699–718.

Gallese, V. (2003). The manifold nature of interpersonal relations: The quest for a common mechanism. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 358*, 517–528.

Gergely, G., Bekkering, H., & Király, I. (2002). Rational imitation in preverbal infants. *Nature, 415*, 755.

Gleissner, B., Meltzoff, A. N., & Bekkering, H. (2000). Children's coding of human action: Cognitive factors influencing imitation in 3-year-olds. *Developmental Science, 3*, 405–414.

Hamlin, J. K., Hallinan, E. V., & Woodward, A. L. (2008). Do as I do: 7-month-old infants selectively reproduce others' goals. *Developmental Science, 11*, 487–494.

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

Hari, R., & Kujala, M. (2009). Brain basis of human social interaction: From concepts to brain imaging. *Physiological Reviews, 89*, 453–479.

Hauf, P., Elsner, B., & Aschersleben, G. (2004). The role of action effects in infants' action control. *Psychological Research, 68*, 115–125.

Hayne, H., Barr, R., & Herbert, J. (2003). The effect of prior practice on memory reactivation and generalization. *Child Development, 74*, 1615–1627.

Hayne, H., & Herbert, J. (2004). Verbal cues facilitate memory retrieval during infancy. *Journal of Experimental Child Psychology, 89*, 127–139.

Hayne, H., Herbert, J., & Simcock, G. (2003). Imitation from television by 24- and 30-month-olds. *Developmental Science, 6*, 254–261.

Herbert, J., Gross, J., & Hayne, H. (2006). Age-related changes in deferred imitation between 6 and 9 months of age. *Infant Behavior & Development, 29*, 136–139.

Hobson, R. P., & Meyer, J. A. (2005). Foundations for self and other: A study in autism. *Developmental Science, 8*, 481–491.

Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*). *Animal Cognition, 8*, 164–181.

Horner, V., Whiten, A., Flynn, E., & de Waal, F. B. M. (2006). Faithful replication of foraging techniques along cultural transmission chains by chimpanzees and children. *Proceedings of the National Academy of Sciences, 103*, 13878–13883.

Huang, C.-T., & Charman, T. (2005). Gradations of emulation learning in infants' imitation of actions on objects. *Journal of Experimental Child Psychology, 92*, 276–302.

Iacoboni, M. (2005). Neural mechanisms of imitation. *Current Opinion in Neurobiology, 15*, 632–637.

Iacoboni, M., Woods, R. P., Brass, M., Bekkering, H., Mazziotta, J. C., & Rizzolatti, G. (1999). Cortical mechanisms of human imitation. *Science, 286*, 2526–2528.

Jackson, P. L., Meltzoff, A. N., & Decety, J. (2006). Neural circuits involved in imitation and perspective-taking. *NeuroImage, 31*, 429–439.

Johnson, S. C., Booth, A., & O'Hearn, K. (2001). Inferring the goals of a nonhuman agent. *Cognitive Development, 16*, 637–656.

Klein, A. M., Hauf, P., & Aschersleben, G. (2006). The role of action effects in 12-month-olds' action control: A comparison of televised model and live model. *Infant Behavior & Development, 29*, 535–544.

Lepage, J.-F., & Théoret, H. (2007). The mirror neuron system: Grasping others' actions from birth? *Developmental Science, 10*, 513–523.

Lyons, D. E., Young, A. G., & Keil, F. C. (2007). The hidden structure of overimitation. *Proceedings of the National Academy of Sciences, 104*, 19751–19756.

Marshall, P. J., Young, T., & Meltzoff, A. N. (2010). Neural correlates of action observation and execution in 14-month-old infants: An event-related EEG desynchronization study. *Developmental Science*, in press.

McGuigan, N., Whiten, A., Flynn, E., & Horner, V. (2007). Imitation of causally opaque versus causally transparent tool use by 3- and 5-year-old children. *Cognitive Development, 22*, 353–364.

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

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

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

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

Meltzoff, A. N. (1999). Origins of theory of mind, cognition and communication. *Journal of Communication Disorders, 32*, 251–269.

Meltzoff, A. N. (2007a). "Like me": A foundation for social cognition. *Developmental Science, 10*, 126–134.

Meltzoff, A. N. (2007b). The "Like me" framework for recognizing and becoming an intentional agent. *Acta Psychologica, 124*, 26–43.

Meltzoff, A. N., & Brooks, R. (2008). Self-experience as a mechanism for learning about others: A training study in social cognition. *Developmental Psychology, 44*, 1257–1265.

Meltzoff, A. N., & Decety, J. (2003). What imitation tells us about social cognition: A rapprochement between developmental psychology and cognitive neuroscience. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 358*, 491–500.

Meltzoff, A. N., Kuhl, P. K., Movellan, J., & Sejnowski, T. J. (2009). Foundations for a new science of learning. *Science, 325*, 284–288.

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

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

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

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

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

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

Meltzoff, A. N., & Moore, M. K. (1997). Explaining facial imitation: A theoretical model. *Early Development and Parenting, 6*, 179–192.

Meltzoff, A. N., & Moore, M. K. (1998). Object representation, identity, and the paradox of early permanence: Steps toward a new framework. *Infant Behavior & Development, 21*, 201–235.

Mundy, P. (2009). Lessons learned from autism: An information-processing model of joint attention and social-cognition. In D. Cicchetti & M. R. Gunnar (Eds.), *Minnesota symposia on child psychology: Vol 35. Meeting the challenge of translational research in child psychology* (pp. 59–113). Hoboken, NJ: Wiley.

Mundy, P., & Newell, L. (2007). Attention, joint attention, and social cognition. *Current Directions in Psychological Science, 16*, 269–274.

Myowa, M. (1996). Imitation of facial gestures by an infant chimpanzee. *Primates, 37*, 207–213.

Nadel, J. (2006). Does imitation matter to children with autism? In S. J. Rogers & J. H. G. Williams (Eds.), *Imitation and the social mind* (pp. 118–137). New York: Guilford Press.

Nadel, J., Guérini, C., Pezé, A., & Rivet, C. (1999). The evolving nature of imitation as a format for communication In J. Nadel & G. Butterworth (Eds.), *Imitation in infancy* (pp. 209–234). Cambridge: Cambridge University Press.

Nadel-Brulfert, J., & Baudonniere, P. M. (1982). The social function of reciprocal imitation in 2-year-old peers. *International Journal of Behavioral Development, 5*, 95–109.

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

Nagy, E., & Molnar, P. (1994). Homo imitans or homo provocans? *International Journal of Psychophysiology, 18*, 128.

Nagy, E., & Molnar, P. (2004). Homo imitans or homo provocans? Human imprinting model of neonatal imitation. *Infant Behavior & Development, 27*, 54–63.

Nielsen, M. (2006). Copying actions and copying outcomes: Social learning through the second year. *Developmental Psychology, 42*, 555–565.

Nielsen, M., Simcock, G., & Jenkins, L. (2008). The effect of social engagement on 24-month-olds' imitation from live and televised models. *Developmental Science, 11*, 722–731.

Repacholi, B. M. (2009). Linking actions and emotions: Evidence from 15- and 18-month-old infants. *British Journal of Developmental Psychology, 27*, 649–667.

Repacholi, B. M., & Meltzoff, A. N. (2007). Emotional eavesdropping: Infants selectively respond to indirect emotional signals. *Child Development, 78*, 503–521.

Repacholi, B. M., Meltzoff, A. N., & Olsen, B. (2008). Infants' understanding of the link between visual perception and emotion: "If she can't see me doing it, she won't get angry." *Developmental Psychology, 44*, 561–574.

Rizzolatti, G., Fadiga, L., Fogassi, L., & Gallese, V. (2002). From mirror neurons to imitation, facts, and speculations. In A. N. Meltzoff & W. Prinz (Eds.), *The imitative mind: Development, evolution, and brain bases* (pp. 247–266). Cambridge: Cambridge University Press.

Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience, 2*, 661–670.

Rogers, S. J. (1999). An examination of the imitation deficit in autism. In J. Nadel & G. Butterworth (Eds.), *Imitation in infancy* (pp. 254–283). Cambridge: Cambridge University Press.

Rogers, S. J. (2006). Studies of imitation in early infancy: Findings and theories. In S. J. Rogers & J. H. G. Williams (Eds.), *Imitation and the social mind: Autism and typical development* (pp. 3–26). New York: Guilford Press.

Rogers, S. J., & Williams, J. H. G. (Eds.). (2006). *Imitation and the social mind: Autism and typical development*. New York: Guilford Press.

Schulz, L. E., Hooppell, C., & Jenkins, A. (2008). Judicious imitation: Children differentially imitate deterministically and probabilistically effective actions. *Child Development, 79*, 395–410.

Slaughter, V., & Corbett, D. (2007). Differential copying of human and nonhuman models at 12 and 18 months of age. *European Journal of Developmental Psychology, 4*, 31–45.

Southgate, V., Johnson, M. H., Osborne, T., & Csibra, G. (2009). Predictive motor activation during action observation in human infants. *Biology Letters, 5*, 769–772.

Tennie, C., Call, J., & Tomasello, M. (2006). Push or pull: Imitation vs. emulation in great apes and human children. *Ethology, 112*, 1159–1169.

Toth, K., Munson, J., Meltzoff, A. N., & Dawson, G. (2006). Early predictors of communication development in young children with autism spectrum disorder: Joint attention, imitation, and toy play. *Journal of Autism and Developmental Disorders, 36*, 993–1005.

Uzgiris, I. (1999). Imitation as activity: Its developmental aspect. In J. Nadel & G. Butterworth (Eds.), *Imitation in infancy* (pp. 186–206). Cambridge: Cambridge University Press.

VanderBorght, M., & Jaswal, V. K. (2009). Who knows best? Preschoolers sometimes prefer child informants over adult informants. *Infant and Child Development, 18*, 61–71.

Want, S. C., & Harris, P. L. (2001). Learning from other people's mistakes: Causal understanding in learning to use a tool. *Child Development, 72*, 431–443.

Want, S. C., & Harris, P. L. (2002). How do children ape? Applying concepts from the study of non-human primates to the developmental study of "imitation" in children. *Developmental Science, 5*, 1–13.

Whiten, A., Custance, D. M., Gomez, J.-C., Teixidor, P., & Bard, K. A. (1996). Imitative learning of artificial fruit processing in children (*Homo sapiens*) and chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology, 110*, 3–14.

Williamson, R. A., Jaswal, V. K., & Meltzoff, A. N. (2010). Learning the rules: Observation and imitation of a sorting strategy by 36-month-old children. *Developmental Psychology, 46*, 57–65.

Williamson, R. A., & Markman, E. M. (2006). Precision of imitation as a function of preschoolers' understanding of the goal of the demonstration. *Developmental Psychology, 42*, 723–731.

Williamson, R. A., Meltzoff, A. N., & Markman, E. M. (2008). Prior experiences and perceived efficacy influence 3-year-olds' imitation. *Developmental Psychology, 44*, 275–285.

Zack, E., Barr, R., Gerhardstein, P., Dickerson, K., & Meltzoff, A. N. (2009). Infant imitation from television using novel touch screen technology. *British Journal of Developmental Psychology, 27*, 13–26.