11 Imitation in infancy and the acquisition of body knowledge

Susan Jones and Hanako Yoshida

This chapter is about how the study of imitation in infancy can contribute to our understanding of the origins of body knowledge. If we define imitation as the voluntary reproduction of the movements of another, then imitation clearly requires a good deal of such knowledge. The accomplished imitator must know their own body parts – their locations, their interrelations, the possible movements of each, and how to create those movements (singly and in combination) so as to achieve different actions. They must also be able to recognize and represent all of these same aspects of the body and actions of the person to be imitated, and to reliably map their knowledge of their own body onto those representations.

The study of the origins of imitation, then, could also be one way to study the origins of body knowledge. We say "could" because at this time the literature on imitation in infancy has surprisingly little to say about when and how infants develop the requisite knowledge, motor abilities, and motivation to voluntarily reproduce the behaviors of others. However, we believe that new research focused on the mechanisms that account for the emergence and development of imitation will lead to new discoveries and new theoretical directions. In this chapter, we will present data from one study that we believe illustrates this potential – a case study of the development of behavioral matching in one infant across a 12-month period. Data from this study are especially interesting for what they suggest about how infants acquire the body knowledge and body mappings on which the ability to imitate depends.

The fact that so much remains to be discovered about imitation's origins and underpinnings reflects the historical focus of the field. Until the late1970s, mainstream North American researchers attempted to explain imitation as a product of associative learning (e.g. Abravanel *et al.*, 1976; Parton, 1976; Uzgiris and Hunt, 1975). Piaget's (1945) constructivist description of the infant's slow development of imitation was at that time unknown to most American psychologists. The North American discovery of Piaget (e.g. Elkind and Flavell, 1969) was followed by a brief period of developmental research confirming his major observations in American children. However, this enterprise

was soon displaced by research seeking counter-examples to Piaget's stage theory of cognitive development, and in particular to his characterization of the cognitive abilities of infants.

Research on the origins of imitation has provided a particularly startling counter-example, in reports that infants from birth can imitate some simple behaviors from memory, including behaviors that they cannot even see themselves perform (see Anisfeld, 1996; Butterworth, 1999; Meltzoff, 2005 for summaries of this research). These reports have necessarily led theorists to propose that infants are able to represent and compare their own and other people's body parts and body part configurations from birth (e.g. Meltzoff, 2005; 2007a; 2007b; Meltzoff and Moore, 1997). Thus, newborn imitation implies that at least some body knowledge is innate.

Research on infant imitation has produced a range of claims of precocious cognitive feats in both newborns and older infants, including the proposals that newborn infants use imitation to probe the identities of their social partners (Meltzoff and Moore, 1992, 1994), and that older infants choose whether to imitate a model on the basis of their reasoning about contextual and motivational constraints on the model's actions (Gergely *et al.*, 2002; Schwier *et al.*, 2006; Zmyj *et al.*, 2009). However, researchers have paid less attention to questions concerning the development of imitation itself – for example, to the questions of what kinds of behaviors are matched by infants at different ages, or of how and why the quality of infants' behavioral matches may change over time.

The widespread belief that the ability to imitate is innate is likely a major reason for the small amount of work on the development of imitation. The assertion that a feature is innate often acts as a barrier to further psychological research. But many behaviors that appear to be innately hardwired have turned out on further study to have surprising developmental histories (e.g. Gottlieb, 1976, 2007; Kuo, 1932; Lehrman, 1953). For example, the ability of rat pups to find, attach to, and nurse from the mother immediately after birth turns out to depend crucially on prenatal, perinatal, and postnatal learning enhanced by specific sensory experiences provided by the behavior and body contours of the dam and by the compressions of birth itself (Alberts, 2008). Thus, the fact that a behavior appears to be innate should not discourage its study.

Furthermore, there is reason to doubt that the ability to imitate is in fact innate. Below, we will briefly review and weigh both the evidence that newborn infants can imitate and the evidence for an alternative explanation of those findings. We will conclude that the empirical basis for the widespread belief in an innate ability to imitate is not strong: thus, that belief should not discourage research aimed at producing a detailed, empirically based account of the postnatal emergence of imitation.

With such an account in mind, we will next present an overview of the comparatively sparse evidence on infants' imitative abilities beyond the

newborn period. In general, the data indicate that infants are not able to imitate specific motor movements before their second year, although they may reproduce *effects* that they have observed – that is, they may *emulate* (Tomasello, 1998) – at earlier ages. The evidence also suggests that the ability to imitate is not a modular competency of the sort that could be inherited as a unit. Instead, it appears more likely to be a dynamic system – that is, a gradually emerging product of a complex of different cognitive, social, and motor competencies, each developed from a mixture of inherited and acquired features (e.g. Thelen and Smith, 1994).

In the remainder of the chapter we will focus on the particular component of imitation that is relevant to the topic of this book. That component is a competency in matching one's own body parts and actions to the body parts and actions of others. We will describe the development of behavioral matching in one infant from 3 to 15 months of age. The nature of this infant's progress in matching the behaviors modeled by her mother suggests that a potential mechanism for acquiring early body representations and body mappings is embedded in everyday imitative interactions between infants and their social partners. The mechanism we have in mind does not involve infants' imitations of others, for which body representations and interpersonal body mapping may well be prerequisites. Instead, it depends on the high number of interactions in which others imitate the infant.

Can newborn infants imitate?

The central questions in the study of cognitive development concern the origins of knowledge and of the processes by which knowledge is acquired, stored, retrieved, processed, and applied. The claim that newborn infants can imitate is a very important claim for the field because imitation requires quite a bit of knowledge, and imitation in newborns would be evidence that at least some of the required knowledge is innate. Meltzoff (2007a, 2007b; Meltzoff and Moore, 1997) has proposed that newborn infants possess a mechanism that automatically matches visual input from the behavior of others to mental representations of the infant's own behaviors to produce imitation. Similarly, neuroscientists have cited newborn imitation as support for the idea that a system of "mirror neurons" automatically matches observed behaviors with motor programs for performance of those same behaviors from birth (e.g. Iacoboni *et al.*, 1999; Rizzolatti and Craighero, 2004). Because the claim that newborns imitate is so important (and, on the face of it, so improbable), we should not accept it unless compelled by the evidence to do so. In our view, the best evidence for imitative abilities at birth is open to a second, more plausible explanation. Jones (2009a, 2009b) has recently laid out this view in some detail, and we will not repeat the entire discussion here, but will summarize the evidence and arguments.

The evidence for newborn imitation consists of multiple reports that newborn infants have selectively increased their rates of production of certain behaviors when in the presence of a model producing the same behaviors. What is actually observed in such studies, however, is not imitation. What is observed is behavioral matching: and imitation is only one of several reasons why the behaviors of two people might match (e.g. Want and Harris, 2002). While we follow the convention of referring to "newborn imitation" studies, we should bear in mind that behavioral matching is the observed phenomenon, whereas imitation is an interpretation of the observed phenomenon.

Infants in newborn imitation studies have reportedly matched adult models of a range of behaviors, including mouth opening, tongue protruding, sequential finger movements, pouting (e.g. Meltzoff and Moore, 1977), tongue protruding to the side (Meltzoff and Moore, 1994), head-circling (Meltzoff and Moore, 1989), and index finger movements (Nagy *et al.*, 2007). The list is made up entirely of behaviors that newborn infants commonly do. On the one hand, this is necessarily true: an experimenter cannot ask a neonate to imitate a behavior that is not yet in the infant's repertoire. On the other hand, we could be much more confident that an infant was imitating if they matched a behavior that they were very unlikely to produce spontaneously. For example, if an older infant watched a model put a puppet on his head, then put the puppet on their own head, we would infer that the infant's behavior was imitative because the probability that the infant would spontaneously put the puppet on their head was small.

Unfortunately, we cannot think of a single novel action by which imitation of low probability behavior in newborns could be tested. Still, the fact that all of the behaviors matched by infants in imitation experiments are also frequently produced by infants in everyday contexts raises questions about the usual conditions for production of those behaviors, and about whether those same conditions play a role in the increased rate of performance observed in imitation experiments. One obvious candidate cause for an increase in frequency of a common newborn behavior in both contexts is an increase in arousal.

Meltzoff and Moore (e.g. 1977, 1983) argued that newborn infants' matching of adult behavior could not be due to an increase in arousal. Increased arousal would be expected either to indiscriminately increase the frequencies of many behaviors, or to increase the frequency of the same "arousal response" across different situations. But newborn infants reportedly match only the specific behaviors they see modeled; and they reportedly match a range of different behaviors. Infants' selective matching of a variety of different behaviors can only be explained as imitation.

However, Meltzoff and Moore's (1977, 1983) characterization of newborn infants' behavior in imitation experiments was challenged by Anisfeld (1996, 2005), who carried out a meta-analysis of the entire body of data on newborn

imitation and found that only one behavior – tongue protruding – was consistently matched. Anisfeld (1996) suggested that tongue protruding might in fact be an arousal response. This proposal is consistent with reports that newborn infants have increased their tongue protruding in response to a range of potentially arousing sensory experiences, including tactile stimulation of their palms (Humphrey, 1970); auditory stimulation from snippets of the *Barber of Seville Overture* (Jones, 2006); and visual stimulation from advancing and retreating objects (a pen and a small ball: Jacobson, 1979; Jacobson and Kagan, 1979), glimpses of the colorful interior of an opening and closing box (Legerstee, 1991), colored lights, and dangling toys (Jones, 1996). Given increased newborn tongue protruding in response to stimulation in three sensory modalities, it seems fair to conclude that tongue protruding is in fact a general arousal response in very young infants. Furthermore, it is likely that the sight of a tongue protruding model is just another interesting visual stimulus evoking that arousal response (Jones, 1996, 2009a).

In short, the evidence that newborn infants imitate is not compelling. And if there is no compelling evidence that newborn infants imitate, then there is no evidence that either the ability to imitate, or any of the body knowledge that imitation demands, is innate.

Infant imitation beyond the newborn period

If we do not have strong evidence that newborn infants can imitate, do we have other evidence to indicate when the ability to imitate does emerge? Jones (2009a) has recently addressed this question, so we will again summarize the evidence and conclusions from that review.

A small number of studies have tracked infants' matching of tongue protruding and mouth opening into the months just after the newborn period. The data show that matching of tongue protrusions rapidly declines and then disappears by 2 or 3 months of age (Fontaine, 1984; Heimann *et al.*, 1989; Jones, 1996). By the arousal account, this decline would reflect a change in the arousal value of the stimulus – the sight of the tongue protruding model – to the infant.

Other studies have attempted to document early infant imitation during natural social interactions (e.g. Kokkinaki, 2003; Kokkinaki and Kugiumutzakis, 2000; Masur and Rodemaker, 1999; Papousek and Papousek, 1989; Pawlby, 1977). These studies have found that *parents* imitate *infants* at prodigious rates in the first semester; but that infants match their parents' behaviors so infrequently that those matches must be attributed to chance.

Delayed or elicited imitation by infants between 6 and 12 months of age has been reported many times (e.g. Bauer, 1998; Barr *et al.*, 1996). However, in most cases, what is measured is the infants' reproduction of the *outcome* of the model's actions – that is, emulation (Tomasello, 1998; Want and Harris,

2002) – rather than the reproduction of those actions themselves. Emulation may reflect the infant's learning about the features and affordances of objects from watching another person interact with the object; but emulation does not require the infant to even notice, much less copy, the specific actions of the other person, or to have any cognitive access to representations of their own behavioral choices. For example, Barr and her colleagues (e.g. Barr *et al.*, 1996) have reported that infants as young as 6 months of age have imitated a model's 3-action sequence: removing a mitten from a puppet's hand, shaking the mitten to ring a bell inside, and replacing the mitten on the puppet's hand. However, a large majority (75 percent) of infants actually did only one of the actions – pulling off the puppet's mitten. It seems likely that infants might pull off the puppet's mitten, once they saw that this could be done, without any intention of imitating the model. In short, without more attention to how infants actually move in such studies, we cannot say that infants' matching of a model's actions on objects reflects any imitative intention or ability.

Meltzoff (1985, 1988a, 1988b) reported that infants 9, 14, and 20 months of age were able to remember modeled actions for later imitation. However, all of these were actions on objects, and the possibility that infants were emulating rather than imitating was not ruled out. For example, one action was shaking a plastic egg that contained small rattling objects when shaken by the experimenter. If an infant remembered that the egg had made a rattling sound, and if they had produced similar sounds by shaking objects in the past, then they might shake the egg during test and be credited with imitation despite having no memory at all of the experimenter's action on this object.

One behavior in Meltzoff's set is not subject to this criticism, as it involves a novel pairing of action and outcome. Matching of this behavior by infants, then, would be evidence that they did observe and reproduce the specific movements of the model. The behavior was tapping the forehead on the translucent surface of a box, to turn on a light inside the box. Unfortunately, Meltzoff (e.g. 1988b) credited infants with imitation not just when they tapped the box with their foreheads but also when they bent their heads to within 10 cm of the box. Because frequencies of these two behaviors were not separately reported and because infants could have other reasons for bending over the box – for example, to look into it – we cannot know how many of the infants in these studies actually imitated the model's movement. The same criticism applies to more recent reports of "rational" imitation by infants using the same light-box task scored in the same way (e.g. Gergely *et al.*, 2002; Zmyj *et al.*, 2009).

In an attempt to pin down the age range during which infants typically begin to imitate modeled movements (not when they begin to reproduce modeled outcomes), Jones (2007) tested infants from 6 to 20 months of age for their ability (or willingness) to imitate eight simple behaviors likely to be found in most infants' repertoires. Each infant's parent modeled four of the eight

behaviors, giving the infant plenty of time (up to 3 minutes) and encouragement to match each behavior. Two of the behaviors – sequential finger movements and tongue protruding – were chosen from among those that newborn infants reportedly imitate.

The major measures in this study were the proportions of infants at each age level who produced each modeled behavior (1) during the period in which that behavior was modeled; and (2) during the modeling of each of the other three behaviors. Jones argued that infants should not be accorded the ability to imitate any of the behaviors until the age at which the proportion of infants matching the behavior while it was being modeled significantly exceeded the proportion spontaneously producing that same behavior while an entirely different behavior was being modeled. Only one behavior – making "Aah" sounds – met this criterion before the age of 12 months. The other behaviors met the criterion for imitation at different ages ranging from 12 to 18 months. The two behaviors reportedly imitated by newborn infants – sequential finger movements and tongue protrusions – did not meet the criterion for imitation until 16 and 18 months of age, respectively. By the age of 20 months – the maximum in this study – substantial proportions of the infants still failed to reproduce each of the tested behaviors.

Other studies have similarly reported limited imitative abilities in infants well into their second year. Masur (1998; Masur and Rodemaker, 1999) reported that infants aged 10 and 13 months old produced less than one instance of behavioral matching during experimental sessions. At 17 and 21 months, however, infants produced four or five instances on average. Abravanel *et al.* (1976) found that 15-month-olds reproduced only about one-third of twenty-two simple actions modeled for them. Nielsen and Dissanayake (2004) did not observe imitation until 18 to 21 months of age.

Together these studies indicate that there is no single answer to the question of when infants begin to imitate. Imitation of specific actions is sparse but detectable in the first half of the second year. However, imitation does not appear to be typical until later in the second year. Even at 18 or 20 months of age, the imitative abilities of infants are patchy, and depend on the specific actions modeled for them.

The wide spread in the ages at which infants in these descriptive studies begin to imitate different behaviors argues against the general idea that imitation is a unitary ability – a dedicated module, say, of the sort that might be inherited. The similarly wide spread in the ages at which different infants in Jones (2007) began to imitate the same behavior argues against the idea that the origins and developmental course of imitation are the same in different infants. Thus, if there is some biological preparation for human imitation, it clearly requires considerable elaboration by mechanisms that are sensitive to the idiosyncratic experiences of individuals.

Behavioral matching in one infant from 3 to 15 months of age

The descriptive data consistently depict imitation as a competency with an extended period of emergence later in infancy. However, those data do not have much to say about the mechanism(s) by which the ability to imitate emerges. In this section, one infant's behavioral matching through most of her first year and into her second will be described. Observations of this one infant suggest that the ability to match the behaviors of others is rooted in the thousands of social interactions in which the parent imitates the child (Jones, 2005). We do not mean to suggest that infants directly learn to imitate from being imitated – that they imitate imitation, so to speak. Rather, we propose that parental imitation provides infants with the body knowledge that is essential to the ability to imitate. In particular, the interactions we observed between this one infant and her parent presented the infant with the right kinds of information at the right times to teach her about the equivalencies between her body parts and actions, and the body parts and actions of her social partner.

Observing Yo

The subject of the study is Yo Anne, the daughter of the second author. Yoshida began the study as a subject rather than an investigator. She was invited to participate with her daughter in a longitudinal study of "mother–infant interaction" that would focus on playful behaviors. One stated purpose among others was "to look at the baby's early imitative behavior." No mention was made of the fact that the mother's imitation of the infant would also be studied; and nothing was said about what the first author expected to observe.

Yo was videotaped between the ages of 3 and 15 months, as far as possible on a weekly schedule. Because Yo suffered the usual minor illnesses of infancy and also traveled a lot with her parents, the final record consists of thirty-one sessions distributed unevenly over the 12-month period.

In each session, Yo's mother played and talked with Yo for a minimum of 9–10 minutes. During this time, Yo was seated in either a reclining infant seat (to age 10 months, 16 days) or a high chair. Mother and infant were each videotaped by separate cameras feeding to a split screen with time and date superimposed on the combined image. Yoshida was made aware of the true purpose of the study and became a co-investigator when Yo was 7 months of age. Thereafter, the investigation became more experimental, as we attempted to elicit imitation from Yo in a variety of ways. Mother and infant interacted without any other objects until the fifteenth session, when Yo was 10 months 16 days of age. From that point on, toys and actions on toys became the focus of the interactions.

The videotapes were all transcribed as running narratives of time-marked behaviors produced by mother and infant. The two primary coders were

unaware of the purpose of the study and knew little about research on imitation. The transcripts were examined for instances of behavioral matching – either the mother's matching of the infant's behavior or the infant's matching of the mother's behavior – within a 3-second timeframe. A 3-second maximum delay between observation and performance of the same action was chosen to minimize Type 1 errors and also to reflect the pace of turn-taking in this mother-daughter pair. Coding focused on each infant behavior and asked whether the mother had produced the same behavior as the infant within a 3-second period before the infant's behavior (infant imitation of mother) or within a 3-second period after the infant's behavior (mother imitation of infant).

Like parents and infants in previous studies (e.g. Kokkinaki and Kugiumutzakis, 2000; Parton, 1976), this mother consistently imitated her infant at high frequencies and this infant matched her mother's behaviors at what appeared to be chance levels. It soon became clear, however, that the most theoretically interesting aspects of the events which we were witnessing were not the frequencies with which each partner imitated the other. The new information on the development of behavioral matching was found instead in the descriptive narratives of the sequences of behavior produced by mother and infant at each session. Thus, it is from the narratives that the following observations are largely drawn.

The observations

At 2 months 29 days of age (2:29), in the first recorded session, Yo lay in an infant seat while her mother spoke to her, sang to her, tickled her, and played "peek-a-boo." Yo's mother did not model tongue protrusions, but Yo produced tongue protrusions in abundance: Yo's mean rate of tongue protruding across that session was 6.3 tongue protrusions per minute. The rate typically reported in neonatal imitation experiments is about 2.5. Thus, Yo's rate of tongue protruding in response to her mother's voice and touch was quite high and supports the proposal that tongue protruding is an arousal response in young infants.

In each of the next several sessions, Yo's mother *did* model tongue protrusions. In response to the sight of her mother's moving tongue, Yo simply stared. Like other infants beyond the newborn period (Fontaine, 1984; Heimann *et al.*, 1989; Jones, 1996), Yo did not produce any tongue protrusions while watching her mother model tongue protrusions. It is possible that Yo was captured by a strong orienting response to her mother's tongue movements, and that she might have produced tongue protrusions if her mother had become still, as adult models do in imitation experiments. However, the fact is that Yo at 3 months gave no indication that she could voluntarily find her tongue: and, despite having done countless tongue protrusions in her brief life, she gave no indication that she possessed a mechanism that would automatically map the tongue

protrusions she saw onto a motor plan for tongue protrusions (Iacoboni *et al.*, 1999; Meltzoff, 2005, 2007a, 2007b). On the contrary: at 3 months and for many months thereafter, Yo did not match tongue protrusions – or anything else that her mother did.

Yo's mother, on the other hand, imitated Yo *a lot* throughout the study. This observation is consistent with the findings mentioned above (Kokkinaki and Kugiumutzakis, 2000; Masur and Rodemaker, 1999; Papousek and Papousek, 1989; Pawlby, 1977) that parents very frequently imitate their young infants during social interactions. In the early sessions, Yo's mother was not aware that her own behavior would be analyzed. Thus, the mother's spontaneous imitation of the infant could be measured. As the study progressed, Yo's mother began to actively participate in attempts to elicit imitation from Yo, so that the mother's imitation of the infant was no longer naïve and spontaneous. Nevertheless, as will become clear below, we had abundant evidence that both of Yo's parents frequently imitated certain actions across the entire period of the study.

In early sessions, Yo's mother frequently imitated Yo's vocalizations, facial expressions, and head movements. In the first session, Yo's mother imitated Yo thirty times in 9 minutes (M = 3.33 instances per minute). Nineteen of these were imitations of sounds the baby made: eleven were instances of actions – tilting the head, raising eyebrows, facial expressions, and touching the face with a hand. At that rate, assuming something like 1–2 cumulative hours of interaction with parents and other social partners each day, Yo could have experienced from 200 to 400 instances of imitation of her own sounds and actions in a single day. In 1 month, she could have experienced 6,000 to 12,000 instances; in 6 months, 36,000 to 72,000 instances.

Imitation appears to be the parent's attempt to make a social connection with the very young infant, and it is doubtful that the initially high rates of parental imitation persist as the infant becomes increasingly responsive. However, even by more conservative estimates, Yo must have been imitated tens of thousands of times in her first year. It is these thousands of instances of parents imitating their infants that we think may be a key source of body knowledge for infants, and thus a key source of one indispensable component of the ability to imitate. Every time Yo's mother imitated Yo's behavior, Yo's sensorimotor experiences – including visual, auditory, and proprioceptive sensations produced by her own action – were immediately followed by her sensory experiences – visual, auditory, and/or somatosensory – of her mother's matching action. This experience was certainly repeated many times for some specific actions that became familial play routines. Given the likely number of repetitions of these contiguous events, it would be remarkable if Yo did *not* form strong associations among all of these sensory and motor experiences both within and across modalities. Thus, it is very likely that Yo learned to associate her own movements with the same movements produced by her mother; and to

associate the parts of her body that produced those actions with the parts of her mother's body that produced the contiguous actions.

Such an associative learning mechanism could be very important in developing the infant's ability to match her own actions and body parts to those of others, given that the perceptual matches between these objects and events from the first-person and second-person perspectives are often not very good. It seems very *un*likely that Yo would initially be aware of matches between her own actions and the same actions produced by her imitating mother. Nevertheless, Yo would be acquiring a mapping of her body parts and actions to the body parts and actions of her mother in the form of associative links – and this mapping would prepare her to eventually recognize the match between her mother's actions and her own. In short, Yo could acquire a lot of the grounding for the body knowledge and body mapping ability she needed to imitate others as a product of her multiple experiences of *being imitated by* others.

Although body knowledge is necessary for imitation, it is obviously not sufficient. Other components, including some social understanding, and the motivation and intention to imitate are also needed, and we do not know when these develop. So we would not expect Yo to begin imitating as soon as she had learned to associate her body parts and actions with those of her social partners. However, we *would* expect to see Yo *match* her mother's behaviors before all of these components were in place, because some of her mother's behaviors had become learned cues for infant behaviors that just happened to match. That is, once an association was formed between an action produced by Yo and an immediately imitative action by Yo's mother, we would expect to see the mother's action gain the power to elicit a very similar action from Yo.

And that is what we believe we saw. Yo's first matches of her parents' actions appeared to be responses to learned sensory/perceptual cues. What is remarkable to us is that *all* of this infant's behavioral matches, up to 15 months of age, appeared to be responses to acquired cues. We did not see a single clear instance of imitation in any of our taped sessions.

Yo produced her first behavioral match in the lab at age 10:16. The first matched action was "air kissing" – making loud kissing sounds with pursed lips. Yo had often done this spontaneously at home, and both parents had often imitated her. During our session at 10:16, Yo's mother was first to make the air-kissing sound; and after many repetitions, Yo eventually made a similar sound. Again, this was the first instance of Yo's behavioral matching recorded in the lab after more than 7 months of observations! It seemed likely that Yo's air kissing was not imitation but rather a response to the sound cue provided by her mother's air kissing.

Along with "air kissing" with sounds, Yo's mother imitated Yo's "la-la-la" babbles, using exaggerated open-mouthed tongue movements. Yo's mother also frequently reproduced Yo's hand actions, for example imitating Yo's hand

smacks on the high chair tray. Often, Yo's mother imitated an action performed by Yo, and added to it an interpretation and a unique sound: so, for example, when Yo extended one arm or both arms forward in a horizontal plane, her mother would say "Gimme five!" and lightly slap one of Yo's palms with her own.

Eventually, Yo's mother could produce an action with an accompanying sound, and Yo would respond on cue with the same action. But this was not imitation. Instead, in every case, Yo appeared to be responding to an acquired sound cue. Yo gave no evidence that she could imitate any behaviors outside of well-practiced routines, or that she was in any way aware that her behavior matched that of her mother.

Crucially, *all* behavioral matches produced by Yo were actions (1) originally initiated by Yo herself, (2) that either produced or were accompanied by sounds, and (3) that Yo's parents imitated (either imitating Yo's sounds or supplying a standard accompanying sound) repeatedly over many weeks, until (4) the day came when Yo's mother produced the behavior and sound first, and Yo responded with the same behavior.

The importance of the sound cues is evident in an example at age 11:7. Yo's mother held a toy raccoon, tapped the high chair tray with its plastic nose, then gave the raccoon to Yo. Yo pushed the raccoon aside in order to smack the tray with her open palm. It seemed clear that Yo's intention was to reproduce the sound of the tapping, not her mother's action on the object. When Yo was aged 11:21, her mother modeled tonguing twice – first with "la-la" sounds and several minutes later without intentionally making sounds, although one could hear slight sloppy noises as her tongue moved. Yo responded to her mother's tonguing with "la-la" sounds by moving her own tongue in and out of her mouth. However, she responded to her mother's tonguing without "la-la" sounds with air kissing – apparently responding, not to the sight of her mother's moving tongue, but to the slight sounds that her mother's moving tongue produced.

So it appeared that Yo, at almost 1 year of age, still could not find her tongue based on visual input from her mother's behavior. What does this say, then, about newborn tongue protruding? It does not seem likely that a newborn could imitate tongue protruding, when an 11-month-old could not. And what does this say about the likelihood that Yo was born with a mechanism that automatically matched visual input from others' behaviors to motor programs for behaviors in her own repertoire (Iacoboni *et al.*, 1999; Meltzoff, 2007a, 2007b)? If Yo possessed such a mechanism, the sight of the mother's tongue movements should have been automatically matched with Yo's well-practiced motor program for the production of tongue protrusions, resulting at least sometimes in Yo's production of tongue protrusions. But there was no evidence that any of this took place.

Yo had already matched her mother's tonguing *with* sounds at age 10:16 – but then, the tonguing sounds (the "la-la-las") were something Yo frequently

produced by herself in repetitive sequences. It is likely, as Piaget (1945) proposed, that her mother's tonguing sounds functioned in the same way as Yo's own sounds, to cue repetitions of the tongue movements in a circular reaction. Yo did not match the very same tongue movements *without* sound until age 13:25.

Here is another example: Yo, like many infants, sometimes raised both arms and vocalized, as though asking to be picked up. For months, whenever Yo did this, her mother responded with her own bilateral arm raises and an enthusiastic "Bonsai!". At the 11:7 session, Yo's mother repeatedly showed Yo bilateral arm raises while silent, and then several minutes later showed the same arm movements while saying the word "Bonsai!". Yo did not respond with any upward arm movements, either to the sound cue or to silent arm raises. Instead, when her mother raised her arms and said "Bonsai!", Yo first looked up, then pointed at the ceiling. Because Yo's mother was imitating Yo's own arm raises, there is no doubt that the "motor program" for arm raises should have been in the baby's repertoire. But Yo did not imitate arm raises when she saw them. Yo first did arm raises after the sound cue "Bonsai!" at 12:14. She did not raise her arms at the sight of her mother's *silent* arm raises until aged 14:2.

As with these arm raises, all of Yo's matching of movements with no sounds in the late stages of the study was confined to actions that had previously been associated with sounds in one or another of the well-practiced routines – only now, Yo could do them without the sound cues. So Yo's actions were still learned associates, not imitations, of her mother's actions. And there were still doubts about whether any of the behaviors were cued by visual input alone. For example: when Yo was 12:7, Yo's mother had for several weeks been modeling putting an object on her own head, with no effect on Yo's behavior. During this session, Yo's mother tapped the top of her own head with a cone-shaped object (about 16 cm tall), then handed the object to Yo. Yo brought the object close to the side of her head and we thought that she was finally going to imitate her mother's action. However, what Yo had noticed and we had not was that Yo's mother, while tapping her own head with the cone, had been repeating in the same rhythm a single nonsense sound. Instead of tapping her head with the cone as we expected, Yo held the object against her ear as though it was a telephone, and vocalized. Yo's mother interpreted Yo's action just this way, laughing and saying "hello" in Japanese – a word that sounds very like the syllables she had previously repeated. Yo's mother reported that she often said "hello!" when Yo touched her ear with an object. Thus, once again, Yo appeared to be acting in response to learned sound cues, not to the visual input from her mother's modeled action.

One week later (age 12:15), Yo's mother modeled tapping her own head with a plastic stacking ring, again with accompanying sound cues. She repeatedly offered the ring to Yo, who repeatedly handed it back. However, during one of these exchanges, while Yo still held the ring, Yo's mother touched the top of

Yo's head with her hand, then lifted the plastic ring, still in Yo's two hands, to lie flat on the top of Yo's head. When Yo's mother let go, Yo lowered the ring, still in her two hands, then raised her hands again and replaced the ring on her head.

An observer seeing this single exchange in isolation might easily have taken it for an instance of imitation. However, the whole sequence suggested instead that Yo was reproducing, not the action she saw, but the sensations (the touch to the top of her head) that she had just felt. This interpretation is supported by one more observation. A few minutes later, Yo's mother again modeled putting the object on her own head, but did not touch Yo's head. She then handed the ring to Yo. But Yo did not attempt to put it on her own head – we think because this time, there was no immediately preceding sensory experience (of a touch to her head) to reproduce.

That Yo knew how to reproduce the sensation of the ring touching the top of her head was in its own way impressive – but once again, it was not imitation. It was not imitation because the infant did not reproduce her mother's specific movements: rather, she reproduced the outcome of her mother's action. Thus, at best, this was an instance of emulation.

When Yo was 13:4, her mother put a stacking ring on her own head, then bent her head to let the ring slide off. Yo immediately put a ring on her own head. Thus, the sight of her mother's action by itself was now enough to elicit a similar action from Yo. Note, however, that the infant's matching of the mother's behavior was still at least partially elicited by a learned cue. Yo's mother had been doing the same action in every session (and at home) for several weeks by this time, and had many times raised Yo's hand with a plastic ring grasped in it to make Yo's ring touch the top of her head. Thus, Yo had had ample opportunity to learn to associate the sight of her mother's action with her own arm movements that brought the ring to the top of her head, and/or to associate the sight of her mother's action with a sensation of touch on her head that she was independently able to produce. She might thus have been cued by the sight of her mother's action to produce an action – contacting her own head with the ring she held – that was associated with that sight, without necessarily knowing that the two actions matched. Thus, we have no evidence that the infant acted *in order to* reproduce her mother's behavior, and so no evidence that Yo's action was imitation.

To really convince us that she was imitating her mother, Yo would have had to reproduce one of her mother's actions the first time she saw it. But reproduction of actions on the first day they were introduced was not observed *at all* during the entire study. Instead, every attempt to get Yo to match an action of her mother's that was not already part of a play routine was a failure. Again, we are talking about actions that Yo had often spontaneously produced and that therefore should have been "motor plans" in her repertoire. For example: when Yo was 12:0, her mother gave her one of two identical stuffed bears, then modeled

kissing and hugging of the second bear. Kissing and hugging were certainly actions that Yo had in her repertoire. Yo, at 1 year of age, just watched her mother with interest while dangling the bear from one hand.

We were forced by circumstances to stop filming at 15 months. By that time, Yo readily and accurately matched a variety of her mother's behaviors with no hesitation, and generalized matched behaviors – for example, kissing – to new objects. However, right to the end of the study, we did not observe even one instance of Yo's immediate reproduction of a modeled behavior, either transitive or intransitive, that was not part of a familiar play routine that had evolved out of parental imitation of the infant's behavior.

Insights from observing Yo

The findings from this case study are consistent with and bolster those from the normative study of 6- to 20-month-old infants. Yo's developmental course suggests that the ability to imitate is not innate, and that there is no functional "mirror system" or "supramodal act space" available to infants – at least until sometime beyond 15 months of age.

Importantly, the study strongly suggests that *the experience of being imitated* provides associative learning opportunities that may be vital to the development of the ability to imitate. Specifically, parental imitation of an infant's actions puts the visual, auditory, and/or somatosensory input from the parent's movements side-by-side with the infant's sensory-perceptual feedback from her own movements. This is so common in parent–infant interaction that we can assume that the infant forms associations among all of the sensory-perceptual features of the two experiences.

Yo's data suggest that the first associations to affect the infant's behaviors are associations between the sounds made by the infant and the imitating parent. Piaget (1945) believed that this was true, though he did not write in terms of learned associations. Next we see evidence of associations between those sounds and specific movements. Finally, we see evidence of associations between visual input from the actions of others and the infant's experiences of her own actions, as the silent movements of another come to elicit similar movements from the infant.

We propose one further step – one that Yo may have taken but that our method did not reveal – in which the matching behaviors that are first produced by the parent alone, and that are subsequently produced as cued responses by the infant, are eventually recognized by the cognitively more sophisticated infant as behaviors belonging to the same category. This recognition may be facilitated when the behaviors become functionally linked – that is, when the infant observes that the associated behaviors achieve the same outcomes on objects – or when those outcomes are labeled with the same words.

Thus, the strong tendency of infants' social partners to imitate the infants' behaviors is likely to contribute substantially to the development of cognitive representations of the appearance and locations of infants' own body parts; of the relations among them; and of the movement capabilities of those parts, by association with infants' observations of the body parts and movements of others. This learning process is a long one: the data from Yo and from several cross-sectional studies (Abravanel *et al.*, 1976; Horne and Erjavec, 2007; Huang and Charman, 2005; Jones, 2007; Masur, 1998; Vallotton and Harper, 2006) indicate that it extends well into the second year. Our everyday experience suggests that behavioral matching acquired from being imitated extends even further into childhood. As a last example: one visitor to our lab described to us how her adult daughter, having read about newborn imitation of tongue protrusions in her baby book, stuck out her tongue whenever her newborn son protruded his tongue even slightly. Now, at age 2½, our visitor's grandson responds to tongue protrusions performed by his mother and grandmother by poking just the tip of his tongue through his lips. His mother has repeatedly tried to correct him, saying "No, like this!" and sticking out her tongue to its full extent – but her son continues to respond with tiny tongue protrusions. This boy's behavior makes sense if his tiny tongue movements are not attempts to imitate his mother, but are instead the movements that he associates with the sight of his mother's tongue protrusions. If he is responding to her behavior but not imitating her behavior, then he may not only be unconcerned that his behavior doesn't match very well – he may not know that it matches at all.

Conclusions

True imitation – the ability to freely reproduce the movements of others – requires extensive and detailed representations of the bodies of both the imitator and the entity being imitated, and mappings of each to the other. For this reason, research on the development of imitation can be a good source of information about when and how such representations and mappings develop.

Our case study of behavioral matching by Yo suggests that parents' imitation of their infants is central to the development of two crucial components of a dynamic imitation system – the infant's knowledge of her own body parts and actions, and the infant's ability to map that knowledge onto her knowledge of the body parts and actions of others. As other contributions to this volume will illustrate, there are many potential sources of infants' body representations. However, we believe that acquired associations between closely contiguous sensory experiences produced by one's own action and the same action produced by an imitating social partner may provide an important route to infants' awareness of their own actions; to their ability to isolate and identify sensations produced by their own actions; and thus to their eventual ability to reproduce

those actions at will. Parental imitation of infant actions may be even more important as a route to infants' body mapping abilities – that is, to infants' abilities to recognize the body parts and actions of others as like their own, and to analyze those actions into sequences of specific movements of specific body parts by association with their own action experiences.

At present, we can only offer this sketchy description; but we believe that a view of imitation as a multi-component dynamic system with an extended, piecemeal, and complex developmental course provides the best fit to existing empirical evidence and the most promising approach to future research on how the components of the imitation system develop and combine to enable the free, voluntary reproduction of the actions of others.

References

Abravanel, E., Levan-Goldschmidt, E., and Stevenson, M. B. (1976). Action imitation: The early phase of infancy. *Child Development*, **47**(4), 1,032–1,044.

Alberts, J. R. (2008). The nature of nurturant niches in ontogeny. *Philosophical Psychology*, **21**(3), 295–303.

Anisfeld, M. (1996). Only tongue protruding modeling is matched by neonates. *Developmental Review*, **16**(2), 149–161.

(2005). No compelling evidence to dispute Piaget's timetable of the development of representational imitation in infancy. In S. Hurley and N. Chater (eds). *Perspectives on Imitation: From Cognitive Neuroscience to Social Science*, Vol. II (107–131). Cambridge, MA: MIT Press.

Barr, R., Dowden, A., and Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behavior and Development*, **19**(2), 159–170.

Bauer, P. (1998). Development of memory in early childhood. In N. Cowan and C. Hulme (eds). *The Development of Memory in Childhood* (83–112). New York: Psychology Press.

Butterworth, G. (1999). Neonatal imitation: Existence, mechanisms and motives. In J. Nadel and G. Butterworth (eds). *Imitation in Infancy* (63–88). New York: Cambridge University Press.

Elkind, D. and Flavell, J. H. (eds) (1969). *Studies in Cognitive Development: Essays in Honor of Jean Piaget*. New York: Oxford University Press.

Fontaine, R. (1984). Changes in imitative behavior during early infancy. *Infant Behavior and Development*, **9**, 415–421.

Gergely, G., Bekkering, H., and Kiraly, I. (2002). Rational imitation in preverbal infants. *Nature*, **415**(6,873), 755.

Gottlieb, G. (1976). The roles of experience in the development of behavior and the nervous system. In G. Gottlieb (ed.). *Neural and Behavioral Specificity* (25–54). San Diego, CA: Academic Press.

(2007). Probabilistic epigenesis. *Developmental Science*, **10**(1), 1–11.

Heimann, M., Nelson, K. E., and Schaller, J. (1989). Neonatal imitation of tongue protrusion and mouth opening: Methodological aspects and evidence of early individual differences. *Scandinavian Journal of Psychology*, **30**, 90–101.

Horne, P. J. and Erjavec, M. (2007). Do infants show generalized imitation of gestures? *Journal of the Experimental Analysis of Behaviour*, **87**, 63–87.

Huang, C.-T. and Charman, T. (2005). Gradations of emulation learning in infants' imitation of actions on objects. *Journal of Experimental Child Psychology*, **92**(3), 276–302.

Humphrey, T. (1970). The development of human fetal activity and its relation to postnatal behavior. In H. W. Reese and L. P. Lipsitt (eds). *Advances in Child Development and Behavior*, Vol. V (2–57). New York: Academic Press.

Iacoboni, M., Woods, R. P., Brass, M., Bekkering, H., and Mazziotta, J. C. (1999). Cortical mechanisms of human imitation. *Science*, **286**, 2,526–2,528.

Jacobson, S. W. (1979). Matching behavior in the young infant. *Child Development*, **50**, 425–430.

Jacobson, S. W. and Kagan, J. (1979). Intepreting "imitative" responses in early infancy. *Science, New Series*, **205**(4,402), 215–217.

Jones, S. S. (1996). Imitation or exploration? Young infants' matching of adults' oral gestures. *Child Development*, **67**(5), 1,952–1,969.

(2005). Why don't apes ape more? In S. Hurley and N. Chater (eds). *Perspectives on Imitation: From Cognitive Neuroscience to Social Science*, Vol. I (297–301). Cambridge, MA: MIT Press.

(2006). Exploration or imitation? The effect of music on 4-week-old infants' tongue protrusions. *Infant Behavior and Development*, **29**(1), 126–130.

(2007). Imitation in infancy: The development of mimicry. *Psychological Science*, **18**(7), 593–599.

(2009a). The development of imitation in infancy. *Philosophical Transactions of the Royal Society B*, **346**, 2,325–2,335.

(2009b). Imitation and empathy in infancy. *Cognition, Brain, Behavior*, **13**, 391–413.

Kokkinaki, T. (2003). A longitudinal, naturalistic and cross-cultural study on emotions in early infant–parent imitative interactions. *British Journal of Developmental Psychology*, **21**, 243–258.

Kokkinaki, T. and Kugiumutzakis, G. (2000). Basic aspects of vocal imitation in infant–parent interaction during the first 6 months. *Journal of Reproductive and Infant Psychology*, **18**, 173–187.

Kuo, Z. Y. (1932). Ontogeny of embryonic behavior in Aves, Vol. IV. The influence of embryonic movements upon the behavior after hatching. *Journal of Comparative Psychology*, **14**, 109–122.

Legerstee, M. (1991). The role of person and object in eliciting early imitation. *Journal of Experimental Child Psychology*, **51**, 423–433.

Lehrman, D. S. (1953). A critique of Konrad Lorenz's theory of instinctive behavior. *The Quarterly Review of Biology*, **28**(4), 337–363.

Masur, E. F. (1998). Mothers' and infants' solicitations of imitation during play. *Infant Behavior and Development*, **21**, 559.

Masur, E. F. and Rodemaker, J. E. (1999). Mothers' and infants' spontaneous vocal, verbal, and action imitation during the second year. *Merrill-Palmer Quarterly*, **45**, 392–412.

Meltzoff, A. N. (1985). Immediate and deferred imitation in 14- and 20-month-old infants. *Child Development*, **56**, 62–72.

(1988a). Infant imitation and memory: 9-month-olds in immediate and deferred tests. *Child Development*, **59**, 217–225.

(1988b). Infant imitation after a 1-week delay: Long-term memory for novel acts and multiple stimuli. *Developmental Psychology*, **24**(4), 470–476.

(2005). Imitation and other minds: The "like me" hypothesis. In S. Hurley and N. Chater (eds). *Perspectives on Imitation: From Neuroscience to Social Science*, Vol II (55–78). Cambridge, MA: MIT Press.

(2007a). "Like me": A foundation for social cognition. *Developmental Science*, **10**(1), 126–134.

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

Meltzoff, A. N. and Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science*, **198**(4,312), 75–78.

(1983). Newborn infants imitate adult facial gestures. *Child Development*, **54**(3), 702–709.

(1989). Imitation in newborn infants: Exploring the range of gestures imitated and the underlying mechanism. *Developmental Psychology*, **25**, 954–962.

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

(1994). Imitation, memory, and the representation of persons. *Infant Behavior and Development*, **17**(1), 83–99.

(1997). Explaining facial imitation: A theoretical model. *Early Development and Parenting*, **6**, 189–192.

Nagy, E., Kompagne, H., Orvos, H., and Pal, A. (2007). Gender-related differences in neonatal imitation. *Infant Child Development*, **16**, 267–276.

Nielsen, M. and Dissnayake, C. (2004). Pretend play, mirror self-recognition and imitation: A longitudinal investigation through the second year. *Infant Behavior and Development*, **27**, 342–365.

Papousek, M. and Papousek, H. (1989). Forms and functions of vocal matching in interactions between mothers and their precanonical infants. *First Language*, **9**, 137–158.

Parton, D. A. (1976). Learning to imitate in infancy. *Child Development*, **47**, 14–31.

Pawlby, S. (1977). Imitative interaction. In H. R. Schaffer (ed.). *Studies in Mother–Infant Interaction* (203–223). London: Academic Press.

Piaget, J. (1945). *Play, Dreams, and Imitation in Childhood*. New York: W. W. Norton.

Rizzolatti, G. and Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, **27**, 169–192.

Schwier, C., van Maanen, C., Carpenter, M., and Tomasello, M. (2006). Rational imitation in 12-month-old infants. *Infancy*, **10**(3), 303–311.

Thelen, E. and Smith, L. B. (1994). *A Dynamic Systems Approach to the Development of Cognition and Action*. Cambridge, MA: Bradford Books/MIT Press.

Tomasello, M. (1998). Emulation learning and cultural learning. *Behavioral and Brain Sciences*, **21**, 703–704.

Uzgiris, I. C. and Hunt, J. McV. (1975). *Assessment in Infancy*. Urbana, IL: University of Illinois Press.

Vallotton, C. D. and Harper, L. V. (2006). Why don't they just let it go? *Infant Behaviour and Development*, **29**(3), 373–385.

Want, S. C. and 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*, **2**, 1–41.

Zmyj, N., Daum, M. M., and Aschersleben, G. (2009). The development of rational imitation in 9- and 12-month-old infants. *Infancy*, **14**(1), 131–141.