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# The 'like me' framework for recognizing and becoming an intentional agent

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**Abstract**

Infant imitation demonstrates that the perception and production of human action are closely linked by a 'supramodal' representation of action. This action representation unites observation and execution into a common framework, and it has far-reaching implications for the development of social cognition. It allows infants to see the behaviors of others as commensurate with their own—as 'like me.' Based on the 'like me' perception of others, social encounters are interpretable and informative. Infants can use themselves as a framework for understanding others and can learn about the possibilities and consequences of their own potential acts by observing the behavior of others. Through social interaction with other intentional agents who are viewed as 'like me,' infants develop a richer social cognition. This paper explores the early manifestations and cascading developmental effects of the 'like me' conception.


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## 1. Introduction

Understanding the way other people's minds work—and knowing that those minds can be likened to our own—is crucial to our interactions with other people. A dramatic example comes from the impairments of people with autism. Autism has been described as a kind of 'mind-blindness' (Baron-Cohen, 1995) because children with autism do not con-

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ceptualize other people as psychological agents with a rich palette of mental states. They seem to lack what philosophers of mind call the 'commonsense psychology' or 'folk psychology' that is shared by typical adults.

Commonsense psychology may be common among adults, but it has a developmental history. If we want to discover the origins of such psychology, a good place to look is infancy. This paper marshals theoretical and empirical support for what I have called the 'like me' developmental framework (Meltzoff, 2005, in press; Meltzoff & Gopnik, 1993). According to this view, the bedrock on which commonsense psychology is constructed is the apprehension that others are similar to the self. Infants are launched on their career of interpersonal relations with the basic perception: 'Here is something like me.' The aim of this paper is to explore the early manifestations and cascading developmental effects of this preverbal intuition of infancy.

The view suggested here is that infants' primordial 'like-me' experiences are based on their representation of action. Infants monitor their own bodily acts via proprioception and can detect cross-modal equivalents between their own acts-as-felt and the acts-as-seen in others. Without this substrate, other humans might exhibit interesting visual features (eye spots) or physical characteristics (self-propelled), but they would not have the unique place they do in the child's world. In addition to being drawn to interesting visual features, I suggest that young children use a functional analysis: Entities that behave 'like me' are accorded special status. It is this fundamental relatedness between self and other, based on the recognition of shared behavior, that will be explored in this paper.

According to classical theories such as Piaget's (1962), infants could not apprehend equivalences between the acts of self and other. Piaget described the young infant as 'solipsistic,' and explicitly denied such a connection. Among the experiments that changed this view are those showing that young infants imitate (e.g., Meltzoff & Moore, 1977, 1997). Infant imitation shows that perception and production of human acts are deeply intertwined, which belies the idea of a solipsistic cocoon. A privileged connection between perception and production is currently the focus of work in neuroscience (e.g., Gallese, 2003; Iacoboni, 2005; Rizzolatti, 2005; Rizzolatti, Fadiga, Fogassi, & Gallese, 2002) and cognitive psychology (e.g., Hommel, Müsseler, Aschersleben, & Prinz, 2001; Prinz, 2002). The data on infant imitation add a specification of the starting state for humans—before language, complex cognition, and prolonged interaction with the world.

This paper goes beyond action representation per se to consider its implications for social development. Although it is dubbed the 'like me' account, my thesis is that the equivalence between self and other supports *bidirectional learning effects*. Going from the inside out, infants' understanding of others' acts is imbued with a new meaning by performing similar acts themselves. Going from the outside in, infants learn about themselves and the consequences of their own potential action, before and without producing it, by observing the behavior of others. The same underlying mechanism supports learning in both directions. The studies discussed in this paper document the bidirectionality: Perception influences production, and production influences perception, with substantial implications for social cognition.

## 2. The 'like me' framework

This paper describes how infants use the 'like-me-ness' of others to bootstrap themselves into an increasingly more adult-like view of other people as intentional agents. Fig. 1 provides a sketch for the proposed developmental path.

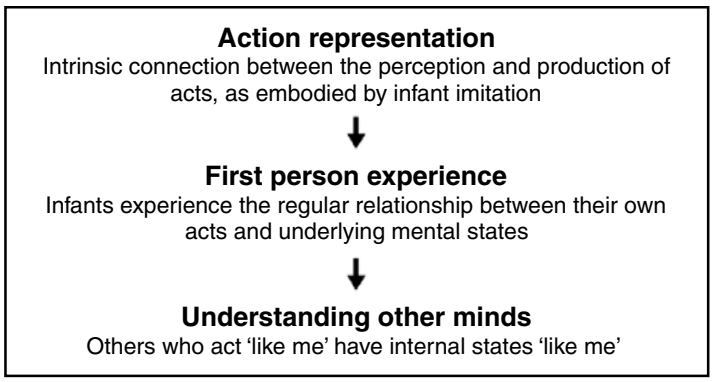


Fig. 1. 'Like me' developmental framework.

The 'like me' developmental framework has three essential components. It describes the infant's initial state (component a) and also provides an engine for development (components b and c). The older child and adult are not locked into the same understanding as the newborn. Their interpretation of others as intentional agents is colored by their own experiences.

### 2.1. Component a: action representation

The first component is functional at birth. Newborn imitation provides evidence that perception and production are tightly bound in human beings—newborns copy simple acts they observe produced by others. Meltzoff and Moore (1977, 1997) hypothesize that imitation is mediated by a 'supramodal' action representation that enables commensurate coding of acts seen and acts done. Progress has been made in describing possible neural embodiments of such a supramodal representational system (e.g., Hurley & Chater, 2005; Meltzoff & Prinz, 2002) and scientists are examining connections between it and theories of action representation in cognitive psychology (e.g., Brass & Heyes, 2005; Hommel et al., 2001; Wilson, 2001).

### 2.2. Component b: first-person experience

The second component is based on individual experience and provides an engine for developmental change. Through everyday experience infants map the relation between their own bodily states and mental experiences. For example, there is an intimate relation between striving to achieve a goal and a concomitant facial expression and effortful bodily acts. Infants experience their own unfulfilled desires and the simultaneous facial/postural behavior that accompany such states. These first-person experiences contribute to a detailed bidirectional map linking internal states and behavior.

### 2.3. Component c: understanding other intentional agents

The third component involves attribution. When infants see others acting similarly to how they have acted in the past, they ascribe the internal state that regularly goes with that behavior. Infants' first-person experiences could not be used in this way if they did not perceive an equivalence between their own acts and those of others (component a). Nor would it get very far if there was no systematic link between their own internal states and bodily

acts (component b). Humans, including preverbal infants, imbue the acts of others with felt meaning not solely (or at first) through a formal process of step-by-step reasoning, but because the other is processed as 'like me.' This is underwritten by the way humans represent action—the supramodal action code—and self experience. The infant's experience with action production and its consequences influence the perception and understanding of action by others.

The 'like me' framework provides only a partial story about understanding others as intentional agents in a mature adult manner. The mental states most amenable to a 'like me' analysis are desires, visual perception, emotions, and simple intentions. For these, there is a relatively close coupling between the underlying mental states and their expression in bodily action. When someone sees *x* or desires *y*, there are telltale bodily movements that correlate with such mental states (leaning towards, grasping, looking in the direction of, etc.). Other mental states are more quarantined from the action stream—for example, the 'belief that *x*' (which may be false) can be held in the absence of any telltale action (e.g., Astington & Gopnik, 1991; Flavell, 1999; Perner, 1991; Taylor, 1996; Wellman, 1990; Wellman & Liu, 2004). Further development is needed for grasping the idea that another who is 'like me' in so many other ways may believe something contrary to me.[1] Thus, the proposal offered here focuses on the initial foothold for interpreting others as bearers of psychological properties commensurate with one's own and does not purport to be a full account of the adult's understanding of other minds.

The paper also provides only a partial analysis in another way as well. I am explicitly focusing on infant *action* as a dependent measure. Infants may 'know' more than they produce (see Baillargeon, 2004; Haith, 1998; Meltzoff & Moore, 1998; Onishi, Baillargeon, & Leslie, 2007; Spelke, 1998 for debates about perceptual parsing versus action measures of infant cognition). This paper focuses on infants' motor production for two key reasons. First, in the real world, other people respond to infants' actions. The feedback infants receive from the social world is largely based on what the infant does (Rochat, 2007). To understand what caretakers see in real-life, we need to examine infants' motor behavior. Second, there have already been several careful reviews of infants' perceptual parsing of intentional action based on the visual habituation, preference-for-novelty technique, (e.g., Csibra, 2003; Gergely, 2002; Sommerville & Woodward, 2005b; Wellman, 2002; Woodward, Sommerville, & Guajardo, 2001), and space precludes a full treatment of that literature.

This paper examines infants' motor behavior that relies on a construal of others as intentional agents like the self. I present work in a reverse developmental order, starting with tool-use in 2-year-olds, working backwards in time to 18-month-olds, and finally to the behavior of newborns in the initial state. This organization has the benefit of establishing the endpoint that children reach by the conclusion of infancy. My hope is that by describing some characteristics of that endpoint, it will be easier to understand the precursors that are necessarily more ambiguous.

A related developmental caveat pertains to the word 'me' in the 'like me' framework. The use of this word is not meant to imply that young infants have a mature notion of self. The 'me' of the adult entails verbal self-reflection. As we will see, the embryonic 'me' of the infant at first involves proprioceptive information and representations of their

[1] Children even have difficulty understanding that their own future states may be different and contradictory to their current states (Atance & Meltzoff, 2006)—i.e., they exaggerate the similarity of their own future self with the present self.

own acts as distinct from the acts they see performed by others. Care will be taken in emphasizing developmental change throughout the paper.

## 3. Experiment 1: learning tool-use by observing others

### 3.1. Background

In the developmental and animal psychology literatures, one of the most celebrated and controversial examples of goal-directed intelligent action is the case of tool use. The debate concerns whether animals (and young infants) use tools based on trial-and-error or on insight (e.g., Povinelli, 2000; Tomasello & Call, 1997). For the purposes of this paper, I am interested in exploring tool use from a different perspective. I examine the role of imitation in learning to use a tool (for which the animal literature comes to mixed conclusions: Povinelli, 2000; Tomasello & Call, 1997; Whiten, Horner, & de Waal, 2005). Previous research shows that infants can discover how to use sticks as tools when left to their own devices (Bates, Carlson-Luden, & Bretherton, 1980; Brown, 1990; Piaget, 1954), but there is much sparser evidence concerning learning how to use tools from watching others (see Horner & Whiten, 2005; Want & Harris, 2001, 2002 for work on older children). The extant work with infants involves simple tools for which the degrees of freedom are highly constrained, such as a toy-on-a-support requiring pulling the support platform (Goubet, Rochat, Maire-Leblond, & Poss, 2006; Provasi, Dubon, & Bloch, 2001), or the simple use of a stick/object to press a spot on another object to obtain an effect (e.g., Meltzoff, 1995; Nielsen, 2006).

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

Based on the 'like me' framework, I hypothesized that it would be possible to demonstrate such tool-use learning at younger ages by transforming the situation. Instead of having the infant sit across the table from the adult, I had them sit side-by-side. In that way the adult's actions could more easily serve as a blueprint for the child's own action plans. Recent brain imaging studies with adults show the facilitative effects of seeing a to-be-imitated action from one's own point of view (Jackson, Meltzoff, & Decety, 2006).

### 3.2. Empirics

The sample consisted of 120 infants, with 30 infants each at 16, 18, 20, and 22 months of age. Within each age group, infants were randomly assigned to one of the three test conditions:

(a) Control 1 (Baseline)—infants saw no modeling and were simply given the rake.
(b) Control 2 (Stimulus enhancement)—infants saw the adult using the rake to touch the goal, thereby drawing attention to the tool and also to the fact that it could make spatial contact with the goal object (but correct use of the rake was not demonstrated).

(c) Learning by observation—the adult modeled the correct use of the rake to obtain the out-of-reach goal.

The instrument was a 44-cm long rake-like object. It was placed horizontally in front of the infant, with approximately a 64-cm spatial gap between the infant and the goal object (a rubber giraffe). Infants were given a 1 min response period in which to solve the problem. Infants were highly motivated to obtain the desirable object (stretching out their arms, vocalizing, etc.). In the two control groups, there was no significant difference in the successful use of the stick as a function of age. Only 7.5% (6 of 80) of the infants solved the problem spontaneously in the control groups. In contrast, fully 50% (20 of 40) of the infants succeeded after they saw the adult show them how to use the tool, $p < .001$. The older infants (20 and 22 month olds) profited far more from observation (70% succeeded) than did the younger infants (30% succeeded), $p < .05$.

### 3.3. Implications for theory

Infants learn from observation, but what they learn varies with age. After watching the expert, the young infants do not exceed spontaneous rates by the same degree that the older infants do. One possibility is that the observer has to be 'on the cusp' of solving complex tool-use problems themselves to profit maximally from seeing how someone else solves it (Gopnik & Meltzoff, 1986, 1997; Vygotsky, 1978, for the 'zone of proximal development'). Older infants could be more intelligent consumers of the adult modeling because they know 'what to look for' based on their own prior motor productions and attempts using simpler tools. This would be an example of 'like me' at an attentional/cognitive level, inasmuch as infants would be using their own background experience and past motor productions (successes and failures) to parse and interpret the motor productions of others (see also Sommerville & Woodward, 2005a, 2005b for related work using looking-time measures). Thus the relation between the child's own level of causal understanding and the model's demonstration may be a significant factor in studies of tool-use imitation. It is an example of imitation not being blind or automatic, but rather of prior knowledge influencing what you encode and use from the modeling of others (e.g., Carpenter, Call, & Tomasello, 2002; Gergely, Bekkering, & Király, 2002; Williamson & Markman, 2006).

This study was the first to show infants how to use complex tools 'from their own perspective.' Sitting shoulder-to-shoulder with the child closes the gap between the perceived and executed actions. The model becomes more 'like me.' Recent brain imaging studies have systematically varied 'first-person' versus 'third-person' perspectives in adult fMRI studies of imitation. The results reveal that seeing an action from a first-person perspective prompts significantly more activation in sensory-motor brain regions, suggesting that the observer has a heightened preparation to take action (Jackson et al., 2006).

## 4. Experiment 2: understanding others as intentional agents

### 4.1. Background

In the previous study, infants saw a perfect model, that is, an adult who deftly wielded the rake and drew the goal-object to himself. In the real world, infants and adults often witness people whose actions are less than perfect and who do not reach the goal. The

model may lack the motor control to fulfill their intentions, but there still is much to be learned from this unsuccessful motor act. Adults can extract a person's goals from the pattern of behavior they exhibit even if the goals are not achieved. Can infants 'read' the motor productions of others in this socially intelligent way? This is an important issue for illuminating what infants know about others as intentional agents.

Researchers have used visual habituation, looking-time techniques to address this question (e.g., Csibra, Bíró, Koós, & Gergely, 2003; Csibra, Gergely, Bíró, Koós, & Brockbank, 1999; Gergely, Nádasdy, Csibra, & Bíró, 1995; Sommerville & Woodward, 2005a, 2005b; Sommerville, Woodward, & Needham, 2005; Woodward, 1998). I developed a more active procedure that allowed us to use infants' motor production as a measure of their action understanding. This 'behavioral reenactment procedure' capitalizes on imitation, but it uses this proclivity in a new, more abstract way. It investigates infants' ability to read below the visible surface behavior and to use the goals of others to guide their own action.

### 4.2. Empirics

One study involved showing 18-month-old infants an unsuccessful act (Meltzoff, 1995; for related work see also Carpenter, Akhtar, & Tomasello, 1998; Johnson, Booth, & O'Hearn, 2001). For example, the adult 'accidentally' under- or overshot his target, or he tried to pull apart a dumbbell-shaped object but his hand slipped several times from the ends as he pulled outwards. Thus the goal-state was not achieved. To an adult, it was easy to read the actor's intentions although he did not fulfill them. The experimental question was whether infants also read through the literal body movements to the underlying goal of the act. The measure of how they interpreted the event was what they chose to produce when given the object. In this case the 'correct answer' was to achieve the actor's goal, which remained unfulfilled.

The study compared infants' tendency to produce the target act in several situations: (a) after they saw the full target act demonstrated, (b) after they saw the unsuccessful attempt to perform the act, and (c) after it was neither shown nor attempted. Infants who saw the unsuccessful attempt and infants who saw the full target act both produced target acts at a significantly higher rate than controls. Evidently, young toddlers can understand our goals even if we fail to fulfill them. In another study (Meltzoff, 1995; Experiment 2), it was shown that infants did not re-enact the target act if they saw a mechanical device rather than a person performing the 'slipping' movements. The device did not look human and had poles as arms and pincers instead of fingers, but it traced the same spatiotemporal pattern as did the person's yanking. Infants did not pull apart the dumbbell at any higher than baseline levels in this case. They did, however, correctly perform the target act in another condition in which the mechanical device succeeded in pulling apart the dumbbell. This makes sense, because in the case of success the object transformation is visible (it is pulled apart), but in the case of the unsuccessful attempt, there is no object transformation, only a 'slipping' motion that has to be interpreted at a different level.

#### 4.2.1. Developmental changes in inferences about others' intentional acts

At what age do infants develop the ability to infer the goals and intentions of a person even if he does not successfully achieve them? In our work with 9- through 15-month-olds ($N = 55$), we found developmental change during a 6-month window. The 15-month-olds

behaved much like the 18-month-olds in the original 1995 study, but 9-month-olds did not respond above baseline levels to the unsuccessful-attempt demonstrations, even though they succeeded when the adult demonstrated successful acts. Evidence for such a developmental change has been provided by other studies using the behavioral re-enactment technique (Bellagamba & Tomasello, 1999). Researchers using looking-time techniques also have reported a developmental shift between approximately 9 and 15 months (e.g., Wellman & Phillips, 2001; Woodward et al., 2001; see also Carpenter, Nagell, & Tomasello, 1998; Tomasello, Carpenter, Call, Behne, & Moll, 2005 for related developmental studies).

#### 4.2.2. Persistence and emotions as markers of infants' intention

In further work, I showed 18-month-olds ($N = 33$) the standard unsuccessful-attempt display, but handed them a trick toy. The toy had been surreptitiously glued shut before the study began. When infants picked it up and attempted to pull it apart, their hands slipped off the ends. This, of course, matched the surface behavior of the adult. The question was whether this imitation of the adults' behavior satisfied the infants. It did not. When infants matched the surface behavior of the adult, they did not terminate their behavior. They repeatedly grabbed the toy, yanked on it in different ways, and appealed to the adult for help by looking and vocalizing. About 90% (20/23) of those who tried to pull apart the object immediately stared at the adult after they failed to do so (mean latency = 1.74 s). Why were they appealing for help? They had matched the adult's surface behavior. Evidently, they were striving toward something else: the adult's goals, not his literal behavior.

### 4.3. Implications for theory

This work indicates that infants can extract the goal of an act from the adult's unsuccessful attempts and use it to formulate their own subsequent motor plans. Other work also highlights the role of goals in imitation (Bekkering, Wohlschläger, & Gattis, 2000; Carpenter, Call, & Tomasello, 2005; Csibra & Gergely, 2007; Elsner, 2007; Gattis, Bekkering, & Wolschläger, 2002; Gleissner, Meltzoff, & Bekkering, 2000; Meltzoff & Moore, 1997; Tomasello et al., 2005; Williamson & Markman, 2006; Wohlschläger, Gattis, & Bekkering, 2003). Our work helps address developmental origins. By 18 months of age, infants do not construe the behavior of others simply as, 'hold the dumbbell and then remove one hand quickly' (a mere physical description), but rather interpret it as an *effort* at pulling it apart. They then adopt this as the goal of their own act. We also conducted related neuroscience work in adults. The results reveal that neural structures known to be involved in adult theory-of-mind tasks (medial prefrontal cortex) are activated in tasks requiring adults to infer unconsummated goals in basic action tasks (Chaminade, Meltzoff, & Decety, 2002; see also Reid, Csibra, Belsky, & Johnson, 2007, for related work). This suggests a tie between the processing of action sequences in terms of goals and more sophisticated aspects of social cognition.

The infant work shows that all spatiotemporal patterns are not equal in the infant's mind. Infants did not use the 'unsuccessful' motions of a clearly inanimate device as a basis for forming their own action plans, yet these same patterns were shown by a human prompt re-enactment of the person's goal. Our adult commonsense psychology includes a distinction between the types of entities that are accorded goals and intentions and those that are not. We ascribe a goal to the archer not to the arrow that reaches (or misses) the

target. This is not to say, however, that only people are accorded goals (see Csibra & Gergely, 2007; Heider & Simmel, 1944; Johnson, 2003; Song, 2007). A topic of interest is the criteria and cues infants use for inferring unseen goals and intentions and appropriating them to guide their own subsequent action. The mechanical pincers used in Meltzoff (1995, Exp. 2) establish a lower boundary for infants that is not sufficient; using the same paradigm, Johnson et al., 2001 reported success when infants were presented with an interactive, nonhuman puppet with eyes and hands. I am currently exploring whether mechanical devices such as social robots can be treated as 'like me' based on bodily structure and/or the type of behavior they exhibit, prompting action imitation by the infant. Preliminary results suggest so.

## 5. Experiment 3: treating intentional agents as a cause—a call to action

### 5.1. Background

Other intentional agents, just like the self, can cause things to happen. Do infants respond to events differently when an agent is thought to be the cause of events? In particular, does the involvement of a 'like me' agent prompt infants to self-action, perhaps through the social comparison, 'if he can do it, I can too'?

### 5.2. Empirics

I showed 18-month-old infants ($N = 28$) a causal sequence and varied whether a person was involved in producing the result. Infants saw the dumbbell-shaped object in three successive states. The three views were separated from each other by raising a black screen, so that the infants saw three static views of an event. After infants saw the three static displays, they were given the dumbbell. The question was whether they produced the target behavior, which was to pull the object apart. Three experimental groups were used.

(a) Group-1 was a baseline control condition to assess infants' spontaneous behavior. For this control, infants simply saw three identical states—the assembled object sitting in place with no person present.
(b) For Group-2 the three views revealed the affordances of the object but did not specify the involvement of a person. The views were (i) Object assembled, no person present, (ii) object disassembled, no person present, and (iii) object assembled again, no person present. Thus the infants saw the end-state of 'object-apart,' but had no information that a person was the cause.
(c) For Group-3 the views revealed an agent as a potential cause. The views were (i) Object assembled, in the person's hands, (ii) object disassembled, in the person's hands, and (iii) object assembled, in the person's hands.

As expected, baseline control infants (Group 1) did not tend to pull the object apart spontaneously: They mouthed it, banged it, and slid it across the table, but they did not spontaneously discover pulling it apart. Infants in Group-2 did not significantly differ from the baseline controls. In contrast, infants in Group-3 pulled the object apart significantly more often than the other groups, $ps < .05$.

### 5.3. Implications for theory

These results are especially interesting when combined with the earlier work on intention-reading (Meltzoff, 1995), because both show that the actions of an intentional agent who is 'like me' motivate infants to take action themselves. In the 1995 study the person is 'trying' to achieve an end, but the correspondings results are not shown. In the current study, it is shown that the person does not visibly move, but the person's (unseen) behavior can be interpreted as a potential cause for the visible effect. In both cases, infants produce an object manipulation that was never directly observed, but only inferred.

## 6. Experiment 4: learning acts by perception and strengthening memory by production

### 6.1. Background

In the foregoing work the question was whether infants could infer the goal of an act even if it was not achieved. Other work from our laboratory zeroed in on whether the infant would adopt the *means* used by the adult—the particular way or manner that he did things (Hobson, 2002; Hobson & Lee, 1999; Williamson & Markman, 2006). This explores whether children are motivated to 'act like' another in terms of particular mannerisms, actions, and strategies—not simply whether they adopt the same goals as those suggested. We also explored the ability of infants to imitate completely novel acts, ones for which they have had no prior motor experience. The results show the extraordinary abilities for human infants to formulate new motor acts based on perception.

### 6.2. Empirics

#### 6.2.1. The power of perception

In Meltzoff (1988) 14-month-old infants served as subjects. The adult put a flat box on the table and then bent from the waist, touching it with his head, which caused it to illuminate. The infants simply observed this act and were not allowed to touch or play with the object in any way. Infants were then sent home and returned 1-week later to be presented with the panel. Control infants showed that in the absence of seeing this odd event modeled by the adult, the spontaneous probability of infants touching the panel with their foreheads was literally 0%. Yet, 67% of the infants who had seen the demonstration leaned forward from the waist and touched the panel with their own foreheads, $p < .0001$. This establishes that infants can learn novel *means*—how to do something—from watching others. The effect has been replicated and extended by Gergely et al. (2002) who showed that infants would perform this act flexibly, duplicating the novel means used under certain circumstances and not others (see Williamson & Markman, 2006 for related work). These head-touch studies show that infants can learn a novel act simply by watching others. Perception lays down a blueprint to be used later in production. What does production add?

#### 6.2.2. The power of production

Providing the perceiver with an opportunity to produce the act may enrich the representation, because the actor would experience the act in a new way—motorically. In order to investigate this I used a memory procedure appropriate for 14-month-olds ($N = 48$). Infants in Group 1 were shown two target acts (shaking an object that made a sound

and dangling an object from a vertical string and bouncing it on the tabletop). They were not given the opportunity for immediate imitation. Infants in Group 2 were shown the same demonstrations but were allowed to imitate immediately (almost all of them did). Both groups of infants were then sent home for a 24-hour delay. At the second session infants from both groups were treated identically: Infants were presented with the objects, one at a time, each for a 20 s response period. Infants in Group 2 produced more target behaviors than the other group and generated the imitative acts with significantly shorter latencies, $p < .05$. Something appears to be gained if infants perform the action themselves directly after observing it (see also Hayne, Barr, & Herbert, 2003 for related work with 18-month-olds).

### 6.3. Implications for theory

The 1988 head-touch study provided the first evidence that infants could remember and imitate novel actions based on observation alone. This establishes the power of perception even in the absence of concurrent production (infants were not allowed to touch the toy until a week later) or motor familiarity with the act (it was a novel act with 0% probability in the control groups). Thus perception leads to a stored representation of the act that can drive subsequent production with one's own body.

This is not the end of the story, however, because the other study shows that memory performance is enhanced if infants imitate before the delay. Production enriches the representation derived from observation alone. Action reproduction is a way for the perceiver to take something of the other and make it their own—transforming the event from 'I saw that' to 'I did that,' with all the richness engendered by self-produced motor experience (including feelings of intentionality and emotional fulfillment at succeeding). It becomes a 'personal experience' that, I argue, is distinctively tagged and not confused with the acts of others that were witnessed purely in perception (see also Hauf & Prinz, 2005; Hayne et al., 2003; Meltzoff & Moore, 1997). In a related brain imaging study with adults, we found differences in the neural correlates of action observation alone versus production alone versus a combination of action perception and production (Decety, Chaminade, Grèzes, & Meltzoff, 2002).

Taken as a whole, these findings support the *bidirectionality* that was hypothesized in the Introduction. Infants learn the possibilities of their own acts from watching others (mapping from others to self); and they also enrich their observation, memory, and interpretation of others through producing like acts themselves (mapping from self to other). This bidirectionality is underwritten by the nature of the representation of action.

## 7. The representation of action in infancy

According to classical theories of developmental psychology, the imitation of facial gestures is a landmark achievement first passed at about 1 year of age. Before this age infants had no way of 'connecting up' or 'associating' the seen acts of another with the invisible acts of their own.

We discovered that infants could imitate facial acts, forcing a revision in developmental theory (Meltzoff & Moore, 1977, 1997). Our research showed that 2- to 3-week-olds imitated tongue protrusion, mouth opening, lip protrusion, and simple finger movements. This finding reveals a close mapping between perception and production for certain basic

acts: Infants observe the act and produce a matching response even though they cannot visually monitor their productions. Because these results did not fit with classical theory, they were initially the topic of much discussion. The findings of early imitation have now been replicated and extended cross-culturally in more than 24 different studies in over a dozen countries (see Meltzoff & Moore, 1997 for a review). We even tested newborns with an average age of 32 h old. The results again showed successful imitation (Meltzoff & Moore, 1983, 1989). Evidently, some primitive capacity for behavioral matching is present in the human newborn.

### 7.1. A proposal about early action representation

This work on infant imitation has implications for how action is represented pre-linguistically (see Fig. 1, component 'a'). Meltzoff and Moore (1977, 1997) hypothesized that infant imitation depends on a process of active intermodal mapping (AIM). The view holds that imitation, even early imitation, is a matching-to-target process. The goal or behavioral target is specified visually. Infants' self-produced movements provide proprioceptive feedback that can be compared to the visually specified target. AIM proposes that such comparison is possible because the perception and production of human movements are registered within a common 'supramodal' representational system.

We called it a supramodal act space because it is not restricted to modality-specific information (visual, tactile, motor, etc.). Although infants cannot see their own faces, their faces are not unperceived by them. They can monitor their lip and tongue movements through proprioception and compare this felt activity to what they see. There is thus something like a primitive body scheme that allows infants to code human acts—whether perceived or performed—in one common framework. Metaphorically, we can say that perception and production 'speak the same language' and are intimately bound at birth. A more detailed analysis of the functional architecture of AIM and the metric of equivalence for uniting perception and production is provided elsewhere (Meltzoff & Moore, 1997), including discussion of the possible contribution of in utero motor experience to developing the initial body scheme.

### 7.2. Analysis of supramodal representation

Three pieces of data suggest that the supramodal system in humans is not reducible to a Gibsonian resonance device for turning observations into like movements—a direct perception-production transducer. First, the observations of others' acts can be stored and accessed after a delay (Meltzoff & Moore, 1994, 1998). At minimum, there is an intermediary representation and not simply an automatic transduction. Second, infants correct their imitative efforts (Meltzoff & Moore, 1994, 1997). Information about one's acts has to be available for comparison to the representation of the adult's act, but the representation of the observed act is not confused with or modified by one's own multiple motor attempts. Third, infants show special interest in being imitated themselves; they recognize when their behavior is being copied (e.g., Meltzoff, 1999, 2005; see Agnetta & Rochat, 2004 for a replication and extension). Such recognition implies that there is a representation of their own bodily acts.

This takes us beyond a simple Gibsonian resonance device. The representations of the observations of others are 'tagged' so as to differentiate them from the representation of

one's own motor acts. The cognitive act is to compare these two representations—in one case to match one's own acts to the other (imitative correction), and in the other case to detect being matched oneself (recognition of being imitated). The mental code may be abstract enough to unite perception and production, but the representations deriving from observation and self-action are not confused. Some source information is retained. The other is *like* me but is not confused with me. Recent brain imaging work in adults has focused on the neural basis for differentiating self-action from the matching acts of others. The research suggests that the right inferior parietal lobe plays a key role in this self-other differentiation (Decety et al., 2002; Meltzoff & Decety, 2003).

### 7.3. Connections among developmental science, cognitive psychology, and neuroscience

The idea of a supramodal representation for acts fits well with proposals from cognitive psychology about action coding (e.g., Hommel et al., 2001; Prinz, 1987, 2002) and neuroscience about a mirror system in humans (e.g., Chaminade, Meltzoff, & Decety, 2005; Gallese, 2003; Iacoboni, 2005; Iacoboni et al., 1999; Jackson, Meltzoff et al. (2006); Rizzolatti et al., 2002). An important task for scholars focused on perception-production links is to analyze the commonalities and differences in the mechanisms proposed by neurological, developmental, and cognitive levels of analysis. Relevant interdisciplinary papers are beginning to appear (e.g., Brass & Heyes, 2005; Frith & Wolpert, 2004; Hurley & Chater, 2005; Meltzoff & Decety, 2003; Meltzoff & Prinz, 2002; Wilson & Knoblich, 2005).

## 8. General discussion

Piaget (1952, 1954) argued that the infant is born a 'solipsist'; Fodor (1987) supposed that a full-fledged intentional understanding of others was hardwired into the human brain. The 'like me' theory offers a third perspective. It grants more to the infant than the first view, while still adopting a developmental framework. My thesis is that a starting point for social cognition is that human acts are represented within a supramodal code that applies to the self as well as others. Infants bring this representation to their very first interactions with people, and it provides an interpretive framework for understanding the behavior they see.

Philosophers have discussed whether an analogy between self and other plays a role in our treatment of others as intentional agents (Baldwin, 1906; Goldman, 2005; Gordon, 2005; Hume, 1962; Husserl, 1960; Lipps, 1907; Smith, 1966).[2] The problem has traditionally been that this self-other connection was thought to be a late achievement and perhaps dependent on language, and therefore thought not to play a formative role during infancy. A quarter century of research on infant imitation has turned this proposition upside down (Gallagher & Meltzoff, 1996). It indicates that young infants can represent the acts of others and their own acts in commensurate terms. The recognition of self-other equivalence is the starting point for social cognition, not its culmination.

[2] It has not escaped notice that the human capacity for empathy may also be related. For recent neuroscience work in adults see Iacoboni (2005), Jackson, Meltzoff, and Decety (2005), and Jackson, Brunet, Meltzoff, and Decety (2006). The latter study experimentally manipulated whether the hand subjects saw being 'injured' belonged to a person or a mannequin (not like me), with differential neural responses.

That infants can interpret the acts of others in terms of their own acts and experiences provides them with enormous leverage and an engine for development (Meltzoff, in press). For example, when infants want something they reach out and grasp it. They experience their own internal desires and the concomitant bodily movements (hand extension, finger movements, etc.). The experience of grasping objects to satisfy their own desires gives infants leverage for making sense of the grasping behavior of others. When the child sees another person reaching for an object, she sees the person extending his hand in the same way she does and the fingers curl around the goal. Reaching and grasping acts can be imbued with goal-directedness, based on the child's own experience. A 'like me' process may thus underlie the findings that the infant's motor experience influences action perception as assessed by looking-time measures (Hauf, Aschersleben, & Prinz, in press; Sommerville & Woodward, 2005a, 2005b; Sommerville et al., 2005).

A similar argument applies to the goal-directed behavior used in Meltzoff's (1995) studies of action production using the behavioral re-enactment procedure. Infants have goals and act intentionally. Indeed in the second half-year of life they become obsessed with the success and failure of their plans (e.g., Gopnik & Meltzoff, 1986, 1997; Moore & Meltzoff, 2004). They repeatedly test their own plans, explore why they failed, and systematically alter the means as if experimenting with various ways of achieving the same goal. When an infant sees another act in this same way ('like me'), the infant's self-experience could suggest that there is a goal, plan, or intention beyond the surface behavior. Thus infants would come to read the other's unsuccessful attempts, and the behavioral envelope in which they occur, as an effortful pattern of striving, rather than ends in themselves (see Fig. 1).

Based on the 'like me' perception of others' actions, social encounters are more interpretable than supposed by classical 'solipsism' theories such as Piaget's. Infants can use themselves as a framework for understanding the subjectivity of others and reciprocally learn about the possibilities inherent in their own actions by observing the actions of others. Through social interaction with other intentional agents who are viewed as 'like me,' infants develop a richer social cognition.

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