

# The Case for Developmental Cognitive Science: Theories of People and Things

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## Introduction

A hundred years ago few scientists studied infants. Scholars interested in the brain (the forerunner of today's neuroscience) and those interested in epistemology and experimental psychology (the forerunners of cognitive science) did not perceive infants as a key population for psychological research. Attention was devoted to rodents and undergraduates. This has begun to change. Neuroscientists and cognitive scientists now turn to

This chapter is dedicated to my friend and colleague, George Butterworth. George and I spent many days discussing the topics that have made it into this chapter. He was a pioneer in object permanence and joint visual attention and thought deeply about imitation and intentionality. Every conversation with George sparked an idea; every interaction was a joy. I miss him. I am deeply indebted to Alan Slater and Gavin Bremner for their extreme patience and help as I composed this chapter. Thanks also to three collaborators with whom I've discussed many of the ideas presented here: Keith Moore, Alison Gopnik, and Rechele Brooks. Pat Kuhl provided useful insights on the writing, and Craig Harris and Calle Fisher helped in putting the chapter together. Work on the chapter was provided by a grant from NIH (HD-22514).

infancy to sharpen their understanding of mind, brain, and evolution (e.g., Diamond, Casey, & Munakata, in preparation; Meltzoff & Decety, 2003; Johnson & Karniloff-Smith, chapter 5 in this volume).

Popular though it is, infancy is not a settled field. Piagetian theory no longer reigns. Modularity-nativism gained adherents in the 1990s, but is now being challenged. There is uncertainty about how to explain the new data pouring out of laboratories. This chapter discusses this theoretical ferment with particular reference to infants' knowledge of people and things. I conclude by sketching foundations for a *developmental* cognitive science that may allow us to escape from between a rock (Piagetian theory) and a hard place (nativism).

## Infant Theories: Standard Model and New Proposals

The Piagetian view of infancy was built on two fundamental axioms: the *action* assumption and the *invisibility* assumption. The former holds that infant knowing is rooted in their taking action. To know an object is to use it, and the acquisition of new knowledge requires motor exploration. Preverbal infants are confined to "knowing how," not "knowing that." The invisibility assumption proposes that when young infants lose sensory contact with an object, the object ceases to exist for the infant. To the young infant, an object is nothing more than "a mere image which re-enters the void as soon as it vanishes" (Piaget, 1954, p. 11). It does not have an independent, stable existence in external space.

The classic designation of infancy as the "sensorimotor period" codifies these two axioms. Infant intellectual growth is based on increasingly elaborate sensorimotor connections (practical habits), without mediating mental representations. The crowning achievement of the sensorimotor period is the birth of representation at about 18 months of age. Representation allows children to go beyond sensorimotor hooks and resonances with perceptually present stimuli. Representation allows infants to escape the eternal present. It undergirds their ability to perform deferred imitation and solve complex object permanence problems involving serial invisible displacements (Piaget, 1952, 1954, 1962).

The classic sensorimotor view of infancy has not received overwhelming empirical support. The action assumption was undermined by results showing that infants recognize familiar vs. novel displays they have never manipulated (Bower, 1982; Cohen,

Chaput, & Cashon, 2002; Fantz, 1964; Haith, 1998; Quinn, 2002; Slater, 1989, 1997). Infants learn, remember, and categorize without the necessity for motor involvement.<sup>1</sup> Research has also been directed at the invisibility assumption. Studies of deferred imitation and object occlusion discovered that young infants link objects and events across temporal gaps involving disappearances. Contrary to Piaget, the evidence shows that the absence of sensory contact does not terminate *mental* contact (e.g., Baillargeon, 1993; Meltzoff & Moore, 1998; Spelke, 1998).

Several alternative theoretical approaches have been suggested to replace Piaget. In this chapter I will suggest that the infant is not a sensorimotor organism but a representational one right from the neonatal period. Infants never go through a purely sensorimotor period, in which they operate solely with habit knowledge. Such a stage was postulated but does not exist.

However, moving beyond Piaget does not mandate acceptance of the modern-day nativism of Fodor (1983) or Spelke (1994, 1998). Although a young infant is more than a bundle of reflexes and sensorimotor habits, it does not follow that infants possess adult knowledge. The newborn's conception of persons and objects undergoes radical conceptual change as a function of the input received. What we need is a non-Piagetian theory of conceptual change in infancy.

Table 6.1 outlines four theories of infancy. This 2 × 2 table casts theories according to their views on two dimensions: the status of *representation* at birth and the reality of *conceptual change* in infancy. Obviously, a more complex description could be envisioned, but this suffices to capture critical points on which modern theories of infancy differ.

The classical Piagetian position occupies the "No-Yes" cell. It holds that infants have no representational system at birth and that there is a profound cognitive difference between newborns and 18-month-olds. Spelke's core knowledge thesis is the opposite:

Table 6.1 Four theories of infancy

Conceptual change at birth		Example theorist		Theory
No	Yes	Piaget	Sensorimotor	
Yes	No	Spelke	Core knowledge	
No	No	Thelen & Smith	Dynamic systems	
Yes	Yes	Meltzoff, Moore, & Gopnik	Theory theory	

it couples innate representation (a "yes" to Piaget's "no") with no conceptual change; the core concepts of adults are present in infants in mature, unchanging form (Spelke, 1994, 1998; Spelke, Breilinger, Macomber, & Jacobson, 1992). Thelen and Smith's (1994) dynamic systems theory shares the Piagetian view that there is no innate representation, but differs from Piaget in eschewing infant conceptual development. Thelen and Smith do not see sensorimotor coordinations as precursors to infant mentalization and believe that explaining infant behavior at a conceptual level is misguided. On this view, the theoretical account of infants' response to problems should be in terms of the perceptual-motor demands and habitual responses involved in each specific situation. Children are limited to "know how" from birth to 3 (and possibly beyond). There is behavioral reorganization but not conceptual change because there are no infant concepts to work with. Meltzoff and Moore (1998) incorporated both an initial representational capacity and conceptual change in a model of infancy. This position is a particular instance of a more general formulation of cognitive and semantic development called "theory theory." This view holds that infants understand the world in ways that change according to the data obtained and the experiments they perform (Gopnik & Meltzoff, 1997; Gopnik, Meltzoff, & Kuhl, 1999). In short, the theory is that infants have changeable theories of the world – not sensorimotor reactions (Piaget; Thelen & Smith) or adult theories that are masked by performance constraints or uncoordinated with action (Spelke).<sup>2</sup>

In this chapter I provide examples of how the theory-theory approach can be cashed out. I will consider four "hot topics": representation, joint visual attention, intentionality, and object permanence. The view presented is not a familiar one. I will argue that young infants have innate representational capacities and will discuss what this means. I will show that they can perform deferred imitation, but do not have a notion of object permanence in the first half-year of life. I will further sketch ideas about how object permanence, joint attention, and intentionality may develop with experience.

## Innate Representation

### *What's at stake*

Piaget thought that representation first emerged at 18 months of life. Both facial imitation and deferred imitation were used to

buttress this view. Facial imitation was thought to be a late attainment, because the child's face was invisible to him or her. Deferred imitation was impossible because the target-to-copy was absent from view. These behaviors simply could not be early developments, and it took elaborate theoretical work to explain their appearance in the second year of life. It was critical for theory that deferred imitation first became possible at about 18 months of age in synchrony with higher-order symbolic behaviors such as language, pretend play, and the understanding of invisible displacements.

Piaget's theory does not conform to the modern empirical research (Meltzoff, 1999; Meltzoff & Prinz, 2002; Nadel & Butterworth, 1999). It has been shown, for example, that young infants perform deferred imitation. Evidently, invisibility is not an insurmountable problem. Infants can recall the past and use the past to guide their present actions.

### *Empirical findings*

In assessing the new data on deferred imitation and its impact on classical theory, it is important to distinguish between (1) forming a representation of an event from observation alone without motor involvement and (2) repeating one's own behavior or motor habits after a delay. For Piaget (1962), only the former qualified as deferred imitation. At stake is whether infants must motorically produce the act at Time-1 for it to be preserved at Time-2.

Meltzoff (1985, 1995) addressed this issue by introducing an "observation-only" design to explore early deferred imitation. In this paradigm infants were shown target acts on objects but not allowed to touch or handle the objects at Time-1. A delay was then imposed. After the delay, the objects were presented to the infants, and deferred imitation was assessed. Thus, infants could not be repeating their own actions with the objects, because interaction with them had been barred at Time-1. Using this design, deferred imitation of actions on objects has now been documented in infants as young as 6 to 9 months of age (Barr, Dowden, & Hayne, 1996; Heilmann & Meltzoff, 1996; Meltzoff, 1988b).

Even if deferred imitation is possible, there are other hurdles to overcome before the theoretical implications are clear. For example, if deferred imitation in the pre-18-month-olds was restricted to highly familiar behaviors, it would sharply limit the implications for representation. Several experiments have addressed these issues using novel acts. Meltzoff (1988a) showed infants an adult who leaned forward and pressed a panel with

his forehead. The infants were not allowed to play with the panel and were sent home for a 1-week delay interval. The baseline rate of producing this novel act was 0 percent for the control groups who did not see the adult display. However, 67 percent of the infants who saw the display reproduced the act after the week's delay. Gergely, Bekkering, and Király (2002) replicated this imitation of the novel head-touch act and showed it is not an automatic response, because there were conditions under which infants choose to duplicate the adult's odd behavior and conditions where they did not. Infants also imitate novel event sequences after a delay (e.g., Barr & Hayne, 1996; Bauer & Hertsgaard, 1993; Bauer & Mandler, 1992).

Researchers have investigated the length of delay that can be tolerated by young infants, with surprising results. Infants as young as 6 to 9 months of age successfully imitate after delays of 24 hours (Barr et al., 1996; Heimann & Meltzoff, 1996; Meltzoff, 1988b), 12-month-olds perform deferred imitation after 1-month delays (Klein & Meltzoff, 1999), and infants in the second year can imitate from memory after 4 months or longer (e.g., Bauer & Werwka, 1995; Mandler & McDonough, 1995; Meltzoff, 1995). Once formed, representations evidently tend to persist and can be used as the basis of subsequent action.

In light of the evidence so far presented, there might be a temptation to tinker slightly with the classic theory to allow deferred imitation and representation at about 6 to 12 months old instead of 18 months. However, these capacities seem to be part of the initial state, at least when simple body actions are presented. Infants soon after birth can perform deferred imitation of facial gestures. Such facial imitation is representationally mediated: it has been demonstrated using an observation-only design, with novel gestures, and over long delays. Thus we infer that neonates have some primitive form of representation that allows them to organize action based on stimuli no longer in the perceptual field.

One early study used the observation-only design with neonates. Infants sucked on a pacifier while an adult demonstrated mouth opening and tongue protrusion (Meltzoff & Moore, 1977). This technique blocked infants from imitating while the display was in the perceptual field. The adult then stopped the demonstration, assumed a neutral face, and only then removed the pacifier. The results showed that 3-week-old infants imitated the gestures in the subsequent response period, despite the fact that the target gesture was no longer visible. Other studies have also reported early facial imitation when the gesture was no longer visible (Fontaine, 1984; Heimann, Nelson, & Schaller, 1989; Heimann & Schaller, 1985; Legerstee, 1991; Meltzoff & Moore, 1989).

Young infants have also been shown to imitate across longer delays. In one study, four groups of 6-week-old infants saw different gestures on Day 1 and returned on Day 2 to see the adult with a neutral pose (Meltzoff & Moore, 1994). The results showed that 6-week-old infants differentially imitated the gestures they saw 24 hours earlier. They imitated based on their representation of things past.

Finally, 6-week-old infants are able to imitate a somewhat novel gesture, a tongue-protrusion-to-the-side (Meltzoff & Moore, 1994, 1997). It is interesting that such young infants do not imitate this novel act on first try but modify their behavior over successive efforts, without feedback from the adult. We interpret this to mean that imitation is an active process in which infants cross-modally compare their own motor productions to a stored representation of the absent stimulus and correct the behavior to bring the two into register, as described by the active intermodal matching (AIM) model of imitation (see Meltzoff & Moore, 1997, for further analysis of the mechanisms underlying early imitation).

### Larger implications

These findings impact theories of representational development (Hayne, 2002; Slater, 2002). Three inferences can be drawn: (1) representations can be formed from observation alone, without concomitant motor action; (2) representations are durable mental entities in the preverbal period; and (3) they are a sufficient basis on which to organize action. The modern data suggest that young infants are not confined to sensorimotor coordination and motor habits. It is too conservative to build a theory of infancy that does not impute innate representational capacities. This weighs against the Piagetian and dynamic system theories (table 6.1). A richer starting state is needed.

### Joint Visual Attention

#### What's at stake

In the adult psychological framework, head and eye movements have special significance. Adults realize that others direct their attention toward objects, picking up information about them from afar, despite the spatial gap between attender and target. We ascribe intentionality to the perceiver who turns his or her head. Do infants? Or are headturns interpreted as physical motions with no notion that they are directed toward the external object?



It is already known that young infants follow another's gaze, but there is a debate about mechanism (Butterworth, 2001). Nativists propose that infants have an innately specified shared attention module (Baron-Cohen, 1995). Others argue that this overinterprets gaze following. One proposal is that such behavior is based on infants being attracted to the spatial hemifield toward which the adult's head is moving. The infant visually tracks the adult and thereby swings his or her own head to the correct half of space without processing the adult's gaze or attention to an object (e.g., Butterworth & Jarrett, 1991; Moore & Corkum, 1994). On this view, infants do not understand the adult as a perceiver but simply process the salient movements regardless of what the organs of attention, the eyes, are doing.

### Empirical findings

A recent study zeroed in on whether infants understand the object directedness or referential value of adult attentive movements (Brooks & Meltzoff, 2002). Two identical objects were used, and the adult turned to look at one of them with no verbal or emotional cues. The infants were 12, 14, and 18 months of age. The interesting manipulation was that the adult turned to the target object with *eyes open* for one group and with *eyes closed* for

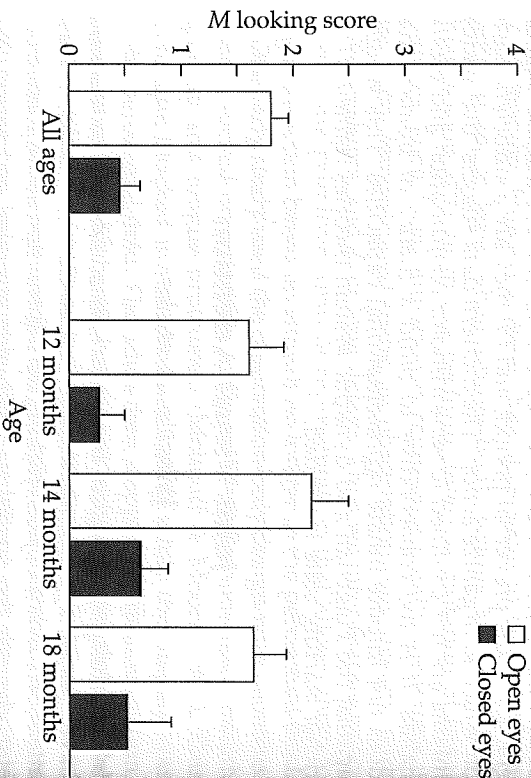


Figure 6.1 Mean looking score (+ SE) for open-eyes and closed-eyes groups at each age ( $n = 32$  per age) (from Brooks & Meltzoff, 2002).

the other group. In each case infants interacted contingently with the adult before the trial. If infants rely simply on gross head motions, they should turn in both cases. If they rely on an abstract rule to look in the same direction as a "contingent interactant" (Johnson, Slaughter, & Carey, 1998), they should also look whether the adult's eyes were open or closed, because the adult's interactive behavior was identical in both groups.

The findings showed that the infants at all three ages turned selectively (figure 6.1). They seem to realize that a person may either be looking or not, depending on the status of his or her perceptual systems. This is sophisticated behavior for a 1-year-old, but it is not based on innate knowledge. Recent research shows that 9-month-olds turn just as readily in the direction of the adult's turn, regardless of whether the adult's eyes are open or closed (Brooks & Meltzoff, 2003). As Butterworth predicted, these young infants seem to be governed by the adult's gross head movements and do not take into account whether or not the adult is actually gazing at the object. We are currently studying this important developmental transition (see also Carpenter, Nagell, & Tomasello, 1998).

Brooks and I also noticed two responses that have not been systematically investigated in the joint visual attention literature. First, we found that infants pointed to the target object significantly more often if the adult looked at it with open vs. closed eyes. The infant's response involved a different motor movement than the adult's. The goal was the same, making reference to an object, but the means were different. Second, we discovered that

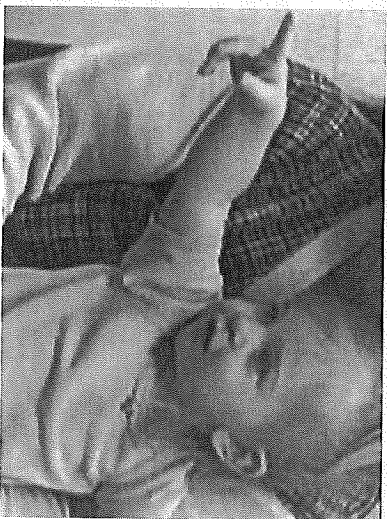


Figure 6.2 An 18-month-old pointing to the correct target (from Brooks & Meltzoff, 2002).

infants visually inspected the object longer when they followed the adult's open eyes. This is significant because the object, in itself, is the same whether the adult turns with open or closed eyes. This suggests that the inanimate object takes on special valence because it is referenced by another person. It becomes more interesting to infants, and they visually inspect it for a longer period of time.

### Larger implications

Taken together, the pointing and visual examination data suggest that infants are not simply observing meaningless motions. Infants are not simply coding physical motions, but making a psychological attribution to the perceiver. The findings do not prove that infants ascribe to the adult an "internal experience of attending," but they move beyond the leanest interpretations of gaze following. At minimum, they suggest that by 12 months of age, infants represent the object directedness of adult gaze. They see head movements as directed toward the external world and not mere bodily movements without significance (Butler, Caron, & Brooks, 2000; Johnson, 2000; Wellman & Phillips, 2001; Woodward, in press).

In the conclusions of this chapter I show how infants' experience with their *own* eye opening-closing - cutting off and reaccessing the world through it - may contribute to their understanding the visual perception of others. My hypothesis is that they see others as "like me" and use the experience gained through their own self-action to help them interpret the behavior of others. This "like-me" framework, I will suggest, may be an engine for developmental change in infants' understanding of gaze and other acts as well (Woodward, Sommerville, & Guajardo, 2001).

### Intention

#### What's at stake

Persons are more than dynamic bags of skin whose actions can be represented and imitated and whose direction of gaze can be followed. In the mature adult notion, persons have beliefs, desires, and intentions that predict and explain human actions. One cannot see, hear, or taste others' mental states, but it is an essential part of our commonsense psychology that we

believe people have them. So-called "theory-of-mind" research addresses the development of this understanding of people.

A strong nativist view was provided by Fodor (1987, p. 132): "Here is what I would have done if I had been faced with this problem in designing *Homo sapiens*. I would have made a knowledge of commonsense *Homo sapiens* psychology innate; that way nobody would have to spend time learning it." Leslie (1994, 1995) also laid out the case for an innately specified theory of mind module. What do the recent data say about the development of infants' understanding of other minds and especially the intentions of others?

### Empirical findings

To begin to tackle this issue, Meltzoff (1995) developed a procedure called the behavioral reenactment technique. The 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 to the underlying goals and intentions of the actor.

One study involved showing 18-month-old infants an unsuccessful act, a failed effort (Meltzoff, 1995). For example, the adult "accidentally" under- or overshoot his target, or he tried to perform a behavior but his hand slipped several times; thus the goal-state was not achieved. To an adult, it was easy to read the actor's intention 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 reenact. In this case the correct answer was not to copy the literal movement that was actually seen, but to copy the actor's goal, which remained unfulfilled.

The study compared infants' tendency to perform the target act in several situations: (1) after they saw the full target act demonstrated, (2) after they saw the unsuccessful attempt to perform the act, and (3) after it was neither shown nor attempted. The results showed that 18-month-olds can infer the unseen goals implied by unsuccessful attempts. Infants who saw the unsuccessful attempt and infants who saw the full target act both produced target acts at a significantly higher rate than controls. Evidently, young toddlers can understand our goals even if we fail to fulfill them.

At what age does this understanding of others emerge? My research suggests that it is not available innately. I have found

that 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 (Meltzoff, 1999). Importantly, control conditions indicated that 9-month-olds succeeded if the adult demonstrated successful acts. The 9-month-olds imitated visible acts on objects, but gave no evidence of inferring intentions beyond the visible behavior itself. This finding of developmental change in infants' understanding of others' goals and intentions has also been documented in other studies (Bellagamba & Tomasello, 1999), so there is converging evidence for an important developmental change between 9 and 15 months. We have also shown that children's understanding of goals continues to change and influence behavior in the 3- to 6-year-old age range (e.g., Gleissner, Meltzoff, & Bekkering, 2000), and many have argued that making sense of others' goals and intentions is a lifelong enterprise (Bruner, 1999).<sup>3</sup>

In the adult psychological framework, people and other agents have goals and intentions, but inanimate devices do not. Do infants carve the world in this way? In order to assess this, Meltzoff designed an inanimate device made of plastic and wood (Meltzoff, 1995, Exp. 2). The device had poles for arms and mechanical pincers for hands. It did not look human, but it traced the same spatiotemporal path that the human actor traced and manipulated the object much as the human actor did. The results showed that infants did not attribute a goal or intention to the movements of the inanimate device when its pincers slipped off the ends of a dumbbell that it was "trying" to pull apart. Infants were no more (or less) likely to pull the toy apart after seeing the failed attempt of the inanimate device than they were in baseline levels when they saw nothing. This was the case despite the fact that infants pulled the dumbbell apart if the inanimate device successfully completed this act. Evidently, infants can pick up certain information from the inanimate device, but not other information: they can understand successes, but not failures. This makes sense because successes lead to a change in the object, which gives them an endstate to achieve, whereas failures leave the object intact and therefore must be interpreted at a deeper level.

### Larger implications

The research shows that infants distinguish between what the adult meant to do and what he actually did. They ascribe goals

to human acts; indeed, they infer the goal of an act even when the goal is not attained. This differentiation lies at the core of our commonsense psychology. It underlies communication as well as moral judgments. Thus, infants already exhibit an essential aspect of our commonsense psychology: the acts of persons (but not the notions of unambiguously mechanical devices) are understood within a psychological framework involving goals and intentions.<sup>4</sup>

## Object Permanence

### What's at stake

Before 8 months of age infants do not search for objects hidden by an occluder. Piaget interpreted this as evidence that they had not yet developed the concept of a permanent object. Object permanence is the notion that material objects are not annihilated by virtue of their occlusion. They continue to exist in a spatial location behind the screen and are simply hidden from view. The fact that burning, melting, and explosion destroy objects does not violate the adult notion of object permanence. Object permanence does not mean that we think objects are forever permanent and cannot be destroyed. The essential point is that we do not think that an *occlusion* event, in and of itself, destroys an object. We would be shocked (and disbelieve) evidence that an object "disappeared into thin air" by virtue of being occluded by a screen.

The problem that has bedeviled developmentalists is that the failure of pre-8-month-olds to search for occluded objects may not reveal a deficit in understanding object permanence. Search errors may be due to other factors such as a lack of motor skill, memory, and/or means-ends coordination (e.g., Bremner, 1994; Butterworth & Jarrett, 1982; Diamond, 1985; Harris, 1987; Moore & Meltzoff, 1999; Munakata, 1998; Munakata et al., 1997). Researchers have attempted to circumvent this by measuring infants' visual response to object occlusions. Infants' preferential looking to novelty after habituation/familiarization has been used to investigate object permanence. Typically, these findings are interpreted as showing that infants as young as 3.5 months of age, and perhaps from birth, exhibit object permanence (e.g., Baillargeon, 1993; Spelke et al., 1992).

Recently, the attribution of early object permanence based on looking-time studies has been questioned (Bogartz, Shinsky, & Schilling, 2000; Cashon & Cohen, 2000; Haith, 1998; Meltzoff & Moore, 1998). In particular, Meltzoff and Moore (1998) suggested

that infants' representational capacity itself, in the absence of permanence, would be sufficient to generate increased looking times. Infants could represent the pre-hiding event and compare this scene with the post-hiding situation. Pre-post discrepancies would recruit increased looking without requiring an understanding of the object's continued existence *in a specific location behind the occluder while it is out of sight*. Meltzoff and Moore (1998) reviewed looking-time studies and found they could be accounted for by the operation of infant representation and identity rules alone, without the notion of object permanence. Whether this view provides a complete account of all the early permanence work (e.g., Baillargeon, 2002) is an issue that will continue to be debated, but we think we have accounted for the classic studies based on different (less developmentally mature) mechanisms than permanence. Recently, we returned to the gold standard of manual search. Our reasoning was as follows. If infants actively search for an occluded object, this is good evidence for permanence. They are searching in the invisible place precisely because they think the object exists in that spatial location even though the object is not in sight. The problem has always been that failures were hard to interpret. We designed a new study in which failures as well as successes were interpretable. The results suggest that object permanence develops through a progressive understanding and is not innately fixed.

### Empirical findings

In Moore and Meltzoff (1999) infants were shown two different types of total occlusion in which the *same* toy is hidden in the *same* place behind the *same* screen. If young infants solve one hiding but not the other, this task dissociation cannot be attributed to differences in motor skill, means-ends coordination, or other ancillary factors, because the same response is needed to find the toy in both. In other words, the tasks controlled for the ancillary factors that are often invoked to account for search errors. The tasks differed only in the type of cognitive problem they posed to the infant (in ways that will be described below).

In these experiments, we adopted three criteria for isolating permanence-governed search:

- 1 Infants were precluded from reaching until the occlusion was complete. If search is based on permanence, infants should be able to initiate search after the disappearance event has

terminated. Search acts that start before occlusion is complete do not necessitate permanence, because they could be planned and launched from direct perception.

- 2 A strict criterion for the form of the search act was adopted. If infants represent a hidden object as spatially localized, for example under a cloth, the aim of search should be to uncover that space and thus the object. Pointing at or even touching the occluder do not unequivocally index a hidden location; they may simply mark where the last perceptual change occurred in the visual field.

- 3 The infant's gaze during the act of uncovering was measured. If search is permanence-governed, the infant's gaze should be directed toward the hidden location as uncovering begins, because they are looking for the object under the occluder. (The last two points help distinguish infant play with occluders from permanence-governed search, as discussed by Butterworth, 1977; Willatts, 1984.)

Experiment 1 involved 10-, 12-, and 14-month-old infants. Each infant was given both hiding tasks in a counterbalanced order. Figure 6.3 displays the two occlusion events. They differed in a subtle way – so subtle that existing theories do not predict any difference between them. In the hiding by screen, the occlusion is accomplished by putting the object in a place on the table top,

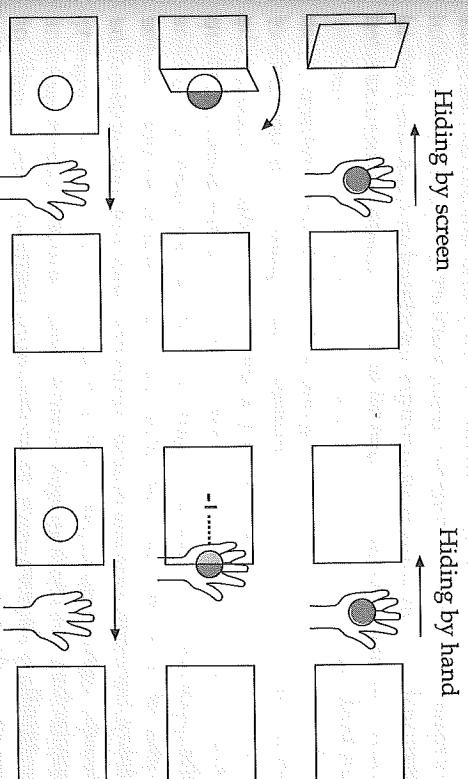


Figure 6.3 Object permanence is not an all-or-none acquisition. There is a significant dissociation in infants' performance on the two tasks; see text for details (from Moore & Meltzoff, 1999).



Table 6.2 Number of infants succeeding/failing as a function of type of occlusion

	Hiding by hand	
	Fail	Succeed
Hiding by screen	15	36
	Fail	Fail
	20	1

and then covering it with the screen. In the hiding by hand, the occlusion is accomplished by putting the object on a platform (the hand) and moving the platform under the screen to deposit the object underneath the screen. Piaget made no distinction between these: in his scheme they are both simple, complete occlusions at one location (indeed in Piaget, 1954, he sometimes hides objects one way and sometimes another, without discrimination).

The results showed that the hiding by screen was systematically solved earlier than the hiding by hand. The data are displayed in a 2 × 2 table showing how many infants solve both tasks, neither task, or one vs. the other. The crucial cells fall on the diagonal (table 6.2, bold cells), because they show a change in performance from one task to the other. As shown, 15 infants solve hiding-by-screen but not hiding-by-hand, vs. only one infant who does the reverse ( $p < 0.001$ , McNemar test). Further analyses showed that this task dissociation was strongly exhibited in both the 10- and 12-month-olds, but that almost all of the 14-month-olds succeeded on both tasks.<sup>5</sup>

Experiment 2 tested the generality of these findings with 10-month-olds. We hid the objects under pillows on one side of the room, far out of reach of the infants. In order to recover the object, they first needed to crawl/walk across the room to lift up the occluder. The mean length of time to navigate across the room after the hiding and before recovery was 11 seconds, so the delay between occlusion and recovery was not negligible. The results replicated Experiment 1: 9 infants solved the hiding-by-screen but not the hiding-by-hand, and 0 did the converse.

Ancillary factors such as motivation, memory, motor skill, or means-ends coordination cannot explain the task dissociation, because these were equated in the two tasks. Piagetian theory cannot explain the dissociation, because both tasks were occlusions in one location. Nor does nativism fare well: if adult object

permanence is part of core knowledge, infants should search for the object for *both* occlusions (if they have the skill) or *neither* occlusion (if there are performance constraints or knowledge-action disconnects).<sup>6</sup>

Some development in object permanence *per se* seems to occur between 10 and 14 months of age, inasmuch as 14-month-olds solve both tasks, whereas 10- to 12-month-olds can solve only one of them. The question is how to characterize this development.

### Larger implications

Moore and Meltzoff use these results to support the idea that object permanence is not innately specified and fixed. We hypothesize that at the ages studied here, the object permanence rule used by infants is: "an object continues to exist in the *place* it disappeared." In the hiding-by-screen, this rule leads to success. The object is on the table, in the place it resided when it was occluded. Conversely, hiding by hand is more challenging because the place the object disappeared and now should be (the hand) is empty. This confronts infants with perceptual evidence that the object no longer exists, according to their rules (not in the place of disappearance). The empty hand leads young infants to interpret this type of hiding as one that does not preserve permanence. Thus the same rule that allows infants to understand one hiding leads them astray for the other.

Moore and Meltzoff's shorthand for this is that the concept of object permanence develops, or more strictly, the range of hidings over which permanence is understood becomes increasingly comprehensive, over age and experience. Infant object permanence is not a once-and-for-all attainment. Young infants at first interpret the world as showing that certain transformations preserve the permanence of objects and others do not. Permanence is *occlusion-dependent* in infancy.

The idea that permanence depends on the type of disappearance, rather than being all-or-none, should not surprise developmentalists. In the adult's theory, certain disappearances do not preserve the permanence of objects, e.g., burning, melting, exploding (Michotte, 1962). Adults believe that the object is annihilated in these cases. The difference, however, is that adults understand that all *occlusions* preserve permanence. Infants only gradually come to the adult view that material objects, qua objects, are permanent across any and all occlusions – that occlusions prevent perceptual access to objects but do not remove them from the

external world. There is a series of logically ordered steps that infants go through as they acquire this adult concept of object permanence (see Moore & Meltzoff, 1999, for a more comprehensive developmental theory).

## Elements of a Developmental Cognitive Science

In this chapter we explored four issues in infancy: representation, joint visual attention, intention, and object permanence. It would be overreaching to say that the debates in each are identical. Nonetheless, we can profit from the commonalities. Each domain has boosters and scoffers – those who claim infant knowledge is equal to adults' and those who seek to reduce infant reactions to motor habits, hardly worthy of the name knowledge at all. In this chapter I have tried to advocate a developmental view that endorses a rich innate state but still embraces conceptual change. Consider infants' developing understanding of people and things from this developmental perspective.

### *Developing knowledge of objects*

Object permanence and imitation stand out as test cases of infant theories. Young infants were supposed to fail on tests of object permanence and deferred imitation, according to sensorimotor theory. Both involve removal of perceptual contact. Although infants were thought to respond adaptively to the perceptual world (they categorize, reach, track, etc.), invisibility was said to be an insurmountable hurdle. Infants could adapt their actions to the current situation, but could not represent the invisible – hence, they must fail on object permanence and deferred imitation tests.

In both cases, research challenged this standard model, and a lively debate ensued. This chapter interprets the evidence in a somewhat novel way, by suggesting that deferred imitation is innately present but object permanence is not. Most theories assume that if infants represent absent stimuli and engage in deferred imitation, they will also have a notion of object permanence. But this is not a logical entailment.

If we are to make headway in constructing a new developmental theory, we must differentiate the concepts of representation and permanence.

There is a crucial distinction between:

- 1 *existence of a representation of absent objects and*
- 2 *representation of the existence of absent objects.*

Manual search for occluded objects relies on the latter: deferred imitation (and the looking-time studies of "early permanence") rely on the former.

An example may help bring this conceptual distinction into sharper focus. Crudely put, think of a balloon. If the balloon explodes, we maintain a mental representation of it, but we do not think that the balloon still exists in the world. The representation persists, but we do not think the object does. Maintaining a representation of the object is not the same as representing it as permanent. Meltzoff and Moore (1998) systematically reviewed the "early permanence" literature and concluded that the preferential-looking results rely on representation but not object permanence.

We define object permanence as representing an object as continuing to exist in a hidden location during the time that it is invisible. In order to investigate object permanence defined in this way, Moore and Meltzoff (1999) used manual search. Importantly, the study instituted new controls that rendered both failure to search and successful search more interpretable. The results showed that infants responded to two types of occlusions in different ways. Occlusion of an object by movement of a screen over it was solved at an earlier age (about 10 months old) than occlusion in which an object was carried under the screen (about 14 months old). This dissociation cannot be explained by ancillary factors such as motivation, motor skill, or means-ends coordination, because for both tasks the same object was hidden in the same place under the same screen and required the same uncovering response. In contrast to the nativist position, the 10-month-olds' understanding of occlusions is not equivalent to the adult's understanding, and moreover, it is not even fixed in an all-or-none fashion within infancy, because there is evidence for a sharp developmental shift over a 4-month interval.

However, rejecting a strong nativist account of object permanence does not send us back to Piaget. Piaget's only explanatory tools were the sensorimotor schemes (e.g., competing motor habits, means-ends coordination, etc.) that were demanded by one hiding or another. Moore and Meltzoff (1999) propose that object permanence develops from simpler beginnings involving maintaining the numerical identity of objects (based on spatiotemporal

parameters involving place and trajectory). We propose that permanence is an interpretation infants impose to make sense of multiple appearances of the numerically *same* individual over occlusion events. In the absence of identity rules for maintaining numerical identity and experience with disappearance–reappearance events, infants would have no basis to infer the permanence of objects. Permanence is a concept infants develop to “bridge the gap” between two visual appearances of the same thing. (This identity-based theory of object permanence development is fleshed out in more detail in Meltzoff & Moore, 1998; Moore & Meltzoff, 1999; Moore, Borton, & Darby, 1978.)

### *Developing knowledge of persons: The “like-me” mechanism*

Philosophers have long wondered how we come to ascribe beliefs, desires, and intentions to others – in short, where our ability to understand other minds comes from. The empirical work shows that 18-month-olds have already adopted an essential aspect of the adult intentional framework. However, this framework does not come out of nowhere. It has developmental roots.

My thesis is that imitation provides a foundation for developing our understanding of other minds. Below is a sketch of a three-step developmental process.

- 1 *Innate foundations.* Infants recognize equivalences between acts they perceive in others and produce themselves. They have neural machinery that allows them to code others as “like me” (Meltzoff & Decety, 2003). This is the starting state as documented by motor imitation in newborns (Meltzoff & Moore, 1997).
- 2 *Self-learning.* As infants perform particular bodily acts they have certain mental experiences. Behaviors are regularly related to mental states. For example, when infants produce certain emotional expressions (e.g., smiling) or bodily activity (e.g., struggling to obtain an out-of-reach toy), they also experience their own mental states (happiness, thwarted desire). Infants register this systematic relation between their own behaviors and underlying mental states. They construct a detailed map linking bodily acts and mind.
- 3 *Attributions to others “like me.”* When infants see others behaving “like me” – producing the same expressions and bodily acts – they hypothesize/infer/project that others have

the mental experiences that are linked to those behaviors in the self. This gives infants purchase on understanding other minds until spoken language can be used. This “like me” projection is most compatible with mental states that have relatively reliable outward bodily expressions – such as emotion, intentional action, visual perception, and desires. These are, in fact, the mental states that infants first attribute to others. The attribution of false belief is, admittedly, not as easily accomplished by the above mechanism, and interestingly is a later acquisition. Thus, the foregoing mechanism may be key for the earliest construal of other minds, with further development needed to flesh out the fully mature adult state (Flavell, 1999; Goldman, 1992, 2000; Gordon, 1995; Meltzoff, Gopnik, & Repacholi, 1999; Taylor, 1996; Wellman, 2002).

Let us examine how the foregoing model provides infants leverage on understanding the intentions and visual perspective of others.

According to the model, infants may come to understand others’ intentions in part because they have experience with their own intentionality. Infants have experienced their own desires and acts of “try and try again.” When an infant sees another act in this same way, the infant’s own experience would suggest that there is a goal beyond the surface behavior; the surface behavior would be seen as a familiar type indicating effortfulness, purposiveness, or striving, rather than as an end in itself.

The “like-me” mechanism could also help explain how younger infants come to understand the attentional acts of others. Infants in the first year of life can imitate head movements (Meltzoff, 1988a; Meltzoff & Moore, 1989; Piaget, 1962). These data indicate that infants can map between their own head movements and those they see others perform. Because they recognize that the other person’s headturn is similar to their own, infants could use their own subjective experiences gained from “turning in order to see” to make sense of the head movements of others. Moreover, infants know something about the effects of eye closures. The infant’s own experience is that eye closure cuts off his or her own visual access to objects. Because an infant can map his or her own eye closure onto those of others (as manifest in imitating blinking; Piaget, 1962), he or she can give felt meaning to the eye closures of others. Rather than interpreting the adult’s head and eye movements as a purely physical motion (a physical analysis), infants have the tools for interpreting them within a psychological framework that connects gazer and object, as a primitive act of “seeing” rather than meaningless “lateral motion in space.”

The more general point is that the basic human tendency to construe others as sentient beings with intentions, desires, perceptions, and emotions need not be preloaded into the infant's mind. Rather, the "like-me-ness" of others, first manifest in imitation, may be the wellspring of more mature forms of social cognition and an engine for its development. At first infants realize that others can act like me; from this foundation they develop the more abstract idea that others who act like me also have mental states like me. Without the neural machinery and social interaction provided in early infancy, the adult notion of other minds would not take the form that it does.

### *The value of staying open-minded*

Empirical work over the past 25 years revealed a much richer innate state than Piaget assumed. One might say that the nativists have prevailed. Two distinct schools of nativism have been offered, however, and they have profound differences. One view, final-state nativism (Fodor, 1983; Spelke et al., 1992), argues that the initial state is equivalent to the final state. The other, starting-state nativism, argues that radical conceptual revision begins at birth (e.g., Gopnik & Meltzoff, 1997; Meltzoff & Moore, 1998).

Fodor advocates final-state nativism for social cognition. He thinks the newborn innately possesses the mature theory of mind: it is culturally universal and adaptive, so why waste time learning it? Spelke advocates final-state nativism concerning material objects. She argues that age-related changes in infants' response to object occlusions are due to the lifting of performance constraints that block the expression/use of innate core knowledge.

In contrast, the starting-state view does not portray infants' similarity to adults in terms of unchanging core knowledge but in the striving for a coherent interpretation of the behavior of people and things. Infants do not begin life with adult concepts, but rather with discovery procedures that lead them to develop adult concepts. The regularities infants use come from many sources, including the laws of physics, the actions of others, and experience of the self as an intentional agent.

Development is thus an open-ended process. Early concepts are used to interpret the behavior of people and things and are revised in light of data. The benefit is social and cognitive adaptability. Human babies are special. What makes them special is not that they are born so intelligent but that they are designed to change their minds when faced with the data.

### NOTES

- 1 Piagetians often respond to this challenge by arguing that visual perception is itself action. Thus, they argue that visual preference-for-novelty in the absence of manipulative experience does not violate Piagetian theory.
- 2 Table 6.1 does not offer a survey of all positions in infancy. Baillargeon (2002) argues for innate object permanence but developmental changes in other aspects of physical knowledge in infancy. Carey (1985, 1991, 1995) largely endorses Spelke's model of infancy, but proposes conceptual changes in childhood. Other theorists have considered only one dimension of the  $2 \times 2$  table, or offered positions not fully captured by the two dimensions of this table (Bertenthal, 1996; Karmiloff-Smith, 1992; Munakata, McClelland, Johnson, & Siegler, 1997).
- 3 Researchers have used visual habituation and preferential-looking-to-novelty to investigate 6- to 12-month-olds' understanding of goal-directed actions (e.g., Gergely, 2002; Gergely, Nádasdy, Csibra, & Biró, 1995; Wellman & Phillips, 2001; Woodward, 1998, 1999). It is a subtle point, but useful for theory, to acknowledge that the infant looking-time measures and action measures (behavioral reenactment technique) do not always ask identical questions. For example, Woodward constructed a stimulus that involved an adult grasping an object in one of two locations. The question was whether infants treated the object as the goal of the reach even if the object was moved to a new location. In this case the "goal of the reach" is the *seen* physical object (a toy ball or bear). Similarly, the goals in the Gergely work are spatial locations, physical endpoints (such as "next to the large circle" or "in the left-hand corner of the screen") seen during the habituation phase. This kind of "goal" differs from an *unseen* goal that was never visually presented to the infant, as was tested in Meltzoff (1995). Consistent with the viewpoint of this chapter, I do not think understanding goals and intention is all-or-none in infancy. There is development in infants' understanding of goals. The development may be from external, visible endstates to invisible, internal states of mind in the actor. A value of the behavioral reenactment approach is that it allows us to assess something like the bridge from the former to the latter (Meltzoff, 1995). Both habituation and action techniques are useful and provide complementary evidence for mapping the entire developmental pattern.
- 4 In certain circumstances infants seem to make intentional attributions to pretend humans (stuffed animals and puppets; Johnson, 2000) and dynamic displays that are ambiguous as to animacy (e.g., 2D spots that leap and move spontaneously; Gergely, 2002; Gergely et al., 1999). This does not contradict the proposals made here. On the one hand, even adults make mistakes and overattributions in some contexts (acting as though the light "doesn't want" to come on). On the other hand, the Meltzoff study used a wood/plastic display that was clearly inanimate and not acting like a psychological agent, whereas



the Johnson/Gergely displays capture aspects of animacy and agency. Experiments are needed that manipulate the stimulus within one paradigm to explore the boundary conditions. One must also be attentive to developmental change: younger infants may assign goals/intentions to either a narrower or broader range of entities than older infants. These are empirical questions.

5 The journal paper includes further details that will interest object permanence aficionados, some of which are these. Two screens, laid out in a left-right orientation, were used for each S. For each S, both tasks were administered on the same side (counterbalanced across Ss), thus there was no change of location (pp. 627-8). The vast majority of the unsuccessful searches were due to infants not initiating recovery efforts; only a few infants searched in the wrong location (p. 631). Infant looking behavior was tightly coupled to their reaching behavior (p. 631). We proposed ideas about the developmental relation between object *identity* and object *permanence* (pp. 638-41) and distinguished these tasks from Piaget's more complex serial invisible displacements (p. 640).

6 Moore and Meltzoff (1999) and Munakata (1998; Munakata et al., 1997) agree that object permanence is not an innate given and develops with experience. But the theories are not identical. Munakata's view is that development entails a gradual strengthening of the representation of the hidden object. As currently formulated, this does not predict the task dissociation, observed here, because there is no reason why the object representation should be stronger or weaker in one hiding or the other. The same object and occluder were used in both hidings. Meltzoff and Moore think that the spatiotemporal parameters (place and trajectory) embodied in the hiding are key to understanding this task dissociation and developmental change, rather than a more generic "strengthening" of representations. The two views are not wholly incompatible and a hybrid model would be possible.

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