INVITED ARTICLE

NATIVISM, EMPIRICISM, AND THE ORIGINS OF KNOWLEDGE

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What aspects of knowledge emerge in children prior to their first contacts with the objects of their knowledge, and what aspects emerge through the shaping effects of experience with those objects? What aspects of knowledge are constant over human development from the moment that infants begin to make sense of the world, and what aspects change as children grow and learn? What aspects of knowledge are universal, and what aspects vary across people in different cultures or with different educational backgrounds? Finally, what aspects of knowledge can people change in themselves or their children with sufficient insight or effort, and what aspects are invariant?

These questions are central to a dialogue that has spanned more than 2000 years of intellectual history. Contributors to the dialogue have raised the questions in order to shed light on larger concerns about human nature, child development, education, science, and society. Although contributors have tended to be labeled "nativists" or "empiricists" according to the kinds of answers they thought most plausible, most have viewed these questions as empirical matters to be resolved not by ideology but by studies of the origins and development of knowledge. Research on cognition in infancy remained a dormant enterprise throughout most of the history of the nativist-empiricist dialogue, however, because the tools then used to probe human knowledge were not appropriate for young children.

Today, the study of early cognitive development has overcome this longstanding barrier to progress. A number of tools have been developed over this century for investigating human cognitive states and processes, and some of these tools have been adapted for studies of preverbal children. New tools of enormous promise are appearing, moreover, with the rapid development of cognitive neuroscience. For the first time, these tools allow

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developmental scientists to use studies of infancy to shed light on the central questions of the nativist-empiricist dialogue.

As ancient obstacles have been overcome, however, new obstacles have arisen. Countering the advance of research are intellectual attitudes that impede studies of cognition in infancy and undermine the larger questions those studies address. Investigations of infant cognition are sometimes dismissed on the grounds that young infants are known *a priori* to be incapable of true knowledge or cognitive processes, and investigators are sometimes handicapped by demands that no empirical enterprise can meet. The questions of the nativist-empiricist dialogue have lost much of their allure, moreover, because of widespread arguments that claims for innate knowledge are incoherent, false, or dangerous to society.

In this article, I argue that our intellectual ancestors were right to ask the questions of the nativist-empiricist dialogue, and that developmental scientists should address these questions vigorously through research on early cognitive development. My defense of the dialogue is divided into three parts. First, I discuss one example of research on cognition in infancy—studies of object representation—in hopes of showing how this research is advancing understanding of the origins and development of knowledge. Second, I consider some contemporary critiques of this research. Arguing that the criticisms are based on skewed interpretations and impossible standards, I suggest a different set of standards against which all research on early cognitive development could productively be evaluated. Third, I consider some popular, contemporary arguments against the nativist-empiricist dialogue, focusing in particular on arguments against any claim that knowledge can emerge through intrinsic growth processes, without prior shaping by encounters with the objects of knowledge. I conclude that the arguments are mistaken and that the concerns that motivated them instead should lead developmental scientists to embrace the dialogue and pursue research on the origins of knowledge.

OBJECT REPRESENTATION IN INFANCY

Human adults perceive their surroundings as a layout of continuous surfaces furnished with material objects. These objects typically are represented as internally connected and externally bounded, with surfaces that continue behind nearer, occluding objects. When an object moves, it is represented as behaving in a coherent manner, and this representation supports predictions about the object's future behavior. When motion carries an object fully out of view, the object continues to be represented; such representations guide actions on hidden objects.

For centuries, contributors to the nativist-empiricist dialogue have puzzled over the origins and development of these abilities, and a spectrum of possibilities have been envisaged (Figure 1). At one extreme, object representations might be shaped entirely by children's perceptual encounters with objects. All abilities to represent objects as bounded, persisting bodies with predictable motions might arise as children explore objects and discover that they have these properties. At the opposite extreme, object representations might emerge entirely by virtue of intrinsic processes of growth, independently of any specific encounters with objects. Between these extremes are a wealth of intermediate possibilities, because certain aspects of mature object representations may stem from intrinsic properties of humans' perceptual and cognitive systems whereas other aspects may stem from learning about the particular characteristics of surrounding objects.

Although many contemporary investigators appear to regard the first, radically empiricist hypothesis as most plausible (e.g., Baillargeon, 1993; Elman, Bates, Johnson, Karmiloff-Smith, Parisi, & Plunkett,1996; Haith, 1997; Munakata, McClelland, Johnson, & Siegler, 1997; Thelen & Smith, 1994), this predilection is not supported by evidence from studies of object representation in infancy. In my view, such studies have not

wholly shaped by encounters with objects

wholly independent of encounters with objects

FIGURE 1
Theories of the development of object representations within the nativist-empiricist spectrum.

yet eliminated *any* region of the spectrum in Figure 1, and so investigators need to consider the entire spectrum of possibilities. Fortunately, studies of infants have greatly reduced the density of tenable developmental hypotheses within this spectrum, bringing the questions of the nativist-empiricist dialogue into greater focus. I believe these studies also suggest that intermediate positions in Figure 1 are more plausible than positions at either extreme.

Object Representations in 3-6 Month Old Infants

Over last 25 years, many studies of the early development of object representation have focused on infants in the second trimester of postnatal life. The time from 3 to 6 months is of theoretical interest, because most empiricist theories have rooted the development of object representations in actions such as reaching for objects, manipulating objects, and moving through the spatial layout (e.g., Berkeley, 1709/1975; Helmholtz, 1867/1962).[1] Between 3 and 6 months of age, most infants begin to engage in object-directed reaching and manipulation, and some infants begin to locomote independently. Investigations focused on these ages therefore can discover whether any object representations emerge before the onset of these activities, and how object representations change once these activities have begun. To summarize briefly the findings of many studies,[2] there is evidence that infants are capable of forming certain object representations before they can act on objects effectively, and also evidence that object representations undergo changes over the time period when reaching and manipulation develop.

Consider, for example, infants' representation of the boundaries of objects in visible scenes. Perception of object boundaries has been investigated by preferential looking methods, focused on infants' novelty reactions (longer looking) to arrays in which the boundaries of objects are changed, and also by reaching methods, focusing on infants' tendency to direct their hands toward the perceived edges of objects. Converging conclusions emerge from these two lines of research: even the youngest infants tested perceive object boundaries in certain visible scenes, but their perceptions are considerably less specific than those of adults. By 3-4 months of age, infants perceive figure-ground relationships by analyzing the relative motions and depth relations among visible surfaces , but not by analyzing the two-dimensional Gestalt relations among surfaces (Termine, Hrynick, Kestenbaum, Gleitman, & Spelke, 1987; Yonas & Granrud, 1985). Similarly, 3-month-old infants perceive the boundaries of adjacent objects when the objects are separated in depth or undergo different motions. When the objects are adjacent and stationary, young infants are less sensitive to their boundaries (Hofsten & Spelke, 1985; Spelke,

Hofsten, & Kestenbaum, 1989; Spelke, Breinlinger, Jacobson, & Phillips, 1993; Xu & Carey, 1996; although see Needham, Baillargeon, & Kaufman, 1997).

Infants' perception of the continuity of an object behind a partial occluder has been investigated primarily with preferential looking methods, in which infants are familiarized with a center-occluded object and then their novelty reactions are observed to displays in which the occluder is removed to reveal either a gap (novel for adults) or a continuous object. These studies provide evidence that 4-month-old infants perceive a center-occluded object as continuous when its visible surfaces undergo common motion (Johnson & Aslin, 1996; Johnson & Nañez, 1995; Jusczyk, Johnson, Spelke, Kennedy, & Smith, 1997; Kellman & Spelke, 1983; Slater, Morison, Somers, Mattock, Brown, & Taylor, 1990b). Perception of the continuity of a partly occluded object also is affected by the alignment relations among the object's visible surfaces (Johnson & Aslin, 1996), although adults show a greater effect of edge alignment than do infants (Kellman & Spelke, 1983). Finally, infants' perception of center-occluded objects does not appear to be affected by either synchronous changes in a stationary object's brightness or hue (Jusczyk, et al., 1997) or by differences in the color and texture of a stationary object's visible surfaces (Kellman & Spelke, 1983; cf. Needham, 1994).[3]

Further experiments have investigated infants' representation of the continuing existence of objects that are fully occluded. Some experiments have used preferential looking methods, focusing on infants' novelty reactions to events in which visible object motions violate physical constraints imposed by the existence and location of hidden objects; other experiments have used reaching methods, focusing on infants' reaching for objects in darkness. These studies provide evidence that 3- to 6-month-old infants represent the continuous existence of an object that is first visible and then fully occluded (e.g., Baillargeon, 1993; Clifton, Rochat, Litovsky, & Perris, 1991; Craton & Yonas, 1990; Hood & Willats, 1986; Rochat & Hespos, 1996; Wynn, 1992). Under certain conditions, infants also represent fully occluded objects whose separate parts move into view at different times (Van de Walle & Spelke, 1996), although this ability shows striking limits (Arterberry, 1993). Infants are capable of representing at least two hidden objects within a single scene (Baillargeon, 1986; Wynn, 1992), but their representations appear to break down when larger numbers of objects are occluded (see Chiang & Wynn, 1996). Infants also can extrapolate the motions of occluded objects in accord with certain constraints on object motion: for example, they infer that interacting inanimate objects change their motions on contact (Ball, 1973; Leslie & Keeble, 1987). Young infants are not sensitive to all the constraints on objects that adults recognize, however, and they do not represent object properties as robustly as do adults (e.g., Spelke, Katz, Purcell, Ehrlich, & Breinlinger, 1994; Xu & Carey, 1996).

The findings of all the above studies provide evidence for an early-developing system of object representation that operates in accord with general constraints on object motion (Leslie, 1994; Spelke and Van de Walle, 1993) and, to a lesser degree, in accord with Gestalt relationships such as edge alignment (Johnson & Aslin, 1996; Needham, 1997; van Giffen & Haith, 1984). In the context of the nativist-empiricist dialogue, we may ask how this system develops. Because 3-month-old infants do not yet reach for objects or crawl around them, knowledge of basic properties of objects does not emerge through shaping effects of these actions. Instead, early-developing object representations likely emerge either through prior visual experience with objects or through intrinsic growth processes. Studies of younger infants have not yet distinguished these possibilities, but they are progressing toward that goal. To illustrate, I discuss one recent line of research focusing on very young infants' perception of partly occluded objects.

Representation of Partly Occluded Objects from Birth to 4 Months

Although newborn infants do not reach for objects, they show systematic looking preferences (Fantz, 1961), including a preference for novel displays over familiar ones (e.g., Friedman, 1972). Investigators therefore have used variants of Kellman and Spelke's (1983) preferential looking method to investigate whether very young infants perceive a center-occluded object to continue behind its occluder. In the first study using this method, Slater, et al. (1990b) confirmed that 4-month-old infants perceive the unity of a moving, center occluded object but found that newborn infants do not: After familiarization with a center-occluded object, newborn infants looked longer at a connected object than at a display with a gap where the occluder had been. This looking preference, opposite to that of the older infants, suggests that newborn infants fail to perceive the unity of a moving, center occluded object. Subsequent research by Johnson and Nañez (1995) revealed a transitional looking pattern at 2 months of age: After familiarization with a center-occluded object similar to those used by Kellman and Slater, 2-month-old infants showed no preference between a complete object and an object display with a gap. These studies provide evidence for a developmental change in perception of the visible surfaces of Kellman's center-occluded objects, from unconnected (newborn) to ambiguous (2 months) to connected (4 months).

The discovery of this developmental change allows investigators to pose more focused questions: What perceptual capacities are developing over this period, and what causes their development? Successful representation of the unity of a moving, center-occluded object requires that infants perceive the three-dimensional arrangements and motions of surfaces in the visible layout and then group these perceived surfaces into objects (Figure 2). One may investigate, therefore, whether the developmental changes in object perception result from changes in depth perception, motion perception, or object perception proper. Although existing research does not fully resolve this question, investigators are very close to an answer.

Slater, Johnson, Kellman and Spelke (1994) investigated whether developmental changes in object perception resulted from changes in depth perception by presenting newborn infants with occluded object displays containing enhanced depth information known to be detectable at that age (Slater, Mattock, & Brown, 1990a). Infants' looking preferences were not affected by this manipulation, suggesting that developmental changes in sensitivity to depth do not account for developmental changes in perception of partly occluded objects. Johnson and Aslin (1995) next investigated whether developmental changes in object perception resulted from changes in sensitivity to motion relationships within a visible scene. They presented 2-month-old infants with partly occluded object displays in which the detectability of common motion was enhanced through three separate, ingenious manipulations of the occlusion display (see Johnson & Aslin, 1995). Under all three conditions, 2-month-old infants succeeded in perceiving the unity of a center-occluded object. This finding provides evidence that 2-month-old infants have a functional system for representing partly occluded objects, and that limits on motion sensitivity account for their failure to perceive such objects when tested with Kellman's original displays. Newborn infants also may have a functional system of object representation, but existing experiments do not address this possibility.

Object Representations in Newborn Chicks

Newborn human infants' poor acuity and motion sensitivity may mask a number of perceptual abilities at the start of postnatal life, complicating the task of students of perceptual development (see Banks & Shannon, 1993).

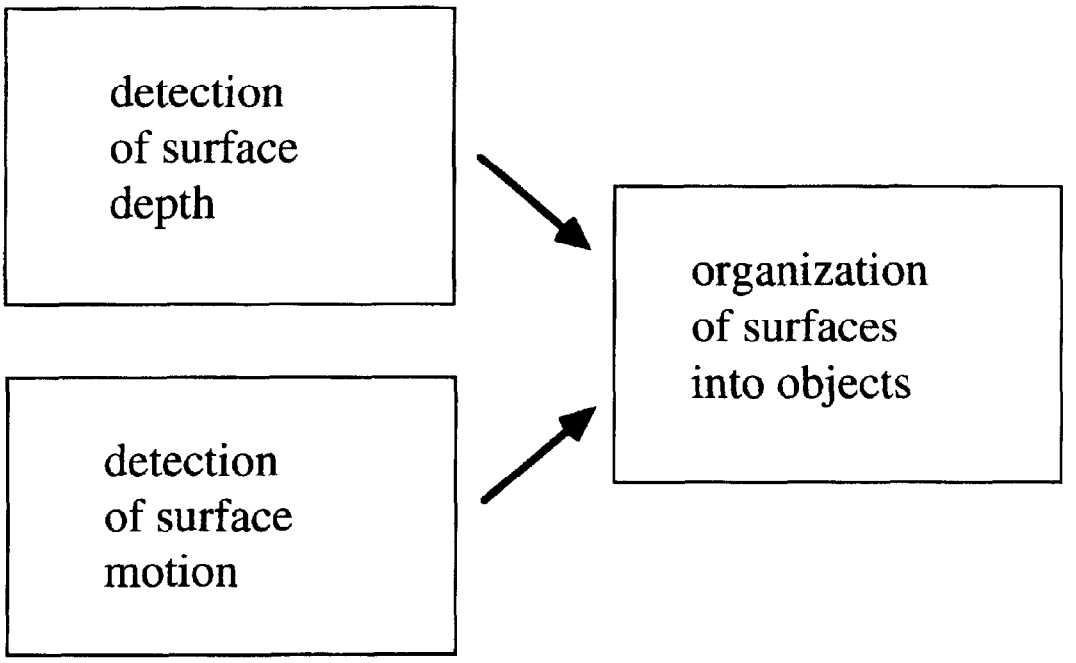

FIGURE 2
Processes underlying perception of moving, center-occluded objects at 4 months of age (after Kellman & Spelke, 1983). Because 4 month-old infants perceive partly hidden objects as connected only when their surfaces undergo common motion and stand behind a nearer occluding object, failure to perceive partly hidden objects at younger ages could stem from limits to any of the component processes.

Fortunately, comparative studies of the anatomy, physiology, and functional organization of the visual system suggest that many of the basic perceptual mechanisms found in humans are shared by other vertebrates. If mechanisms for perceiving and representing objects are not unique to humans, then insights into the early development of object representations may come from studies of other animals whose sensory systems are more mature at birth.

Recent studies have investigated object representations in newborn chicks, using an imprinting method (Lean, Slater & Regolin, 1996; Regolin & Vallortigara, 1995). Regolin and Vallortigara placed chicks in a cage containing a single visible triangle. Because the object was dangled from the center of an otherwise empty chamber, a chick never saw the object occluded by any other object. After two days' exposure to the object, chicks exhibited "imprinting" in a novel test chamber by maintaining proximity to the familiar object, located at one end of the chamber, relative to a novel object located at the other end of the chamber. The investigators therefore used this measure of imprinting to assess the chicks' representations of occluded objects. In a series of studies, chicks who were imprinted to the fully visible triangle were presented with occlusion displays for the imprinting test (see Figure 3). Although the chicks had never seen any occlusion display before, they showed imprinting to a center-occluded triangle, relative to non-occluded displays containing the same visible surfaces of the triangle. This finding and others (see Lea et al., 1996; Regolin & Vallortigara, 1995) provide evidence that chicks, like 4-month-old human infants, perceive center-occluded objects as connected. Mechanisms for representing the complete

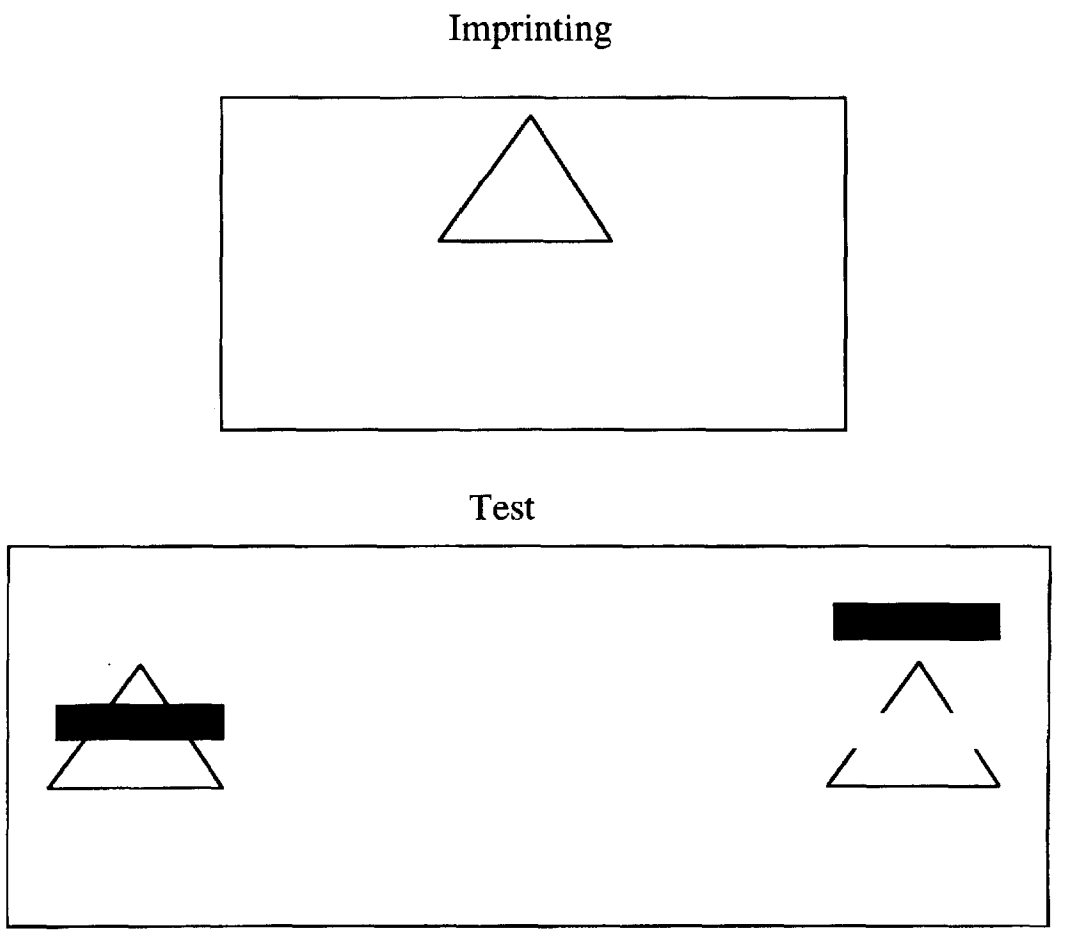

FIGURE 3
Displays and apparatus for studies of perception of center-occluded objects by 2-day-old chicks. After spending their first days in a cage with a triangle (top), chicks are tested with occluded and interrupted triangle displays (bottom) (after Regolin & Vallortigara, 1995).

shapes of partly hidden objects evidently are innate in chicks, for they are present and functional the first time a chick sees an occlusion display. As research by Slater, Johnson, Aslin and other investigators continues, we may learn whether these abilities are innate in human infants as well.

Development of Object Representations after 6 Months

As noted earlier, the object representations of 3- to 6-month-old infants differ in some striking ways from those of adults, providing evidence for developmental changes in some perceptual or cognitive mechanisms. For decades, investigators have tried to understand these changes through further studies of object representation in infants. Here, I focus on one much-studied change, reflected in children's developing abilities to search for fully occluded objects.

The landmark research of Piaget (1954) revealed striking limits in young infants' search for occluded objects. Until about 9 months of age, infants do not attempt to reach

for objects that are visibly occluded, even though younger infants reach for objects obscured by darkness (Hood & Willats, 1986; Clifton et al, 1991) and give evidence of representing visibly occluded objects in their looking behavior (e.g., Ahmed & Ruffman, 1996; Baillargeon, 1993). Starting at about 9 months, infants begin to obtain occluded objects by reaching around or displacing their occluders. What accounts for this developmental change?

According to one family of hypotheses, developmental changes in search for occluded objects stem from changes in the infant's action capacities. Successful search may depend on emerging abilities to coordinate actions into means-ends relationships (Piaget, 1952), to inhibit prepotent actions on visible arrays (Diamond, 1990a; Thelen, 1995), or to reach on indirect paths (Diamond, 1990b; Noland, 1996). Studies of chicks—a species with more precocial behavioral as well as perceptual capacities—are consistent with these accounts, for newborn chicks have been found to solve "object permanence" tasks failed by 8-month-old human infants (Regolin, Vallortigara & Zanforlin, 1995). Developmental changes in human infants' action capacities therefore may contribute substantially to developmental changes in search for occluded objects. But are they the only source of changes in children's reactions to hidden objects?

The hypothesis that object representations are invariant over the development of object search, and that only changes in action capacities produce the dramatic changes in infants' behavior, leads to a straightforward prediction: All developmental changes in object search should disappear when infants are given search tasks that do not require means-ends coordination, suppression of prepotent responses, or indirect reaches. Two lines of experiments have tested this prediction and disconfirmed it: Six-month-old infants fail to retrieve occluded objects even when all the above action demands are minimized or eliminated.

First, Munakata, et al. (1997) trained infants to retrieve an object by pulling a blanket or pressing a button. After training, infants received a succession of trials in which either the object or the empty stage was covered by an opaque or transparent occluder. Infants acted to retrieve the object when it was present more than when it was absent in the conditions with the transparent occluder (indicating that they were capable of performing a differentiated search response) but showed no such difference with the opaque occluder. Second, Hofsten, Spelke, Feng, & Vishton (1994) investigated infants' reaching for a moving object that entered reaching space after either moving on a continuously visible path or moving briefly behind an out-of-reach occluder. Although the object could be obtained by a simple, direct reach under both these conditions, infants' reaching was greatly perturbed by the occluder. In both situations, infants failed to engage in actions within their repertoire that would have sufficed to obtain a temporarily occluded object. Limits on sensory-motor coordination therefore are not sufficient to account for infants' search failures.

These findings suggest limits to infants' representations of occluded objects, but what are the nature and sources of these limits? Although research has not fully answered this question, suggestions come from a recent experiment by Munakata (1997). Munakata hypothesized that 6-month-old infants represent both occluded and visible objects, and that their representations have two properties found also in adults. First, representations of visible objects are stronger than representations of occluded objects: Objects are experienced more vividly and in greater detail when they are directly visible. Second, representations of different, simultaneously present objects compete with one another for attention: As the number of objects in a scene increases, the amount of attention devoted to any one object declines. Putting these two properties together, Munakata hypothesized that competition from a strong representation of a visible occluder weakens (but does not

fully abolish) infants' concurrent representation of an occluded object.

Munakata's thesis led to an otherwise counterintuitive prediction: When an infant views a moving object that is briefly occluded before entering reaching space, the suppressive effect of the occluder will diminish, and reaching will increase, if the infant is plunged into darkness: Introduction of a blackout period at the time of occlusion will *enhance* reaching for the occluded object. This prediction has received an initial test in a predictive reaching experiment in which an object's visibility was briefly interrupted by occlusion, by a blackout period, or by both occlusion and blackout. Although 6-month-old infants showed low levels of reaching in all 3 conditions, reaching levels were higher when the loss of visibility was caused by the blackout period than when it was caused by occlusion, consistent with the findings of previous studies (Hood & Willats, 1986). Most important, the combination of occlusion and blackout led to levels of reaching as high as that for blackout alone and higher than that for occlusion alone. Munakata concluded that the blackout period diminished the strength of the representation of the occluder and thereby strengthened the representation of the occluded object.

This new finding suggests an explanation for part of the developmental change in search for occluded objects. At all ages, including early infancy, humans may be capable of representing occluded objects. At all ages, moreover, representations of visible objects may be stronger than representations of hidden objects, and representations of distinct objects within a single scene may compete for attention. These properties of object representations may combine to make actions on occluded objects more difficult, at all ages, than actions on visible objects. With development, however, children may become increasingly adept at deploying attention so as to boost activation of particular object representations in relevant task contexts. The boost in object representations that young babies get from a period of blackout may come to older infants and adults through the voluntary direction of attention. If this suggestion is correct, then there is both constancy and change in object representations over early cognitive development, explaining both infants' early-developing capacities and some of the limits on those capacities.

In summary, basic questions about the origins and early development of object representations are still outstanding, but progress is being made. The most popular developmental theories of past generations can now be rejected, and the set of tenable theories, although still large, has been narrowed significantly. Most important, recent research suggests that investigators have the tools to make further progress by continuing current research trajectories. These tools are being supplemented by new methods from cognitive neuroscience (e.g., Casey, et al, 1997; Dehaene-Lambertz & Dehaene, 1994), and they are being extended to probe early cognitive development in other domains of knowledge including knowledge of number (e.g., Wynn, 1995), of object categories (e.g., Mandler & McDonough, 1993), and of people (e.g., Gergely, Nadasdy, Csibra, & Biro, 1995; Woodward, 1995; Wu, 1997). All these investigations, however, face a serious impediment.

CHALLENGES TO THE STUDY OF COGNITION IN INFANCY

Like all empirical research, studies of cognition in infancy can thrive only in an environment in which investigators are open to any discoveries their research might yield, including evidence for knowledge in the mind that did not arise through the shaping effects of sensory contact with the things that are known. A number of students of development are persuaded, however, that such openness is inappropriate, and that the field should reject either the questions at the center of the nativist-empiricist dialogue or any answer to those questions short of extreme empiricism. When minds are closed, research can only suffer. Here, I consider a family of skeptical attitudes

to research on infant cognition, first discussing skeptical reactions to specific research findings and then discussing the prevalent attitude of wariness toward nativist claims.

Standards for Research on Cognition in Infancy

Anyone who has conducted research on perception or cognition in infants has likely encountered colleagues, science writers, and others who have expressed disbelief at his or her findings. Evidence for perceptual and cognitive capacities in infants strains the beliefs of many people because it conflicts with prevalent conceptions about infants and intuitions about cognitive development. Haith (1997) states this conflict clearly and casts his lot on the side of intuition, criticizing students of infant cognition for "asserting that young infants know things about objects, events and people far earlier than seems reasonable."

When data conflict with intuition, however, intuition is rarely the best guide for advancing understanding. Intuition has proved to be an especially poor guide to understanding human perception and cognition. Cognitive psychologists and cognitive neuroscientists have repeatedly made discoveries that either violated prevailing intuitions or that intuition never would have contemplated: recent examples include the evidence for implicit memory, for multiple representations of objects, and for separate visual coding of surface color and motion. If human intuitions are not a trustworthy source of knowledge about the cognitive processes of adults, they are hardly likely to be more trustworthy guides to knowledge about cognition in infants. The intuitions and preconceptions of scientists can never be eliminated from science, but they should not be used to filter the evidence that research brings.

Related to this skeptical reaction is a tendency to judge the findings of studies of cognition in infancy against an impossible standard. For example, Haith (1997) claims that investigators who use preferential looking methods to probe infants' cognitive capacities "must fend off every possible perceptual interpretation of differences [in looking times] to entertain default cognitive interpretations." That is, no evidence for any cognitive ability in infants can be accepted until every sensory and perceptual interpretation of the evidence, *however implausible and empirically unsupported*, has been eliminated.

For example, Haith (1997) considered Wynn's (1992, 1995) experiments, in which the looking patterns of infants who viewed a succession of occlusion events on a single stage provide evidence that the infants represented two objects on the stage, even though only one object was visible at a time. He argued that infants' looking patterns should not be interpreted as evidence for object representations, because there is an alternative interpretation that has not been eliminated: infants' looking patterns could be produced by extremely long-term sensory persistence evoked by each object before it was occluded. Haith's alternative interpretation is implausible, because abundant research with adults provides evidence that sensory persistence in lighted environments is at least an order of magnitude shorter than his argument would require (e.g., Sperling, 1960). His interpretation also has no empirical support: no evidence for prolonged sensory persistence has been provided by any studies of sensory processes in infants. These considerations have no force, however, if Haith's default rule is accepted. Even the most implausible and unsupported sensory interpretation of data from infant studies is preferable, by this rule, to any cognitive interpretation.

The requirement that claims of cognitive competence be proved by the elimination of every alternative claim, however implausible and unsupported, sets an impossible standard for research on cognition in infancy. Like any other branch of science, the study of cognitive development is not an exercise in logic resulting in irrefutable conclusions: Hypotheses can be rejected or supported by evidence but can never be proven correct. Because there are an infinite number of alternative interpretations of

any finding in any area of science, empirical progress requires that scientists select and evaluate interpretations in accord with evidence, not in accord with *a priori* preferences for some interpretations over others. No hypothesis can be held to be true or false until *proven* otherwise.

A third problem facing investigators of cognition in infancy is a tendency of some critics to consider individual studies in isolation, rather than to develop unitary and principled accounts for a larger body of research. One example of this tendency is discussed in footnote 3. As a second example, Haith's (1997) suggestion that sensory persistence accounts for apparent cases of object representation is framed in the context of a discussion of studies in which infants view stationary objects that first are fully visible and then are occluded for several seconds (e.g., Baillargeon & Devos, 1991; Wynn, 1992). This suggestion cannot account for the findings of numerous studies presenting much longer occlusion times (e.g., Baillargeon & Graber, 1988; Wilcox, Rosser, & Nadel, 1994), occluded objects that move or change (e.g., Rochat & Hespos, 1996; Koechlin, Dehaene & Mehler, 1997; Simon, Hespos & Rochat, 1995), or objects with surfaces that are never visible (e.g., Johnson & Aslin, 1995; Kellman & Spelke, 1983; Van de Walle & Spelke, 1996). Although separate explanations could be proposed for the findings of each of these studies, our understanding of infant cognition is not likely to advance if we propose new explanations for each new set of findings. Requiring all rival accounts of cognitive development to be responsive to all experimental findings would help to place discussions on a firmer foundation, focusing attention on areas where serious alternative explanations exist and where further research would be most productive.

I do not claim that every study of perception and cognition in infancy has been correctly interpreted by its authors, or that every skeptical reaction to this research impedes progress. On the contrary, the development of competing accounts of findings can be extremely helpful to the field when the accounts are developed in a principled manner and tested by further research. Healthy progress has come, for example, from Cohen's studies of the sources of infants' reactions to violations (and interesting non-violations) of object solidity (Cohen, 1995; Cohen, Gilbert, & Brown, 1996) and Oakes' studies of limits to infants' sensitivity to contact-mechanical motions (Oakes, 1994) and to gravity (Kannass & Oakes, 1997). Further progress may come from Bogartz's new methodological and statistical approaches to preferential looking research, although the sensitivity of these approaches remains to be demonstrated (see footnote 3). Finally, progress is coming from studies revealing surprising limits to infants' representations of occlusion events (e.g., Chiang & Wynn, 1996; Huntley-Fenner & Carey, 1995; Xu & Carey, 1996). To advance understanding of early cognitive development, those who are skeptical of current accounts of cognition in infancy should not ignore their skepticism but submit it to test, adhering to guidelines that all investigators can follow. I suggest four guidelines:

1. Theories should be evaluated in relation to evidence, not compatibility with intuition.
2. No hypothesis should be considered "guilty until proven innocent" or the reverse.
3. All accounts of the findings of infant studies require evidence. In particular, those who would explain infants' performance by appealing to sensory or motor processes must provide evidence for those processes, on a par with those who would explain infants' performance in terms of perceptual or cognitive processes.
4. All theories of early cognitive development must encompass all the relevant data. In particular, explanations of infants' performance that appeal to sensory-motor processes, motivational processes, perceptual processes, and

cognitive processes must all be held to the same standard; no account merits attention if it is based on a small subset of findings and ignores contrary results.

ARGUMENTS AGAINST NATIVIST CLAIMS

It is worth asking why the intuitions of many investigators have favored extreme empiricist theories and skewed standards for evaluating research. A number of arguments in support of these intuitions and standards have been offered. Here, I consider six arguments against any nativist interpretations of research on cognition in infancy, according to which such interpretations are incoherent, false, unparsimonious, empty, denying of flexibility, or socially dangerous. In each case, I suggest the arguments are misplaced, and that the considerations motivating them should lead investigators in a different direction.

Nativism is Incoherent

As developmental biologists have shown in exquisite detail, all development involves a process of interaction between genes and environment. Without the right physical and chemical environment, genes are inert and no development happens. From this finding, some developmental psychologists have concluded that it is incoherent to imagine that any knowledge of the world could have its source solely in the organism (e.g., Oyama, 1985; Thelen & Smith, 1994).

The problem with this argument is that the nativist-empiricist dialogue is not about the interaction of genes and their environment, but about whether knowledge of things in the external world develops on basis of encounters with those things. Do we learn to perceive depth by looking at three-dimensional scenes? Do we learn to see objects by looking at and manipulating objects? Alternatively, do structures for representing three-dimensional scenes furnished with bounded objects develop independently of perceptual encounters with those scenes and objects? These questions are not addressed by research on interactions between genes and gene products but by research on the emerging and changing capacities of children in interaction with their surroundings.

Construed appropriately, the questions about the sources of human knowledge are not incoherent but well-formed, and some of them are straightforwardly testable. Psychologists who study animals can and have asked whether a dark-reared rat perceives depth on first encountering the light, and whether a newborn chick represents an occluded object the first time it sees an object being hidden. Psychologists who study humans can and have asked whether a newborn infant with no visual experience perceives depth, distinguishes faces from other kinds of patterns, or represents occluded objects. Investigators also have asked about the role of specific experiences such as locomotion in the development of perception and representation: a very fruitful contribution to the dialogue (e.g., Bertenthal & Campos, 1990). The fascinating advances in research in neurobiology do not undermine these questions. At its best, research in neurobiology suggests mechanisms by which cognitive structures can develop in advance of sensory contact with the external world, as well as mechanisms by which these structures can be shaped and modified by such contact.[4]

Nativism is False

When the findings of studies of early cognitive development are scrutinized with appropriate rigor, some investigators argue, they yield no evidence for knowledge of things preceding experience with those things. Rather, the evidence suggests that all knowledge results wholly from dynamic interactions with the external environment (Elman et al, 1996; Munakata et al, 1997; Thelen & Smith, 1994).

This conclusion rests in part on skewed interpretations of studies of cognition in infancy, as discussed above, and it is further

nourished by a general error of interpretation of developmental data. Faced with evidence for a developmental change in some capacity, investigators are apt to conclude that the cause of the change is learning, ignoring two alternative possibilities. First, the capacity may be constant over development but the ability to express it may change because of other developmental changes (see Banks & Shannon, 1988; Thelen, 1984, for examples). Second, the capacity may emerge over development but the cause of its emergence may be maturation or triggering rather than shaping by experience (see Held, 1985, for an example). This error of interpretation fosters the conclusion that knowledge has been acquired through learning when all that is known is that behavior on some task has changed.

Instead of drawing empiricist conclusions automatically, students of cognitive development should conclude that learning has taken place only when there is evidence for learning, from research revealing that different knowledge emerges under different environmental conditions. If one bases conclusions only on evidence, then I believe that studies of infants suggest that development is not strongly skewed toward either pole of the nativist-empiricist dialogue. There is some evidence for innate knowledge, embodied in structures that develop in advance of their function and in advance of relevant perceptual contacts with the objects of knowledge. (This evidence seems to me strongest in the cases of depth perception and face processing.) There is also some evidence for learning, from situations where children's knowledge varies with, and because of, variations in their experience. (This evidence seems to me strongest in the cases of speech perception and certain spatial representations.) Finally, there are vast areas of ignorance, where the contributions of innate structures and learning have not been disentangled. Students of development should not be surprised or discouraged by the extent of our ignorance, because the experimental study of cognition in infancy is a young enterprise and it *is* progressing. Above all, investigators should not be discouraged from conducting research to reduce that ignorance by skewing their interpretations of the evidence already at hand.

Nativism is Unparsimonious

Some investigators have granted that questions about the origins of knowledge are meaningful and empirical. Because existing research does not yet resolve these questions in many cases, they argue, the most parsimonious assumption is that knowledge is lacking early in development. Until the evidence forces one to a different conclusion, on this view, one should assume that young infants lack all knowledge and cognitive processes.

This argument rests, I believe, on misunderstandings of the role of parsimony considerations in science and of the nature of developmental theories. First, parsimony is appropriately invoked in cases where a rich body of evidence is consistent with two or more detailed theories. When evidence is sparse and theories are sketchy, as in the study of cognitive development, scientists need to collect further evidence, not jump to conclusions on grounds of parsimony. Second, theories of development aim to describe and explain how the capacities of adults come to be. Parsimony arguments apply to these theories *as wholes*: The most parsimonious theory of cognitive development is the theory providing the simplest account of the development of mature knowledge, not the simplest description of the young infant. Because all theories must arrive at the same end state of mature knowledge, accounts with simpler characterizations of the initial state will tend to have more complex characterizations of developmental change. If one focuses on the simplicity of developmental theories as wholes, rather than the simplicity of the pieces of those theories characterizing the initial state, then parsimony considerations do not automatically favor one voice over others in the nativist-empiricist dialogue.

Nativism is Empty

Perhaps the most common argument against nativist claims is that they do not explain development: To say that a given aspect of knowledge is innate is not to account for its emergence or its form. Nativist claims, it is argued, only shift the burden of explaining development to some other discipline, such as developmental biology.

This argument misconstrues the nature of explanation in developmental psychology. All theories of cognitive development have the dual task of characterizing the initial state of knowledge and the processes that transform this initial state into mature knowledge. In extreme empiricist theories, the initial state typically is held to consist of a set of innate sensory transducers and one or more mechanisms of learning; in other theories, the initial state and developmental mechanisms are characterized differently. Because all theories across the nativist-empiricist spectrum have the same general form, the explanatory value of each theory depends only on how well it accounts for the phenomena of development and on theory-internal qualities such as completeness and consistency. A theory's explanatory value does *not* depend on the content it assigns to the initial state.

To build good explanatory theories, students of cognitive development must seek the most complete, consistent, and empirically adequate account of the initial state and subsequent growth of knowledge. As psychologists learn more about cognition in infancy, the constraints on all theories grow and the explanatory virtues of different theories will become clearer. Developing better explanatory theories requires vigorous programs of research addressing the questions at the center of the nativist-empiricist dialogue; it is not aided by *a priori* rejection of one side of the dialogue.

Nativism Denies Flexibility

Investigators of cognitive development sometimes characterize initial knowledge as a set of "constraints on learning" (e.g., Gelman, 1990; Keil, 1981; Spelke, 1990). This terminology is in some ways unfortunate, for it appears to imply that innate knowledge prevents people from learning (see Quartz & Sejnowski, 1997). In fact, innate structures have traditionally been proposed in order to explain how it is possible for humans to learn anything. They do not deny human flexibility but instead participate in attempts to understand both human flexibility and its limits.

For example, theories positing initial knowledge have been proposed to explain how is it possible for human children to learn any human culture's language, motor skills, and object taxonomies, or formal belief systems (e.g., Chomsky, 1975; Hirschfeld & Gelman, 1994). Theories that posit unlearned systems of knowledge have even been proposed to account for the development of humans' most flexible, formal belief systems (e.g., Carey & Spelke, 1994, 1996; Sperber, 1994). Debates between nativists and empiricists are not denials and assertions of flexibility but contrasting accounts of the sources and the nature of humans' often flexible cognitive performance.

Nativism is Dangerous

Perhaps the most serious argument against nativist claims focuses on the impact of these claims on society. The thesis that certain systems of knowledge are innate in our species is sometimes said to go naturally with the thesis that some people are inherently more capable thinkers and knowers than others. As is well known, this second thesis has underpinned social evils such as racist immigration policies, it serves to rationalize social injustice, and it threatens to foster further, regressive social changes. By this argument, nativist claims should be shunned so as to avoid these social consequences (Elman et al, 1996; Fischer & Bidell, 1994).

The problem with this argument lies in its first premise: The question whether any knowledge is innate in our species is entirely different from the question whether there are

any innate *differences* between people in knowledge or cognitive ability. Consider, for example, a scientist who believes that a system of knowledge of objects is innate in all people, and who asks why adults differ in the extent to which they go beyond this system: why one student of physics gets an A whereas another gets a C, or why one athlete-in-training consistently hits baseballs whereas another consistently misses. It is completely open to this scientist to believe that all differences between people stem from differences in their experiences: their differing opportunities to extend their knowledge and abilities in classrooms or on athletic fields. Consider now a second scientist who believes that all knowledge of objects is learned and who asks the same question about the sources of individual differences in adults. It is entirely open to this scientist to believe that differences among physics students and baseball players stem from differences in people's innately given learning capacities.[5] For better or worse, claims about the sources of the knowledge that all people share do not bear questions about the sources of the abilities that distinguish one person from another.

THE NATIVIST-EMPIRICIST DIALOGUE IN A LARGER SOCIAL PERSPECTIVE

Although studies of cognition in infancy do not reveal the sources of individual differences in ability or achievement, I believe that they cast a valuable new perspective on those differences. When experiments reveal systems of knowledge that emerge early in human development and that persist and grow in common ways over all children, they suggest that the cognitive differences between people are not as great as many current discussions imply. Debates over the genetics of IQ and over cultural differences in language and thinking tend to overlook the cognitive capacities and attainments that all people share, because most of our common cognitive endowment is obscure to intuition whereas differences between people are salient. Studies of the origins and early development of knowledge serve to increase awareness of the vast common ground uniting all human thinkers, helping us to understand what it is to be a human thinker and knower in any culture and in any set of circumstances. Much of the heat in the controversies over IQ and multiculturalism may dissipate as this understanding grows.

Research guided by the nativist-empiricist dialogue does not, however, deny human differences. On the contrary, it sheds light on the particular circumstances that lead different people to extend their knowledge and skills in different directions. Where knowledge is found to vary across people in different cultures or circumstances, that variability teaches us something about our own potential and that of others. This information can guide choices about how to educate children and structure societies, and it can help everyone to view the differing accomplishments of different people with understanding and respect.

These are not new reasons for asking about the origins and growth of knowledge, for they trace back to the beginnings of the nativist-empiricist dialogue. What is new are the advances in cognitive science that now allow students of cognitive development to address these questions empirically. By pursuing that work and overcoming old prejudices, our understanding of human knowledge and human nature may grow considerably in the coming years, enriching and informing long-standing social dialogues on human nature, human differences, and human development.

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NOTES

1. Although Piaget's (1954) theory of the development of object representation cannot be placed clearly within the framework of the nativist-empiricist dialogue, Piaget also emphasized the importance of object-directed actions for the development of object knowledge.
2. Kellman and Arterberry (in press) and Spelke and Newport (1998) offer more complete reviews of this research. Kellman and Arterberry (in press) and Spelke and Newport (1998) offer more complete reviews of this research.
3. Bogartz and Shinskey (in press) recently reported a divergent finding. Like the five sets of investigators cited above, Bogartz and Shinskey habituated one group of infants to a center-occluded object and then tested them with a fully visible continuous object and with an object with a gap. In contrast to the infants in the above studies, these infants showed equal looking times to the two test displays. In further conditions similar to two control conditions reported by Kellman & Spelke (1983, Experiments 2 and 4), Bogartz and Shinskey habituated two further groups of infants either to a fully visible continuous object or to a fully visible object with a gap and then tested them with the same two fully visible displays. In contrast to the infants in Kellman & Spelke's (1983) control conditions, these infants also showed equal looking times to the two test displays. Bogartz and Shinsky based their discussion only on their own findings and those of one condition of Kellman & Spelke's (1983) first experiment, without citing any other experimental conditions or investigators. They suggested that infants fail to show novelty preferences when tested with the method and displays of Kellman and Spelke, but the findings reported by Kellman & Spelke (1983, Experiments 2, 3, and 4), Slater et al (1990b, Experiment 4), Johnson & Aslin (1996, Experiments 1 and 2), and Needham (1994) provide evidence against this suggestion. It is not clear why Bogartz and Shinskey's method failed to elicit novelty preferences; their use of small numbers of infants and test trials, a larger number of test stimuli, and older infants are differences worthy of test. Because they did not observe novelty preferences for one fully visible object after habituation to another fully visible object, however, the absence of novelty preferences after habituation to a center-occluded object cannot be taken either as evidence for any specific limitation to infants' perception of partly occluded objects or as any challenge to the findings of Kellman (Kellman & Spelke, 1983, Kellman et al, 1986, 1987), Johnson (Johnson & Aslin, 1995, 1996; Johnson & Nañez, 1995), Jusczyk et al (1997), Needham (1994), or Slater et al (1990b).
4. Spelke & Newport (1998) discuss possible neurobiological mechanisms for the development of object representations.
5. Claims that all knowledge is learned frequently accompany claims that differences in cognitive ability are innate; see Herrnstein and Murray (1994) for a recent example.

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