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How to Grow a Baby: A Reevaluation of Image-Schema and Piagetian Action Approaches to Representation

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Key Words

Action theory · Causality · Concept development · Image-schema theory · Mandler · Memory · Mental representation · Object permanence · Piaget

Abstract

This essay examines the development of representational thought from two divergent perspectives: (a) Mandler's image-schema theory, and (b) an action-theoretical approach fundamentally derived from Piaget's theory. Juxtaposition of the two approaches highlights conceptual problems that are inherent in image-schema theory but become resolved through an action-theoretical approach. Empirical studies in the domains of early concept development, object permanence, causality, and memory are critically reviewed with emphasis on the question of the interpretive validity of findings suggesting an early onset of mental representation. It is concluded that the empirical findings fail to support the hypotheses of early onset, and that representational development is more adequately interpreted within the context of an action-theoretical approach. Finally, the analysis examines the role of the divergent metatheoretical assumptions that contextualize image-schema theory and action theory in the understanding of the development of mental representation.

For action theories generally, and Piagetian theory specifically, *mental representation* is a competence or ability that emerges from a developmental process. This emergence marks a significant cognitive developmental transition. As a novel process, mental representation is the action of deploying symbols and signs as referents to absent objects and events. Thinking, in turn, is the action of manipulating symbols and signs. Piaget [1936/1963, 1937/1954, 1945/1962] argued that (a) mental representation and thought evolve during the 2nd year of life, and (b) a period of differentiation and inte-

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gration of sensorimotor actions is a necessary precursor condition for representational thought. Over the past decade, several critiques of this argument have appeared in print [Gopnik and Meltzoff, 1996; Karmiloff-Smith, 1992; Leslie, 1987; Mandler, 1988, 1992a, 1998; Perner, 1991]. These critiques claim that empirical observation demonstrates that mental representation is innate, or emerges during the first months of life, and, thus, does not depend on prior sensorimotor development. Several contemporary investigators have, in fact, come to treat mental representation as a primitive building block of the mind that requires no further explanation [e.g., Baillargeon, 1993; Gopnik and Meltzoff, 1996; Leslie, 1987]. In this respect, Mandler's [1988, 1992a, b, 1993, 1998] image-schema theory is exceptional because, while standing in opposition to an action perspective, it suggests a developmental mechanism to account for the origin of mental representation. This mechanism, which is assumed to be innate, Mandler terms *perceptual analysis*. Perceptual analysis, in turn, is understood to generate *image-schemas*, and these constitute the first representations.

Mandler's account is significant both because it promises to provide a developmental mechanism that generates mental representations, and because it has become increasingly accepted as a standard interpretation of the nature of representational development. Karmiloff-Smith [1992], for example, considers Mandler's account as 'the most thoroughly worked out speculations about the way in which young infants build representations that are suitable for subsequent linguistic encoding' [p. 41].

There is little doubt that a Piagetian approach to the origin of mental representation stands in need of modification, and the details of such a modification are presented elsewhere [Müller et al., in press]. However, the fundamental thesis of the present paper is that Mandler's and allied proposals have tended to throw out the baby with the bath water. In this respect, our thesis will be that an action-based logic is a necessary prerequisite for the competence of mental representation and that this remains an indispensable feature of any coherent theory of infant cognition. In defense of this argument, we will first critically examine Mandler's image-schema theory by exploring some central concepts inherent in her approach and her arguments against an action-based approach. Then, some critical features of the empirical evidence elicited by Mandler in support of her anti-Piagetian argument will be discussed. Space limitation does not permit consideration of all the empirical evidence presented by Mandler [1988, 1992a, 1998], but several investigations will be treated as exemplary. These include (a) Mandler and her colleagues' [Mandler et al., 1991; Mandler and McDonough, 1993, 1996] research on conceptual development; (b) Baillargeon's [1987] study of object permanence; (c) Leslie's [1982, 1984; Leslie and Keeble, 1987] experiments on infants' understanding of causality, and (d) Meltzoff's [1988a] study of deferred imitation in 9-month-olds.

In order to develop the positive features of our proposal we will pursue the following strategy. First, by confronting image-schema theory with an action-based approach to representation we will demonstrate that each approach is based on fundamentally different metatheoretical assumptions. Second, because any interpretation of empirical findings depends, as Cassirer [p. 28], reminds us, 'on certain fundamental concepts which have to be clarified before the empirical material can bear its fruit' [1944b; see Overton, 1998], we will elaborate conceptual distinctions that have not received sufficient attention from contemporary investigators. These distinctions will then form the base for the proposed alternative interpretation of the findings generated by Mandler, Baillargeon, Leslie, and Meltzoff. In framing this alternative, we will propose developmental sequences for several domains, including concept and memory development that are fundamentally derived from an action perspective. The proposed developmental sequences serve as the framework within which we will contextualize the empirical findings of Mandler et al., Baillargeon, Leslie, and Meltzoff. Such a contextualization of infants' competencies is necessary to clarify whether analogous processes [i.e., processes involving different functional patterns, see Werner, 1948], underlie similar performances, and whether these competencies precede and are prerequisites for more complex competencies [Fischer and Bidell, 1991; Liben, in press; Overton, 1991a; Piaget, 1937/1954].

Image-Schema Theory and Criticisms of Piagetian Action Theory

Mandler's [1988, 1992a, 1998], major theoretical criticism of Piagetian theory is that it does not clarify how sensorimotor schemes become transformed into representational knowledge. Mandler bases her criticism on the recent distinction between procedural and declarative knowledge. Procedural knowledge is defined as implicit knowledge that is not accessible to consciousness and consists of motor and perceptual skills. For example, face recognition has the status of procedural knowledge. Although face recognition may be accompanied by a feeling of familiarity, this is an 'optional accompaniment to a basically unconscious process' [Mandler, 1988, p. 115]. Mandler subsumes sensorimotor action under procedural knowledge, and concludes that sensorimotor knowledge, by virtue of this association, is not accessible to consciousness:

> Hence, the kind of procedural knowledge relevant to the sensorimotor period of infancy is only a subset of procedural knowledge in general, consisting of motor and perceptual activity that does not require that the information being processed is accessible to conscious awareness [p. 115].

Mandler claims that declarative knowledge, in contrast, is explicit knowledge, and is, therefore, accessible to consciousness. Mandler identifies conceptual knowledge with declarative knowledge:

> Concepts are not always in consciousness, to be sure, but they were formed from conscious processes and when we are conscious we are using the conceptual system to carry out our conscious thoughts [p. 115].

The difference between procedural and declarative knowledge for Mandler, therefore, is that 'the latter type of knowledge can be brought to conscious awareness; the former cannot. ... If you are conscious of what you are seeing, you are engaged in conceptual thought' [p. 116].

Mandler's [1988, p. 132] position, then, is that because sensorimotor knowledge is stored in an inaccessible format, declarative knowledge cannot possibly be derived from sensorimotor knowledge. In order to get conceptual knowledge off the ground, Mandler argues, it is necessary to store information as a symbolic code from very early stages of infancy on. As a consequence, she proposes *perceptual analysis* as the mechanism by which accessible knowledge is generated. Perceptual analysis is considered to be innate, and is taken to be in evidence, in a primitive form, quite early in infancy (3–4 months) [Mandler, 1992a, p. 589]. In contrast to other perceptual processes, perceptual analysis is identified as a nonautomatic, conscious process that occurs concomitant with perception:

The process is different from the usual perceptual processing, which occurs automatically and is typically not under attentive control of the perceiver. Most of the perceptual information normally encoded is neither consciously noticed nor accessible at a later time for purposes of thought. Perceptual analysis, on the other hand, involves the active recoding of a subset of incoming perceptual information into meanings that form the basis of accessible concepts [p. 589].

Perceptual analysis consists in comparing one object with another and conceptualizing them as different or the same, or noticing some aspect of a stimulus that had previously gone unnoticed. Mandler gives the following example for the process of perceptual analysis: 'Someone may consciously notice that an acquaintance has started wearing glasses, a fact that may have been missed for several weeks in spite of looking at this person every day' [1988, p. 589].

Perceptual analysis generates abstract, nonperceptual *image-schemas*, which are described as *simplified and condensed redescriptions of the spatial structure* (analog representations) [Mandler, 1992a, pp. 591–592]. Image-schemas themselves are not available to consciousness; rather they are storehouses of meanings from which concrete images are constructed [Mandler, 1992a, 1998]. Mandler [1992a] suggests that image-schemas provide the earliest systems of conceptual meanings upon which 'thought' operates. 'Thought' itself, however, is not developed in Mandler's system. Image-schemas are intermediate between perception and language, and they facilitate the acquisition of the language. They are the base from which concepts such as animacy, inanimacy, causality, agency, containment, and support are generated [pp. 593–598]. From this perspective, for example, infants are thought to abstract self-motion – one of the parameters defining the concept of *animacy* – as a common feature of several inputs. It is suggested that infants come to notice that some entities start movement on their own, and they contrast these entities with other entities that do not start movement on their own. This perceptual analysis then results in a redescription of the perceptual information in an image-schematic format [Mandler, 1992a, 1998].

Evaluating Image-Schema Theory

In several respects, image-schema theory follows Fodor's [1975, 1985] version of the representational theory of mind. Image-schemas are designed to be an iconic *language of thought* [Mandler, 1992a, p. 592]. By subscribing to the assumptions made by Fodor's representational theory of mind, the image-schema approach is vulnerable to the same kinds of criticisms that have been leveled against Fodor's theory [Bickhard, 1993; Goldberg, 1991; Heil, 1981; Lyons, 1991; Russell, 1996; Smythe, 1992a]. More specifically, the following discussion will lay bare the idea that Mandler's iconic version of 'mentalese' fails to adequately ground meaning. First, however, the issue of whether sensorimotor intelligence is, as Mandler argues, inaccessible to consciousness will be critically examined.

Sensorimotor Knowing and Procedural Knowledge

Mandler's argument can be restated as follows: There is a strict dichotomy between procedural/implicit and declarative/explicit knowledge. Procedural knowledge is inaccessible to consciousness. Sensorimotor knowledge is a type of procedural knowledge.

Ergo, sensorimotor knowledge is inaccessible to consciousness and declarative knowledge cannot be derived from sensorimotor knowledge. This argument is based on two assumptions: (a) sensorimotor knowledge as a type of procedural knowledge is inaccessible to consciousness, and (b) there is a strict dichotomy between procedural and declarative knowledge. An examination of the procedural knowledge exemplars offered by Mandler will show that the first assumption is incorrect. Then, we will propose that – rather than drawing a fixed boundary between consciousness and unconsciousness – it is more productive to describe consciousness as several levels that are dynamically related to each other. Before examining Mandler's argument, Piaget's concept of sensorimotor development will be briefly summarized.

For Piaget, the relationship between infant and world is charged with conscious meaning from the start. This is because sensorimotor action schemes embody need states and are, therefore, goal-directed actions [Piaget, 1936/1963, 1965/1971]. Consciousness, *at this level*, is essentially a system of action meanings. The fact, for example, that actions of sucking vary depending on whether infants are hungry and try to nurse, or whether they suck to calm themselves, indicates that consciousness of meaning is already present in infants' sucking activities [Piaget, 1936/1963, p. 38]. While it is true that meaning conferred on objects is *not symbolic* and *not representational* in nature, it is nevertheless conscious meaning, functioning at a practical level. For example, what from the perspective of the adult is a ball, is for the infant a nonsymbolic 'pushable', 'throwable', and 'catchable'. In the course of sensorimotor development, action schemes become increasingly differentiated and coordinated among themselves. As a consequence, things acquire increasingly more complex meaning and become gradually detached from the immediate situation, which is a prerequisite for the emergence of mental representation. Given that sensorimotor knowledge is constituted by consciously directed actions, the transition from sensorimotor to representational knowledge does not consist of a shift from unconsciousness to consciousness. Rather, this transition consists of a shift from *one form of consciousness to a more complex form of consciousness* [Piaget, 1945/1962, 1974/1976b].

Although infants are consciously and intentionally directed toward the world, not all aspects of sensorimotor knowledge are considered to be consciously accessible to them. Rather, what remains unconscious at any level of development is the logical form of the knowledge. Logical form is inherent in the organizing or structuring activity of assimilation and it underlies the projection of meaning onto the world. Or, as Piaget [1970/1976a] expressed it:

> The results of cognitive functioning are relatively *conscious* but the internal mechanisms are entirely, or almost entirely, *unconscious*... The subject is usually *unconscious* of the structures that guide thinking. The structures determine what he can or cannot 'do', and what he must 'do', in the sense that certain logical relations are necessary for his thinking. Cognitive structures are *not* the *conscious* content of thinking, but impose one form of thinking rather than another. These forms depend on the subject's developmental level [p. 64, emphasis added].

Piaget thus distinguished between cognitive structures as they are *used* in mental acts and the meaningful content constituted by these mental acts. It is only the former, not the latter, which remains unconscious at any given level of knowing.

In contrast to Piaget, Mandler claims that sensorimotor knowledge is a subset of procedural knowledge and, as such, is completely inaccessible to consciousness. Because the term *procedural knowledge* usually does not imply absence of any consciousness whatsoever [e.g., Anderson, 1985], close attention must be paid to Mandler's use of the term. Mandler [1988] offers the following procedural knowledge exemplars: the recognition process in general and face recognition in particular, sucking on a nipple, reaching for an object, perceptual process [p. 115], tieing one's shoelace, activation of semantic networks, priming, and retrieval [pp. 130, 132]. The commonality among them is that their 'acquisition does *not* require conscious accompaniments' [p. 115]. They differ from motor skills such as riding a bike and typing which 'require extensive conscious processing during the early stages of their acquisition' [p. 115]. In the following, we examine these exemplars in terms of whether they reflect types of knowledge that are inaccessible to consciousness.

Some of the exemplars (i.e., priming, activation of semantic networks, recognition) suggest that Mandler's distinction between implicit/procedural and explicit/declarative is drawn from recent theories of adult memory [Schacter, 1996; Squire, 1992]. Based on extensive empirical observations, these theories distinguish between two fundamental types of memory: (a) *Declarative* or *explicit memory*, characterized by the conscious recollection of previous experiences, and measured by traditional memory tests such as free and cued recall, and (b) *procedural* or *implicit memory*, characterized by an unconscious, nonintentional form of retention. Measures of procedural memory include, for example, skill learning and priming. Studies using declarative and procedural memory tasks have shown performance on one type of task to be uncorrelated with performance on the other. For example, prior exposure to a list of words (priming) can facilitate the completion of word fragments constructed from words on the same list, although subjects are incapable of identifying these words in a recognition test [Tulving et al., 1982]. Thus, performance on procedural memory tasks is influenced by prior experiences in the absence of conscious recollection. Furthermore, several studies show that amnesic and Alzheimer patients often have a relatively intact procedural memory but an impaired declarative memory [Roediger, 1990; Schacter, 1996; Shinamura, 1986]. In one study, for example, Alzheimer patients were incapable of recalling a list of words, although they were capable of learning a rotary pursuit task [Eslinger and Damasio, 1986].

While the distinction between declarative and procedural knowledge may be supportable for adult *memory*, it is highly questionable whether the same distinction is appropriate for sensorimotor and representational *knowledge*. Memory research does not demonstrate the inaccessibility of procedural knowledge to consciousness. Skill learning such as rotary pursuit engages subjects in meaningful goal-directed actions. Rotary pursuit, for example, requires the conscious coordination of the stylus and the target displayed on a screen. The differential success of amnesic and Alzheimer patients on explicit memory and skill learning tasks is not about consciousness per se. It is about the fact that their knowledge is tied to the immediate situation from which it cannot be detached. Their phenomenal experience is confined to practical space and practical time [Cassirer, 1929/1957]. In a way, the situation of these patients is similar to that of infants whose conscious experience also does not transcend the boundaries of the immediate here and now.

Further, it is difficult to see why the finding that performance is influenced by prior experiences in the absence of conscious recollection implies that sensorimotor knowledge is inaccessible to consciousness. Subjects engaged in implicit memory tasks such as word fragment completion are conscious of what they are doing. Their goal is to complete the word fragments. It is only from the experimenter's, not the subjects', perspective that the task is an implicit memory task. The fact that past experiences influence present performance in the absence of conscious recollection does not imply that present performance is unconscious or inaccessible to consciousness. Mandler inappropriately identifies the absence of a consciousness of having earlier experienced something with the absence of any consciousness whatsoever.

Next, consider the recognition, face recognition, and perception exemplars, suggested by Mandler as further illustrations of procedural knowledge. One could agree here that the *processing of information* may well be inaccessible to consciousness. However, it is arguably the case that *perception* constitutes an intentional activity, and as such it is meaningfully directed towards an object [Marbach, 1993; Merleau-Ponty, 1945/1962; Neumann, 1990b]. The fact, for example, that infants' reactions towards the mother differ from their reactions towards a stranger demonstrates that from early on acts of perceiving entail conscious meanings [Sroufe, 1977]. From an action-theoretical perspective, there is no claim that sensorimotor knowledge requires that infants be conscious of the *information-processing* involved in, for example, face recognition. The claim, rather, is that the objects interacted with have a practical, conscious meaning for the infant. Clearly, image-schema theory and an action-theoretical approach make different assumptions about the nature of psychological functioning. Mandler basically adopts the empiricist idea that input constitutes 'registration' [Melkman, 1988]. According to this idea, meaning is the end product of computational and inferential processes to which uninterpreted sense data are subjected. The registration notion of input, however, leads to an infinite regression because it requires the introduction of homuncular agents carrying out and supervising these processes [Melkman, 1988]. An action-theoretical approach, on the other hand, begins from the assumption that consciousness is always intentional, i.e., consciousness is always meaningfully directed toward objects [Melkman, 1988; Russell, 1996]. An action-theoretical approach replaces the 'registration-of-information notion of input with the interpretive act of assimilation-to-structure, thereby ridding itself of uninterpreted data' [Melkman, 1988, p. 23].

To avoid misunderstandings, it is important to point out that within action theory notions of 'information-processing' and 'computation' maintain a heuristic value. For example, they can be thought of as theoretical constructs that make neural processes intelligible [Russell, 1987]. Neural processes are nonintentional, causal processes that the subject does not directly control [Hacker, 1991; Russell, 1996]. Neural 'information-processing', however, belongs to a different level of analysis than do intentional mental acts that are meaningfully and consciously directed towards objects and events. The difference is that neural processes are located on the subpersonal level of analysis, intentional acts are located on the personal level [Russell, 1996]. Neural processes constitute a causal *condition* for exercising personal-level mental acts. However, intentional mental acts and phenomenal experience are neither simply links in a chain of neural processes, nor the direct final product of neural processes. To hold otherwise inevitably leads to the Cartesian problem of explaining how purely causal processes in the brain can result in conscious mental activities [Hacker, 1991]. By characterizing perceptual processes, and the recognition process, as being inaccessible to consciousness. Mandler fails to distinguish between subpersonal-level information-processing, which is a causal condition for personal-level mental acts and experiences, and personal-level mental acts and experiences themselves. As a consequence, several of Mandler's exemplars (perception processes, recognition processes, priming, retrieval, and activation of semantic network) are not located on the same level as mental acts that are meaningfully directed towards objects. Her failure to recognize that neural information-processing and intentional mental acts represent different and distinct levels of explanation constitutes a category error [Hacker, 1991].

If procedural memory tasks and subpersonal-level information-processing fail to support Mandler's claim that sensorimotor knowledge is inaccessible to consciousness, what about the exemplars of sucking on a nipple, reaching for an object, and tying one's shoelace? On the one hand, it is questionable whether these exemplars differ substantially from riding a bike or typing, which Mandler [1988] claims 'require extensive conscious processing during the early stages of their acquisition' [p. 115]. On the other hand, developmental studies of reaching and grasping [e.g., von Hofsten and Rönnqvist, 1988] clearly demonstrate that these sensorimotor actions require extensive practice. To some extent, even sucking behavior requires practice [e.g., Piaget, 1936/1963; Sameroff, 1968], and this suggests some conscious effort on the part of the infant. Although we are not familiar with studies that examine how children learn to tie their shoelaces, our own observations suggest that this skill also requires extensive practice, and, thus, conscious effort. Practice of these sensorimotor actions does indeed often lead to their automatization. The sensorimotor actions then become embedded in more complex intentional actions and are no longer in the focus of consciousness [Logan, 1988; Neumann, 1984, 1992; Piaget, 1936/1963, p. 136]. However, automatized actions move into focal consciousness in situations where the actions do not lead to the expected outcome [Heckhausen and Beckmann, 1990; Piaget, 1974/1976b, 1974/1978a; Reason, 1979]. When obstacles are met, children's and adults' conceptualization of their actions proceeds from the goal pursued to the means employed [Piaget, 1974/1976b].

All of the examples given to this point suggest that Mandler's strict dichotomy between procedural and declarative knowledge is difficult to apply to processes that operate at the personal level. Recent developments in attentional theory [e.g., Allport, 1987, 1988; Neumann, 1984, 1987, 1990a, 1992] have also cast doubt on the possibility of any strict distinction between procedural (unconscious) and declarative (conscious) knowledge. Neumann [1990a], for example, distinguishes between the field of consciousness and the focus of consciousness:

> One may call the field of consciousness 'preattentive,' but is [sic] should be clear that this meaning of the term is completely different from the concept of preattentive processes in the sense of early steps in processing that have no conscious correlate whatsoever [p. 258].

The focus and the field of consciousness are dynamically related – changing demands in the control of action yield a shift in the focus of consciousness. Such a notion runs counter to Mandler's static view of the relations between consciousness and unconsciousness, but it is consistent with the Piagetian proposal that there are different degrees of consciousness [Piaget, 1933, 1945/1962, 1974/1976b; see also Vygotsky, 1933/1987].

In this section we have sought to demonstrate that Mandler's rationale for postulating a special mechanism to get representational knowledge off the ground is based on the faulty premise that sensorimotor knowledge is inaccessible to consciousness. Sensorimotor actions are intentionally and consciously directed toward objects. A close examination of Mandler's procedural knowledge exemplars provides no evidence for the claim that sensorimotor knowledge, as a whole, is inaccessible to consciousness. Mandler's proposed exemplars of procedural knowledge consist of a collection of heterogenous processes involving personal-level sensorimotor skills, and subpersonal-level neural information-processing. Only the former are relevant to sensorimotor knowledge, and we have illustrated how these skills are goal-directed, conscious actions. Because Mandler fails to provide any evidence for her claim that sensorimotor knowledge is inaccessible to consciousness, the positing of a *special process* such as perceptual analysis is not necessary in order to explain the origin of mental representation.

Moreover, we have argued that there is no need to posit a strict dichotomy between procedural/implicit and declarative/explicit knowledge. In fact, the notions of procedural and declarative knowledge do not appear to be very useful for differentiating between knowing levels. At each level of knowing the organizing activity that generates knowledge remains unconscious, while the content constituted by these activities is, to various degrees, conscious. What changes with development is, thus, not simply whether some processes are inaccessible or accessible to consciousness. Rather, what changes is the complexity of knowledge organization, and, correlatively, the complexity of the content thus constituted. Because at each knowing level children are not conscious of the organizing activity they use, the construction of higher forms of knowing takes the form of becoming aware and reorganizing the knowledge organization of the previous knowing level within the framework of new and more powerful knowledge organization [Campbell and Bickhard, 1986; Moshman and Lukin, 1989]. As a consequence, the distinction between the organizing activity of knowing and cognitive content shifts the focus of study. It shifts it from exploring a strict and static distinction between consciousness and unconsciousness, to exploring the dynamic relationships between consciousness and unconsciousness [see also Mounoud, 1995].

Conceptual Problems of Image-Schema Theory

In this section we will examine a number of problems that surround image-schema theory itself [see Mounoud, 1995, for related criticisms]. These partially arise from the metatheoretical framework that grounds and sustains the theory. The discussion of these problems will also briefly outline alternatives suggested by an action approach. Specifically, 6 problems associated with image-schema will be discussed: (1) the lack of clarity of the phenomenological basis of the perceptual analysis process that generates image-schemas; (2) the problem that, in themselves, images cannot signify abstract and general ideas; (3) image-schemas and images are not suited for on-line categorization of perceptual stimuli; (4) image-schema theory encounters the learning paradox; (5) there is a confusion of the properties of images with the properties of the objects imagined, and (6), although Mandler claims otherwise, image-schema theory does not resolve the symbol-grounding problem.

Image-schema theory's first problem is that the status of perceptual recoding is ambiguous. Mandler states that perceptual recoding is a conscious process. Phenomenologically, however, there is no experience of perceptual recoding. The examples of perceptual analysis given by Mandler [1992a, p. 589] illustrate a shift in the focus of consciousness, but these attentional processes do not involve perceptual recoding [Neumann, 1990a]. In the intentional activity of perceiving, we do not recode information, rather we establish an immediate, meaningful relationship towards an object [Gibson, 1979; Neumann, 1990b; Piaget, 1961/1969b]. In the tradition of empiricist approaches to psychology, however, image-schema theory *splits* perception from action [Mounoud, 1995]. Infants' perceptions are not examined in the context of their overall actions. From an action-theoretical perspective, on the other hand, perceptions are always a function of actual or virtual behavior [Piaget, 1976/1978b]. The meaning assigned to perceptual indicators is influenced by the goal of the action: 'To perceive a house is not to look at an image which has just got into your eye, but to recognize a solid shelter for you to get into' [Inhelder and Piaget, 1959/1969, p. 13].

Proposing images as signifiers of general and abstract ideas constitutes image-schema theory's second problem. As philosophers [Berkeley, 1710/1949, Intro., 16; Cassirer, 1938/1944a; Kant, 1787/1929, B 180] have long argued, images in themselves are particulars and cannot point to general ideas. For example, the idea of a triangle includes the right-angled, acute-angled, and obtuse-angled triangle, but an image cannot be all these at once. Only with the development of the organizing process of knowing, and the comprehension of hierarchical relationships between concepts, does an image of a particular serve as a signifier for general and abstract concepts. In fact, because children at Piaget's preoperational level of consciousness lack the necessary cognitive organization to understand hierarchical relationships between concepts, the images at this level express concepts that remain halfway between the individual and the general [Piaget, 1945/1962, p. 228, p. 244].

Third, image-schemas and images are not suited for on-line categorization of stimuli. Constructing a mental image is an act of visualizing what something looks like or would look like. Imagining is not seeing or perceiving, but quasi-seeing [Marbach, 1993; Ryle, 1949; White, 1990]. When imagining an absent object, a person must, concurrently, remain aware of his or her present surroundings. If this were not the case, the person would be dreaming or hallucinating. Imagining or quasi-seeing interferes with seeing the actually present world:

> While I am actually looking at my presently given spatial surroundings, the visually imagined spatial scene that quasi-appears to the represented visual point of view fades away. The actual, presently occupied point of view conflicts with the non-actual, only represented point of view, as far as the same bodily, sensory, activity is involved at the same time [Marbach, 1993, p. 86].

The interference of visual imagery with perception is a well-established phenomenon in experimental psychology [Perky, 1910; Craver-Lemley and Reeves, 1992; Siegal, 1971]. Because visual imagery interferes with perception, visual imagery is incapable of conceptually categorizing presently given stimuli. Thus, image-schemas are not useful for on-line categorization.

Fourth, in the epistemological tradition of empiricist abstraction theories, image-schema theory assumes that objects are grouped according to common properties, and that the mind abstracts concepts by selecting their common features. By subscribing to the empiricist framework, image-schema theory faces the same problems as empiricist abstraction theories in general [Cassirer, 1923/1953, 1929/1957]. That is, the theory cannot explain the acquisition of concepts by a process of abstraction without presupposing that infants already possess the concept to be abstracted. To some extent, Mandler recognizes this 'learning-paradox' problem as she acknowledges that 'the infant has an innate predisposition to form image-schemas of a certain type' [Mandler, 1992a,

p. 592]. If, however, as Mandler [1988, p. 115] claims, concepts were 'formed from conscious process', then innate predispositions for some image-schemas will not suffice. Rather, the defining features for any concept would have to be innate to allow infants to summon appropriate entities for the recoding process. How could infants otherwise limit the elements from which the concept of animacy is abstracted to animals? How could infants otherwise link (i.e., associate) primitive image-schemas to construct more complex image-schemas? Contrary to her intentions, Mandler [1992a, p. 592] would have to provide richly innate content: if concepts were learned by perceptual analysis, it would be impossible to learn anything genuinely new [see Fodor, 1980, and Russell, 1996, on this problem].

The fifth problem for image-schema theory is that image-schemas are said to be 'spatially structured' [Mandler, 1992a, p. 591]. However, space – like other properties such as color and size – is not a property of the image but a property of the object imagined. Failing to make the distinction between properties of the image and properties of the object imagined 'is probably one of the most ubiquitous and damaging conceptual confusions in the whole imagery literature' [Pylyshyn, 1981, p. 18; see also Dean, 1991; Dean and Youniss, 1991; Liben, in press]. Regarding images as spatially structured is treating them like physical objects in the mind. Part of the confusion here may be due to the fact that mental images seem to be regarded as pictures or portraits. However, as White [1990] points out, 'because the portrait or picture has a medium it can be, for example, large, coloured or square, whereas an image is simply how something is portrayed or pictured and has no medium' [p. 94]. Unlike pictures or portraits, mental images have no life independent of consciousness. Images are not stored, and memory is not peopled with spatial analogues. Rather, imagining an object is being conscious of the object or thinking of it in respect to its visual characteristics. The visual characteristics are used as a symbol to express the thoughts and feelings about the object imagined. Imaging is, thus, a complex representational act that consists of the representative item (visual characteristics), and the intentional act of thinking which makes the imagined visual characteristics the expression of thoughts and feelings [Judge, 1985].

The sixth and final problem for image-schema theory is that it does not resolve the symbol-grounding problem. The symbol-grounding problem refers to the question of how to explain that representative items can have meaning [Bickhard, 1993; Campbell and Bickhard, 1986; Heil, 1981; Smythe, 1992a]. To illustrate, if a vocal utterance did not express any meaning, it would be sheer noise [Vygotsky, 1934/1962]. Mandler [1992a, p. 592] believes that image-schema theory solves the symbol-grounding problem because the meaning of image-schemas resides in their own structure; no other symbols are necessary to interpret them. It is not clear how this proposal solves the symbol-grounding problem because representational meaning cannot be encapsulated within any inner entity [Goldberg, 1991; Heil, 1981; Judge, 1985]. Rather, representational thought must involve a three-term relationship consisting of (a) a representative item – the *signifier*; (b) a content being represented – the *signified* or concept-aspect of the representative item, and (c) the agent who intentionally uses the signifier and signified to refer to some object or event [Judge, 1985; Piaget, 1936/1963, p. 191]. Within this three-term relationship, it is the intentional act of assimilating the signifier to the signified which gives mental images their meaning and refers them to an object or event. 'Whatever the vehicle of signification happens to be, its signification .... occurs only because someone or some thing uses it in that way. So what is important about the symbol is its significatory structure, that is to say, the structure it is given by the intentional act of the user' [Judge, 1985, p. 164].

Thus, in order to avoid the symbol-grounding problem, image-schemas must be conceptualized as meanings that an intentional agent expresses through the use of representative items such as images. However, because Mandler [1992a, p. 589] claims that image-schemas are themselves inaccessible to consciousness, this possibility is excluded. As a result, image-schema theory is left with representative items that are without meaning. In fact, the very notion of an inaccessible internal code is incoherent [Baker, 1987; Hacker, 1991]. If image-schemas were inaccessible, how could images be generated and who would generate them? Further, how could one ever know what one was thinking?

The idea that meaning can reside in the structure of representative items is deeply rooted within the empiricist epistemological tradition, and lies at the bottom of the belief that the mind works like a computer [Heil, 1981; Hyman, 1991; Judge, 1985; Overton, 1994; Taylor, 1995]. Empiricists have considered images to be entities that mediate between stimulus and response. It is claimed that meaning is stored within these mediating entities. Representative items, however, would lose their representational value if they were entities encapsulated within the mind and not used in mental acts directed toward something separate from the mind. In fact, the idea that meaning could reside in the structure of the symbol itself is characteristic of mythical thinking:

> Mythical thinking differs from scientific thinking in that with myth there is no distinction between the sign and the object signified. For mythical thinking, a sign does not represent some independent content lying outside the sign itself, but rather itself participates in that content. There is an immediate identification of the physical substrate of a sign with its non-physical meaning [Kramer-Friedrich, 1986, p. 24].

There is, however, nothing to any physical substrate that makes it a symbol or sign for the expression of meaning because the same physical structure may function as either a signal or as a symbol or sign [Judge, 1985]. For example, rats can be conditioned to jump on the sight of the string of letters JUMP. These rats have learned to use this string of letters as a signal, and confer a significance to it in the context of food-seeking behavior. There is no need to assume that these rats understand the letters as a sign, which is reserved to human beings who know what the letters mean without having to jump.

In this section we have pointed to several theoretical problems for image-schema theory. Some of these problems involve the mechanism of perceptual analysis. We have argued that there is no evidence for the existence of perceptual analysis, and that it would be impossible to learn any new concept through perceptual analysis. Other problems involve the role of image-schemas and images in Mandler's theory. The argument here is that images and image-schemas cannot be spatially structured and, in themselves, cannot express general ideas. Furthermore, because imagining interferes with perception, images are not useful for online-categorization of stimuli. Finally, we have demonstrated why image-schema theory does not solve the symbol-grounding problem. Until these problems are resolved, it is unlikely that image-schema theory can be counted among the theories that further our understanding of the conceptual and representational development in infants.

The Action-Theoretical Account of the Development of Mental Representation

From an action-theoretical perspective, it is the particular organization of the knowing activity that distinguishes signal use from symbol use. The specifics of this proposal are elaborated elsewhere [Müller et al., in press]. Although this proposal adopts several ideas elaborated by Piaget, it modifies his account of the development of mental representation in some respects.

Following Piaget, this action-theoretical proposal claims that multiple levels of mental organization are closely linked to the *operative* aspect of knowing. The operative aspect of knowing refers to the active, coordinating or form-giving aspect of knowing. Complementary to the operative is the *figurative* aspect of knowing. This provides the particular material or input that is organized by the operative. Operative and figurative are complementary and inseparable: the organizing activity of knowing always requires some material to objectify itself. The development of the operative aspect of knowing constitutes the engine of cognitive development because it is the operative aspect of knowing that inserts input into increasingly complex relationships [Piaget, 1961/1969b].

Piaget distinguished between two types of material that the figurative aspect of knowing confers on the operative aspect. The first is composed of *undifferentiated signifiers* (i.e., signals and indications) that have a spatiotemporal linkage to their referent. This very linkage precludes representation (re-presentation) of and reference to absent objects. Representation of and reference to absent objects requires developmentally moving beyond these undifferentiated signifiers to the second type of figurative material, i.e., signifiers that are differentiated from their referent, such as symbols and signs. During the period of sensorimotor knowing, infants' actions do not transcend the boundaries of the immediate here and now precisely because they have not yet constructed differentiated signifiers. Initially, action schemes are not yet differentiated from the objects to which they are applied. In the course of goal-directed interactions with the world, and as a result of successes and failures of these goal-directed actions, the action schemes become differentiated and coordinated. As a consequence, each experience becomes inserted into a network of schemes and thereby detached from any one scheme. Piaget explained the specifics of the transition from undifferentiated to differentiated signifiers in terms of the process of interiorization. This explanation, however, leads to several problems [Müller et al., in press].

A modified action-theoretical account is fundamentally characterized by the elimination of the concept of interiorization, and by the introduction of the concept of operations at the sensorimotor level of functioning. Basically, operations establish hierarchical coordinations between action schemes. Following Langer [1986], we describe sensorimotor development in terms of action schemes and first- and second-order practical operations. The increasing detachment of action schemes from objects is a prerequisite for first-order practical operations [Langer, 1986]. First-order practical operations are single operations that by coordinating schemes construct different kind of relations (similarity relations, difference relations, causal relations, spatial relations, etc). between objects. First-order practical operations are displayed, for example, when infants construct similarity relations between individual elements by uniting two objects into a 2-object composition (e.g., infants put two cups together). Second-order practical operations coordinate first-order practical operations and construct relations on relations, as evidenced, for example, in the simultaneous construction of two sets (i.e., infants put four dolls into one set and four cars into another set). We suggest that the development of second-order practical operations takes place in the 2nd year of life and constitutes a prerequisite for the construction of differentiated signifiers, i.e., the representational relationship between signifier-signified pairs and their referents [Müller et al., in press].

As distinct from both Mandler and Piaget [1945/1962], we locate the onset of mental representation in language, and not in mental imagery. Essentially, this proposal is based on the idea that differentiated signifier-signified pairs constitute a contrastive representational system [Clark, 1987], and that the understanding of the representational relationship between signifier-signified couplings and referents involves the discovery that any signifier-signified coupling receives its value only through relationships with other signifier-signified couplings. The understanding that different signifier-signified couplings are semantically contrastive is reflected in the child's discovery that 'every thing has a name' [Stern, 1914/1930]. A prerequisite for setting up contrasts between different signifier-signified couplings is a stable system of signifiers, which in the case of language is provided by the community of language users. Because mental images are personal symbols [Piaget and Inhelder, 1966/1971], they lack this sort of stability. As a consequence, it can never be ascertained which kind of image was used to refer to a particular thing because this would be 'as if someone were to buy several copies of the morning paper to assure himself that what is said was true' [Wittgenstein, 1953, § 265]. For this reason, we argue that the grasp of the representational relationship between signifier-signified pairs and their referents cannot originate in mental imagery, which, however, does not prevent mental images from playing an important role in acts of imagination in the further course of development. Ironically, Piaget's [1965/1995] explanation of the origin of mental representation fails because, contrary to his overall theoretical framework, he essentially locates the onset of mental representation in private, imagining activity.

Mandler's Studies of Conceptual Development: Image-Schema versus Action Interpretation

In this section, we present an analysis of Mandler's research on concept development. The issue is whether Mandler's image-schema theory, or an action-based theory, more adequately accounts for the findings of these studies. In exploring this issue, the previously sketched developmental action theory will be further elaborated.

Mandler proposes that two criteria must be met for anything to be considered a concept. First, reminiscent of the empiricist notion of natural kinds [for a discussion see Dupré, 1981; de Sousa, 1984; Shain, 1993]. Mandler defines a concept as the idea of the sort of thing an object is, and not just what it looks like [Mandler, 1992b, p. 274; see also Mandler, 1992a, p. 601; Mandler, 1993, p. 142]. Second, Mandler [1988, p. 115] holds that concepts are constructed by conscious processes and used in conscious thoughts. According to Mandler, neither criterion is established in perceptual categorization. This is because, as Mandler [1993, pp. 141–142] says, (a) through perceptual categorization infants process information on a sensorial level, and (b) the information processing involved in perceptual categorization is unconscious [Mandler, 1988, p. 115]. She argues that her concept development studies demonstrate that 7-month-old infants can already distinguish between objects on a nonsensory conceptual or representational basis, and not merely on a perceptual or sensorial basis. Because, with Mandler's definition of concepts, perceptual categorization cannot account for these findings, she invokes perceptual analysis to explain these conceptual competencies of young infants. Perceptual analysis produces image-schemas which form the basis for infants' conceptual activities [Mandler, 1992a].

Now, consider the empirical findings on concept development that are presented as supporting this interpretation. A series of studies [Mandler and McDonough, 1993] explored the concept of animacy and found that 7-month-old infants looked longer at objects from the 'superordinate' category of *inanimate objects* (e.g., a toy vehicle) after they had been habituated to different objects from another 'superordinate' category (e.g., toy rabbits). At the same time, infants did not dishabituate to a fish (i.e., toy fish) after they had been habituated to several dogs (i.e., toy dogs). A similar distinction between animate and inanimate objects was found when the conceptual development of older infants was assessed by (a) successive touching of objects of the same category [Mandler et al., 1991], and (b) the extension of modeled actions to exemplars that share some property with the object for which the target action was modeled [Mandler and McDonough, 1996]. Mandler's [1992a] fundamental claim is that these findings demonstrate that infants' dishabituation could not be due to perceptual categorization because infants did not dishabituate to perceptually dissimilar objects (toy fish vs. toy dog). They dishabituated only to objects that belonged to a different type of thing (toy dog vs. toy vehicle). Infants' dishabituation pattern, according to Mandler [1993], shows that there is 'a nonperceptual "core" notion of animate versus inanimate that is guiding attention on the object examination task' [p. 147]. This core sense of animalness is interpreted as being based on the image-schema of self-movement [Mandler, 1992a].

Mandler and her coworkers' studies have yielded very interesting and valuable findings. However, there are four reasons why Mandler's interpretation of these findings is problematic. The first problem concerns the claim that 7-month-old infants discriminate toy birds and toy airplanes on the basis of self-movement of these objects [Mandler, 1993; Mandler and McDonough, 1993]. An understanding that real airplanes are not self-moving minimally requires that infants (a) have had opportunities to observe real airplanes (at what distance? starting? flying? landing?), and (b) have some kind of causal theory about the functioning of real airplanes. These are not very plausible assumptions concerning infants' experience and knowledge. It appears more parsimonious and reasonable that discrimination between objects from different categories resulted from perceptual differences associated with different category membership [e.g., smooth vs. jagged object contours or presence vs. absence of facial features, see Quinn and Eimas, 1996].

Moreover, the use of toy rather than real animals as stimuli in Mandler's research lends ambiguity to the findings. Toy animals are not the types of things that are animate, they do not move by themselves [in fact, toy dogs and toy vehicles are the same type of thing: inanimate toys, see Oakes et al., 1997]. Mandler [1992a, p. 601] argues that the appendages involved in different kinds of self-movement help to identify something as an animal, even in the absence of movement. If a toy animal is understood to be the same kind of thing as a real animal, infants should not react differently toward a toy and a real animal. This issue remains to be explored [see, for example, Ricard and Allard, 1993, for research that includes a toy, a real animal, and a human being].

The second problem with Mandler's interpretation of her findings again involves her assumption that perceptual categorization is unconscious. As suggested earlier, this assumption is based on the conflating of subpersonal-level information processing and personal-level mental acts. On the personal level, perceptual categorization and identification of objects are intentional mental acts that are directed towards objects [Neumann, 1990b]. As a consequence, there is little reason to believe that infants' discriminative responses in perceptual categorization studies do not imply conscious meanings. Thus, there is little reason to treat Mandler and McDonough's [1993] findings differently from the findings of other studies of perceptual categorization [see also Quinn and Eimas, 1996; Oakes et al., 1997].

Thirdly, it is not clear how perceptual analysis is capable of producing any nonsensory concepts because perceptual analysis generates only a simplified or condensed description of spatial structure. It is claimed that perceptual analysis abstracts specific features of the perceived spatial structure. The simplification and condensation of spatial structure alone, however, cannot generate concepts that have a nonsensory basis. Let us even suppose, for argument's sake, that Mandler and her colleagues' findings were accepted as demonstrating that infants can discriminate between animate beings and inanimate entities – a capacity widespread among animals – and that this occurs on the basis of self-movement. Even under these unlikely conditions it is still not clear why image-schemas would be relevant to this discrimination as image-schemas consist only of abstracted perceptual features [Mounoud, 1995]. Thus, perceptual schemes, or a more complex organization consisting of coordinated action schemes, account more parsimoniously for these findings. Such an alternative interpretation gains further support from the fact that in the described experiments perceptual and manual interaction with different objects remained tied to the immediate situation. Infants were not required to generate some kind of image in order to evoke objects that were absent from their immediate perceptual field. Rather, they had to discriminate objects that were presented either successively or simultaneously.

The fourth interpretive problem is that the methods of concept assessment employed by Mandler et al. [1991] and Mandler and McDonough [1993] do not permit the conclusion that infants relate different objects from one category to each other because infants in these studies merely successively visually explore and touch only one object at a time. When infants successively identify objects that share a salient property (e.g., self-movement), their behavior does not imply that they compare and relate objects from the same class to each other. Their behavior implies only that they discriminate between those objects having a specific property and those objects not having that property. 'Recognizing individual items as x does not amount to an awareness that several things exist that are the *same*. Identifying x is not the same as explicitly equating x with some x_1. These are concepts of different logical types' [Sugarman, 1982, p. 86]. Recognizing individual items as x on the basis of some property does not imply that infants grasp the relation existing between their classificatory actions. Each action might as well exist independently of the other, and the stimuli be unrelated to each other. Thus, Mandler's conclusions go significantly beyond the available data and the precise cognitive basis of the infants' performance in these experiments still needs to be determined.

How might these findings be more adequately interpreted? In the following, we offer the earlier sketched action-theoretical alternative, and briefly outline the implications of this alternative for the course of early concept development. Our proposal differs markedly from Mandler's in the following three respects. First, whereas Mandler defines a concept in an atomistic fashion as a sort of thing an object is 'above and beyond what it looks like' [Mandler, 1992b, p. 274], we consider concepts to constitute an interdependent organizational network of schemes [Gillett, 1992; Piaget, 1961/1966; Woodfield, 1987]. Consequently, classificatory actions are not solely a function of a particular object but are also determined by the degree of articulation (i.e., the level of coordination and differentiation) of the whole network of concepts. Second, whereas Mandler denies that sensorimotor actions play a role in conceptual development, we propose that sensorimotor actions produce interrelated networks of schemes that confer practical meaning to objects. An object is indeed more than what it looks like; it is also what can be done with it. These practical meanings are then expressed on the representational plane of knowing through differentiated signifiers [see also Mounoud, 1995]. Third, in contrast to Mandler, we do not believe that the generation of special code can adequately account for conceptual development. Rather, concepts – regardless of whether they are located on the sensorimotor or representational plane of functioning – always entail mental acts that unite a specific content and a logical form [Piaget, 1936/1963]. We argue that change in the operative organization of these mental acts accounts for conceptual development. Accordingly, in addressing infant and toddler conceptual development, we will distinguish between operational knowing at the sensorimotor level (first- and second-order practical operations), and operational knowing at the representational level (first- and second-order representational operations). Second-order representational operations correspond to the Piagetian notion of concrete operations.

Infants begin psychological life with sensorimotor schemes, including perceptual schemes, which are deployed in the pursuit of practical goals. A scheme is an active mental organization which, by assimilating environmental objects, endows these objects with meaning [Mounoud, 1995]. In a way, each scheme can be said to entail an informal rule that determines its range of application. By integrating different objects into the same scheme, these objects are experienced and treated as equivalent. Practical, sensorimotor concepts thus allow the identification of objects on the basis of intensive properties by assimilating these objects to habitual schemes [Inhelder and Piaget, 1959/1969, p. 13; Sugarman, 1983]. Piaget termed this type of identification *schematic membership relation* [Inhelder and Piaget, 1959/1969, p. 9], and suggested that it is present from early infancy on [Piaget, 1936/1963].

Perceptual categorization and recognition are actions that function on the basis of schematic membership relations [Inhelder and Piaget, 1959/1969]. From early on, infants are conscious of the content being perceptually categorized or recognized, although the experience of familiarity does not necessarily accompany recognition [Hacker, 1991; Piaget, 1937/1954, p. 6]. Because the content of perceptual categorization is conscious, Piagetian theory has no problems accounting for Mandler and McDonough's [1993] study, particularly when the above-mentioned problems of Mandler's interpretation are taken into consideration. The assimilation of different objects to habitual schemes is also evidenced in habituation to familiar objects, and in sequential touching of different objects that belong to the same concept [Mandler et al., 1991; Sinclair et al., 1989; Sugarman, 1983]. These behaviors do not permit the conclusion that infants understand the relationship between the different objects, or the relationship between the objects and the concept that subsumes them. In sequential touching, for example, infants might just select what stands out [Sugarman, 1983].

The process of coordination and differentiation of sensorimotor schemes through action results in the detachment of schemes from any object and to the construction of increasingly complex relations between objects. As a result, around the end of the 1st year of life infants become capable of spatially grouping together objects that belong to a single type [Langer, 1980, 1986; Sugarman, 1983]. Composition of single sets through the use of what we call *first-order practical operations* already requires that infants establish similarity relations between objects on the basis of their perceptual or functional properties through reiterating the same scheme [Sugarman, 1983]. For example, infants generate a single set by reiterating the scheme of putting several spoons next to each other. It is likely that first-order practical operations are involved in the extension of familiar action schemes (sleeping, drinking) to appropriate but not to inappropriate objects [Mandler and McDonough, 1996] because, to selectively limit the extension of an action scheme, the infant must be capable of constructing a relationship between two immediately given objects. Mandler and McDonough's [1996] findings also provide evidence for the social coordination of schemes as infants in their study began to use the schemes in a conventional way [see also Langer, 1986; Sinclair et al., 1989; see Piaget, 1965/1995, on the critical importance of social interaction for concept development].

Further conceptual development involves the successive grouping of objects into two different groups (e.g., first putting all dolls into one set, and then putting all cars into the other set). This demands a flexible shift from one similarity relation to a second similarity relation. Whereas earlier the same scheme was reiteratively applied to a number of objects, now the reiteration of the scheme itself is becoming recursive because objects are first evaluated against one, then against another scheme. Children thus start to coordinate their practical first-order operations [Langer, 1986]. During the 2nd year of life, and into the 3rd year, children recursively shift between groups when they construct two groups [Langer, 1986; Sugarman, 1983]. Their advanced sorting behavior suggests that they now consider two bases of comparison at once, thereby constructing relations on relations, or what we call *second-order practical operations*. However, these comparisons are confined to the immediate spatial-temporal surrounding, and are still made on a step-by-step basis, i.e., inductively [Sugarman, 1983], precisely because children's operative activity has not yet been transferred to the representational plane.

Conceptual development moves to the representational plane with the emergence of differentiated signifiers that extend the range of concepts beyond the immediate here and now. The subsequent progress of conceptual development on the representational plane is closely related to the development of the operative aspect of intelligence. Initially, due to the fact that the signifier (e.g., word) is believed to be an attribute of the object signified [Piaget, 1945/1962; Vygotsky, 1934/1962], children's concepts remain intermediate between the individual and the general. Piaget [1945/1962, p. 221, p. 228] calls such concepts 'prototypes' or 'preconcepts'. For example, children on this level are not able to distinguish between numerical identity and equivalence when they encounter two similar objects at different points in time [Piaget, 1937/1954, Obs. 51; Piaget, 1945/1962, Obs. 106, 107; Stern, 1914/1930, pp. 391–399]. Conceptual development on the representational plane proceeds with the construction of *first-order representational operations* [or functions, see Piaget et al., 1968/1977]. First-order representational operations limit children to one-way mappings of relations which allow them to establish coproperties [Piaget et al., 1968/1977], to construct numerical identities [Piaget, 1968], or to differentiate between numerical identity and equivalence. For example, in order to differentiate between numerical identity and equivalence, children must compare the intensive features of objects that are encountered in temporally, and sometimes even spatially, different contexts, and they must establish a conceptual relationship across these different encounters. In the same manner, correct judgment about the truth or falsity of a true negative sentence ['this is not an apple' when shown a picture of a banana, see Kim, 1985] demands establishing a conceptual relationship of *banana* to *apple* while transforming the concept of banana.

The coordination of many-to-one and one-to-many correspondences through *second-order representational operations* is a prerequisite for constructing hierarchical relationships between concepts and this gives rise to the understanding that different objects can be subsumed under the same concept (F_a, F_b, F_c, F_d, etc., where F stands for a predicate, a, b, c, d stand for different objects), and that the same object can be subsumed, on the basis of its various qualitative features, under different concepts [F_a, G_a, H_a, etc.; see Kesselring, 1981]. As a consequence, children realize that the general concept is of a higher order than its individual members and succeed in tasks that require them to make a quantitative comparison between superordinate concept or class and the subordinate concept or subclass [Chapman and McBride, 1992; Inhelder and Piaget, 1959/1969; Smith, 1993]. Quantitative comparisons between superordinate and subordinate class involve a simultaneous conservation of both classes and the coordination of intension and extension of both classes. The understanding of class inclusion is, therefore, an indicator for the understanding of hierarchical relationships between concepts.

In this section, we have reviewed Mandler's studies of concept development. We suggested explanations of her research findings that do not invoke mental representation. In addition, we have outlined a course of concept development that differs from Mandler's framework in several respects. As opposed to Mandler's approach, ours does not heavily weigh the manner in which concepts are stored. Concepts are not inner pictures, image-schemas, replicas or spatial analogues of external bits of reality. They are not free-floating entities hovering in front of the mind's eye. Rather, concepts constitute an interdependent organizational network of schemes and are used in acts of judgment [Kant, 1787/1929, B 93]. Independently of their use, concepts constitute only potential knowledge; full knowledge is constituted by the application of concepts to the world [Judge, 1985, pp. 55–67]. The users' intentions and the cognitive organization underlying their acts of judgement, and not some special code, determine the use to which concepts are put.

Object Permanence and Causality in Very Young Infants

To support her position that sensorimotor processes are not a prerequisite for mental representation, Mandler [1988, 1992a, 1998] points to Baillargeon's studies on object permanence and Leslie's studies on infants' comprehension of causality. According to Mandler, the works of both Baillargeon and Leslie demonstrate that mental representations are already present in very young infants. In this section, we will first present and discuss Baillargeon's research exploring object permanence, followed by Leslie's studies of causality. Again, we will argue that these findings do not necessitate invoking mental representation as an explanation, and that an action-based explanation of the findings is a parsimonious and reasonable alternative.

In a series of experiments, Baillargeon [1986, 1987; Baillargeon et al., 1985; see Baillargeon, 1993, 1994a, 1994b, for summaries] investigated infants' physical knowledge and their knowledge of object permanence. A study reported in 1987 will be used as an exemplar of this work. In this study, 3½- and 4½-month-old infants viewed a screen rotate back and forth through an arc of 180°. Following habituation to this event, a solid box was placed behind the screen and the infants were shown a possible and an impossible test event. For the possible event, the screen ended its rotation after reaching a 112° position (i.e., the rotation ended exactly where it would have been stopped by the box placed behind the screen). For the impossible event, the screen completed a 180° rotation, and would thus have passed through the box. Most 4½-month-olds and some 3½-month-olds ('fast habituators') looked reliably longer at the impossible than at the possible event. Baillargeon interpreted these findings as indicating that the infants '(a) represented the existence of the box behind the screen; (b) understood that the screen could not rotate through the space occupied by the box, and hence (c) expected the screen to stop and were surprised in the impossible event that it did not' [Baillargeon, 1993, p. 271]. Baillargeon concluded that 'young infants are able to represent the existence and the location of hidden objects and to reason about these objects in sophisticated, adult-like ways' [p. 294].

Several authors have criticized Baillargeon's interpretations of these studies, her principle-based approach which aims at demonstrating either the absence or presence of a particular competence without contextualizing performance within a developmental sequence, and her failure to supply any processes that underlie infants' sophisticated reasoning capacities [Bogartz et al., 1997; Fischer and Bidell, 1991; Gouin-Décarie and Ricard, 1996; Montangero, 1991; Munakata, in press; Munakata et al., 1995; Siegler, 1993; Thelen and Smith, 1994]. In the following discussion of Baillargeon's findings, we first point to two methodological problems of Baillargeon's study, and then we focus on her explanation of why infants ostensibly display object permanence in the visual habituation paradigm, but not in manual search tasks.

There are two methodological problems associated with Baillargeon's [1987] use of the habituation paradigm. First, Baillargeon did not record how infants' looking time is distributed within each trial. A trial in Baillargeon's study ended when an infant either looked away for 2 consecutive seconds after having looked at the display for at least 5 cumulative seconds, or having looked at the display for 60 cumulative seconds without looking away for 2 consecutive seconds (1987, p. 658). Thus, a trial consisted maximally of six 10-second cycles in the impossible event. In both the possible and the impossible condition, the event remains possible until the screen passes 112° arc (i.e., after 4 s). Until then, infants, in contrast to the experimenter, do not know whether they will see a possible or an impossible event. It is, therefore, of critical importance to inspect how the looking time is distributed within each cycle. If one does not want to attribute clairvoyance to the infants, only the last 6 s of each cycle constitute a valid measure of surprise [given the results reported in Baillargeon, 1993, pp. 278–279, the time interval constituting a valid measure should even be shorter]. Baillargeon, however, does not separate the looking times within the different parts of each cycle. Thus, Baillargeon's dependent measure (overall looking time) lacks construct validity as it includes both the portion of the event which is surprising, and the portion of the event which is not surprising [the same confound also exists in Baillargeon et al., 1985, and in Baillargeon, 1987, where only the last 1–2 s of each 10-second cycle determined whether the event was possible or not].

Second, the two events in Baillargeon's [1987] study differ in ways not restricted to simply their possibility or impossibility. These several other potential factors are confounded with the possibility-impossibility, and these may account for the looking time difference. For example, the impossible event may have led to longer looking time than the possible event because it offered 'a greater number of interesting visual opportunities (i.e., successively: yellow box, rotating screen, striped back wall, and eventually yellow box again)' [Montangero, 1991, p. 115]. Another confounding factor is the rotation of the screen: the 180° rotation affords longer looking time or may be more interesting for infants. Wakeley and Rivera's [1997] finding that infants looked longer at a 180° than a 112° rotation regardless of whether a box was behind the screen or not is consistent with this explanation [see Montangero, 1991, and Wakeley and Rivera, 1997, for a discussion of further confounding factors]. Unconfounding these variables requires more rigorous experimental designs than the one used by Baillargeon. The recent work by Bogartz et al. [1997] using such designs strongly suggests that confounding variables rather than possibility-impossibility to indeed account for looking time differences.

Beyond these methodological concerns, Baillargeon's proffered explanation for why infants display object permanence in the visual habituation paradigm, but not in manual search tasks, leads to difficulties in the interpretation of her findings. Baillargeon [1993] adopted the habituation paradigm because, in her view, an inability to plan means-ends relations, and not an underdeveloped object concept, is responsible for infants' poor performance in manual search tasks. Baillargeon suggested that infants' inability to plan means-ends coordinations is due to their lack of subgoaling activity [Baillargeon, 1993, p. 300; means-ends relations are by definition subgoaling activities, see Piaget, 1936/1963, pp. 147–152; Piaget, 1954/1981]. For Baillargeon, support for this suggestion comes from the fact that infants search under conditions in which they do not have to coordinate two separate actions to grasp an object [Clifton et al., 1991; Hood and Willats, 1986].[1]

A central problem with Baillargeon's [1986] rationale is that even if her interpretation of the findings was generally acceptable – and we, of course, argue that it is not – it ignores the fact that in her own research infants also must understand means-ends relations in order to dishabituate to the impossible event. The block placed on the track is a *means* to stop the car [Baillargeon, 1986]. The block placed behind the screen is a *means* to stop the screen [Baillargeon, 1987]. Thus, at this point we are left with a mystery as to the differential performance in habituation tasks and manual search tasks.

[1] The fact that 5-month-olds reach for objects in the dark (i.e., for objects they have seen before the light was switched off) is sometimes interpreted as evidence for the presence of the object concept [e.g., Perner, 1991]. This interpretation cannot be substantiated from a Piagetian perspective. Object permanence is evidenced in tasks demanding the coordination of objects. Because darkness is not an object, reaching in the dark by no means contradicts Piaget's theory [Kesselring, 1993].

Reaching in the dark as demonstrated in experiments by Clifton et al. [1991] and Hood and Willats [1986] does not indicate the presence of active search behavior (sensorimotor stage IV). In Clifton et al.'s [1991] experiment, the objects presented in the dark were manipulated to provide infants with auditory stimuli. The auditory stimuli served as an indicator, analogous to the visible part of a semihidden object [object permanence stage III; see also Bigelow, 1992]. In Hood and Willats' [1986] experiment, infants reached equally as often in trials in which an object was presented before the light was switched off as in trials in which no object was presented before the light was switched off. Furthermore, the first reach in the object trials was directed equally as often towards the target region as towards the nontarget region [Munakata, in press, comes to a similar conclusion].

Further, other visual habituation studies have demonstrated that means-ends relations that are independent of the infant's action are not understood before 6 months of age [Oakes and Cohen, 1995] (but see below for problems concerning the interpretive value of the visual habituation paradigm for the assessment of causality). It cannot be taken for granted, therefore, that the infants in Baillargeon's experiments had acquired the prerequisites to understand the relations inherent in her experimental paradigm. This, of course, raises the puzzling question of how her results can be explained. A finding by Munakata et al. [1995] adds to the puzzle. Munakata et al. found that 7-month-olds who were trained to solve means-ends relations subsequently retrieved objects that remained visible but failed to retrieve objects that were occluded in tasks in which the means-ends demands were equated.

The solution to the puzzle lies in the recognition (a) that Baillargeon's visual habituation paradigm assesses only a primitive perceptual precursor of the mature object concept rather than the mature object concept itself, and (b) the visual habituation paradigm does not involve the understanding of means-ends relations. We, thus, suggest that it is not the case that young infants are able 'to represent the existence and the location of hidden objects and to reason about these objects in sophisticated, adult-like ways'. Rather, young infants do not represent the existence and location of hidden objects; they merely develop a perceptual precursor of this competence. The argument leading to this conclusion is based on Kant's [1787/1929, B 236] conceptual distinction between objective and subjective successions. Perceptions always follow each other in a sequence; the problem is to determine whether the subjective succession corresponds to any objective succession. For example, when we are perceiving a house, the perceptions of the house are successive, but there is no objective succession. Thus, in this example the subjective succession is not correlated with an objective succession [Kant, 1787/1929, B 236; see Beck, 1976]. Following Kant, Piaget [1937/1954] distinguishes between a sequence of perception (subjective succession) and the perception of a sequence (objective succession). Piaget argued that, during the first two sensorimotor stages, the perception of sequences is not yet differentiated from perceptual actions:

> All that we say is that there are not yet concepts of time applying to external phenomena nor is there a temporal field encompassing the development of events in themselves independently of personal action .... time begins as simple duration immanent in the practical series before it is established as an instrument of ordination interconnecting external events with the subject's acts [pp. 325–326].

Piaget [1937/1954, pp. 322–326] called this series a practical series: one perception signals and leads to the anticipation of another perception. Practical series, therefore, result both in perceptual expectation [see Haith, 1993], and the temporal organization of perceptions in time [see Arterberry et al., 1993; Kellman, 1993].

Whereas in a practical series (a sequence of perceptions) one perception follows the other ($R_1 \rightarrow R_2$, etc.), the perception of a sequence requires that infants reconstruct, given only the sight of a certain object (R), the causal condition (C) that led to an interesting event (subjective series, $C \rightarrow R$) [Piaget, 1937/1954, p. 323]. The reconstruction of the cause given only the effect involves a reversal of consciousness [Piaget, 1936/1963, p. 148]. Rather than following the sequence of their perceptions, infants must transcend their visual field and reverse a temporal sequence, which is Piaget's criterion for the emergence of the competence to understand that temporal sequences are independent of the sequence of personal actions [Piaget, 1937/1954, p. 324].

Given these distinctions, it is reasonable to argue that Baillargeon's experimental habituation paradigm assesses only a sequence of perceptions, not the perception of a sequence. In this research, the infant's visual perceptions must follow the movement of the screen. On the basis of previously formed visual schemes about disappearing objects, infants generalize to the movement trajectory of the screen, and expect the screen to stop its movement when it reaches the object [Montangero, 1991; Munakata, in press; Russell, 1978, 1995]. Infants, therefore, anticipate – based on their visual schemes – a sequence of visual perceptions ($R_1 \rightarrow R_2$, etc.). When their visual expectation is violated, they start to dishabituate. By basing infants' dishabituation on visual expectations, it can also be explained why infants habituate to impossible events [Baillargeon, 1986, experiments 1 and 2; Bogartz et al., 1997]: the impossible event is, across trials, perceived by infants to be the regular course of events, and no longer as something unusual.

Following this line of argument, infants at the ages tested by Baillargeon [1987] dishabituate without being capable of perceiving a sequence, and this explains why they fail in manual search tasks. A fortiori, infants in this research do not have to understand means-ends relations to dishabituate because the paradigm measures only whether infants' perceptions are organized in a temporal sequence ($R_1 \rightarrow R_2$, etc.). However, for logical reasons, the understanding of means-ends relations presupposes the competence to understand temporal sequences. This is because the construction of means-ends relations becomes possible when, and only when, the subject develops the ability to arrange in a temporal series events that can be conceived of as being independent of personal actions [Piaget, 1937/1954, pp. 335–338].

To put this differently, in comparison to manual search tasks, the visual habituation paradigm assesses a qualitatively different and cognitively less mature stage in the development of object permanence. In the visual habituation paradigm, infants must pick up perceptual cues within their visual field but they are not required to utilize their visual field. Within the visual system, an organized system of meanings is already elaborated during the first two sensorimotor stages [Piaget, 1936/1963]. However, as long as the visual schemes have not been coordinated with the grasping schemes, any visual scheme receives its meaning only in relation to other visual schemes, and the visual schemes are not yet detached from the objects to which they are applied. As a consequence, visual experience has not yet become differentiated from the subject's action, and is considered to be an extension of the action. This is the reason why infants do not actively search for vanished objects but expect the object to reappear at the place where it disappeared [Piaget, 1937/1954, pp. 4–13]. With the coordination of visual and grasping schemes, infants transcend 'the absolutely immediate' [Piaget, 1937/1954, p. 7], and differentiate between their personal actions and the sequence of events (i.e., they differentiate the perception of a sequence from the sequence of perceptions). As a result, they become capable of utilizing their visual field in pursuit of more complex goals:

> In so far as the organization of the visual schemata forms a more or less closed totality, vision constitutes a value in itself and the assimilation of things is an assimilation to vision itself. On the other hand, in so far as the visual universe is coordinated to the other universes – that is to say, where there is reciprocal organization and adaptation between the visual and other schemata – visual assimilation becomes a simple means at the service of higher ends [Piaget, 1936/1963, p. 76].

From this point on, rather than being trapped in their visual field, infants control their visual field through higher-order coordinations. Infants then enrich the visual field with meanings provided by an increasingly complex network of sensorimotor schemes. Visual perception then becomes relegated to providing indicators on which other schemes confer meaning [Piaget, 1936/1963, p. 190, p. 212; von Uexküll, 1926, p. 150]. This progress is reflected in the transition from the practical to the subjective and, at Piaget's sensorimotor stage IV, to the objective temporal series [i.e., first-order practical operations; for a detailed analysis of the development of object permanence in terms of first- and second-order practical operations see Müller et al., in press]. For example, given an interesting effect in the visual field at $time_1$, infants at this level can reconstruct the cause of this effect at $time_2$ and, given the occlusion of an object by a screen at $time_1$, can remove the screen and retrieve the object at $time_2$ [see Russell, 1987, pp. 100–103]. The removal of a screen to retrieve an object demonstrates true search because (a) this search is active, and (b) it involves new movements (removal of screen) that are intermediate between subject and object and do not simply extend the prior action [Piaget, 1937/1954, pp. 11, 35]. The action of removing the screen signals that the immediacy between action and perception has been broken, because infants must momentarily give up their attempt at direct prehension [Piaget, 1937/1954, p. 36].

Thus, contrary to Baillargeon's [1993] assertions, the infant's ability to construct means-end relations is not accidental to the assessment of the object concept. Rather, means-ends coordinations (i.e., first-order practical operations) indicate the utilization of the visual field and advance the construction of the object concept. The claim that qualitatively different processes underlie visual habituation tasks and manual search tasks gains further support from neurophysiological findings and connectionist modelling [Munakata, in press; Munakata et al., 1995].

In summary, on neither methodological nor conceptual grounds does Baillargeon's research lead to the conclusion that young infants possess representational abilities. Even if methodological problems of the study are left aside, the results can be reasonably explained from an action-theoretical perspective. As a consequence, Baillargeon's research offers no support for Mandler's contention that representation and image-schemas develop independently of sensorimotor actions.

In order to further develop the argument between sensorimotor action and representation, we now turn to Leslie's [1982, 1984; Leslie and Keeble, 1987] studies on infants' understanding of causality, which Mandler [1992a, pp. 595–596] cites as further support of image-schema theory. A brief presentation of the basic paradigm of Leslie's studies will be followed by a critical discussion of Leslie's and Mandler's claim that causality originates in visual perception. We will argue that both Leslie and Mandler fail to specify the critical features that differentiate the concept of causality from visual concepts, and fail to explain how causality comes to be attributed to external events. We will then demonstrate how an action-theoretical approach to the development of causality resolves these problems. Finally, we will provide an alternative explanation of Leslie's findings.

Leslie's research employed an event methodology similar to that earlier used by Michotte [1946/1963] in his classical studies of causality. For example, one object (A) begins moving toward another object (B). Upon being it, the second object (B) begins to move. As long as the movement pattern of the two objects displays specific spatiotemporal properties, adults describe these events as causal events. Leslie used a dishabituation paradigm and found that 6-month-old infants distinguish between those movement patterns that adults described as causal, and those that adults did not describe as causal [for methodological problems of Leslie's experiments see Oakes and Cohen, 1990, 1995; White, 1995]. Leslie [1982, 1984; Leslie and Keeble, 1987] claims that the dishabituation patterns demonstrate that infants are able to perceive causal relationships between events – events that are independent of the infants' actions – at an age much younger than that predicted by Piagetian theory.

Leslie and Keeble [1987] argue that an *innate* visual perceptual module accounts for the infant's understanding of causality. Mandler [1992a, pp. 595–596], on the other hand, claims that an *acquired* image-schema (a vector toward an object A, with another vector leaving A, both vectors are spatiotemporally related) underlies causal understanding. According to Mandler, this image-schema results from the redescription of spatial structure through perceptual analysis. In addition, Mandler [1992a] maintains that Leslie's findings contradict Piaget's theory of causality:

> According to Piaget (1954), psychological causation, or the awareness of one's own intention or efforts to make something happen, is the basis on which later understanding of physical causality rests .... However, both Leslie's (1982, 1984) data and an approach to concept formation in terms of redescription of spatial structure suggest that the ontogenetic ordering may be the other way round ... The experience of intention or volition may not be required to form an initial conception of causality. Indeed, internal states are notoriously difficult to conceptualize [p. 596].

The derivation of the concept of causality from visual mechanisms encounters two conceptual problems. First, because the direct perception of the transmission of movement is impossible, such proposals must detail the visual information that specifies causality. Leslie and Mandler, however, fall short of specifying the information that differentiates causal from spatiotemporal events. Keeble and Leslie [1987, p. 283], on the one hand, admit 'we are not, at this stage, able to say what the crucial information for the causal factor in the event was though the continuity relation is suggestive here' [for a criticism see Oakes and Cohen, 1995, pp. 28–34]. Continuity, however, is a spatiotemporal quality of events and does not explain the specific difference between visual qualities and causality. Mandler [1992a, p. 595], on the other hand, derives causality from spatiotemporal contiguity. Although spatiotemporal contiguity is an important factor in the creation of the impression of causality, causality is not reducible to spatiotemporal contiguity [Hume, 1739/1967]. Causality is simply not a visual quality in the same way as, for example, 'continuity' or 'redness' are visual qualities [Hamlyn, 1957; König, 1978]. Rather, causality is a productive or generative relationship between events [Oakes and Cohen, 1995].

The second problem of a theory of causality that derives causality solely from visual mechanisms is to explain how infants come to attribute causality to external events [Russell, 1995, 1996]. In this context, the problem of differentiating between a sequence of perceptions (subjective succession) and the perception of a sequence (objective succession) is again important. Without such a differentiation infants would be incapable of knowing whether a subjective succession corresponds to an objective succession, and perceptual experiences would amount to nothing but a 'blind play of representations – less even than a dream' [Kant, 1787/1929, A 112]. Mere visual perception, however, leaves the objectivity of the successive experiences indeterminate because visual perceptions always follow each other in a sequence, and visual perceptions in and of themselves do not allow a differentiation between a sequence of perception and the perception of a sequence.

An action approach on the other hand suggests a viable solution to these conceptual problems. Contrary to Mandler's interpretation of Piaget's theory, Piaget does not derive causality from infants' analyses of their own mental states. In fact, Piaget [1937/1954, p. 226] considers such a view as 'unpsychological'. Rather, Piaget [p. 313] holds that *practical concepts* of causality are constructed through sensorimotor actions that establish increasingly complex relationships between personal actions and the external world. These relationships have an internal and an external pole: the feeling of efficacy and phenomenalism, respectively [p. 220]. The feeling of efficacy which consists of muscular sensations that accompany personal action supplies the generative relationship characteristic of causality [see Scheerer, 1987, for a historical review of approaches to derive the impression of causality from the muscle sense]. The external pole of this relation, phenomenalism, stands for whatever the infant perceives. Initially, these two poles are not differentiated, and elementary causality lacks 'both physical spatiality and the feeling of a self acting as internal cause' [Piaget, 1937/1954, p. 220]. The perceived qualities are not yet detached from the action itself and, as a consequence, infants experience complex aggregates in which tactile, visual, gustatory, and auditory sensations are intermingled with sensations of desire, effort, and expectation.

> The universe of the first stages would therefore be a collection of centers of creation or reproduction in which the child localizes his own impressions of effort and activity, but one cannot say that he conceives of these centers as either external or internal to himself [Piaget, 1937/1954, p. 228].

The basic problem then becomes how efficacy becomes externalized, objectified, and spatialized by being transferred to objects independent of the infant's activities. Piaget [1961/1969b, pp. 234–243; see also Baldwin, 1995] suggests that impressions of resistance that arise whenever goal-directed actions such as pushing or grasping are applied to objects are a prerequisite for the externalization of causality. The assimilation of visual schemes to tactilo-kinesthetic schemes [involving proprioception, see O'Shaughnessy, 1995; Scheerer, 1987] then explains why perceptual experiences can give rise to impressions of external causality. The coordination of visual schemes with other action schemes is also necessary to break the immediacy of visual experience. By coordinating visual schemes with other action schemes as, for example, grasping or kicking, visual qualities become gradually detached from the action itself. Moreover, by applying secondary action schemes to two objects – which is a prerequisite for the development of first-order practical operations – infants construct the temporal concepts of *before* and *after*, which initiate the differentiation of a perception of a sequence from the sequence of perceptions [Piaget, 1937/1954, pp. 329–330]. For example, when infants search for a string and then pull it in order to reproduce the shaking of a rattle attached to the string, their actions indicate that they begin to understand that the cause precedes the effect [see Chapman, 1988, p. 113]. Importantly, infants need some sort of material in order to objectify the temporal seriation of their action schemes [Müller et al., in press]. It becomes clear that, in contrast to Leslie's and Mandler's approaches, an action approach derives causality from infants' embodied, practical interactions with the world. The differentiation and coordination of sensorimotor schemes that result from the infant's embodied interactions lead to the gradual differentiation between the internal and external poles of causality.

How, then, should the results from Leslie's experiments be explained? Michotte's [1946/1963] conclusion that adults perceived certain movement patterns as causal was based on subjects' verbal descriptions of the event. Thus, adults not only distinguished between events on the basis of their respective spatiotemporal patterns but, in addition, attributed causality to events with specific spatiotemporal patterns. The fact that adults *describe* certain visual events as causal does not imply that infants who *dishabituate* to these events perceive these events as causal. Therefore, one interpretation of Leslie's observations, provided by Leslie [1982] himself, is that his findings show that infants are able to discriminate between events that display different spatiotemporal patterns. That is, based on their visual experiences, infants would thus discriminate events that adults describe as causal from events that adults describe as noncausal on the basis of purely visual qualities without attributing causality to the former events. According to this interpretation, the infant's expectation would involve a 'mere linking of signifier to signified, based upon the concept of ... indication and not at all on that of causality' [Piaget, 1937/1954, p. 242].

To decide on whether infants understand causal events that are independent of themselves, it is necessary to analyze their means-end behavior [Piaget, 1937/1954, pp. 243–249]. The use of intermediaries (remove screen to recover a toy hidden behind the screen), for example, provides clear evidence that causality has been spatialized and objectified, and subjective and objective succession have become differentiated from each other. Leslie's experiments do not take the entire range of infant sensorimotor actions into consideration. His research findings alone cannot answer the question of whether the infant's dishabituation was based on an understanding of causality or on noncausal visual qualities. Consequently, his findings are inherently ambiguous. Furthermore, on the basis of the conceptual problems for approaches that derive causality from visual mechanisms and mental images, it appears more likely that an understanding of causality develops from the entire range of sensorimotor actions, including vision.

In light of the related distinctions between (a) sequence of perceptions and perception of sequences, and (b) organization inside visual schemes and organization resulting from the coordination of visual schemes with other schemes, looking-time paradigms [e.g., Baillargeon, 1986; Spelke et al., 1992; Leslie, 1982, 1984; Leslie and Keeble, 1987] have severe limitations when used as tools for the assessment of cognitive development because they do not allow one to decide on the kind of cognitive organization that underlies the looking-time difference. Looking-time paradigms simply do not permit strong inferences about the nature of the cognitive organization that is potentially reflected in looking-time differences. The same difference can indicate that certain events are unexpected for infants on a purely visual plane, or it can indicate that the percept has already been differentiated from the subject's action and objectified. What empirical methodology can we employ to facilitate the choice between these alternatives? Piaget has suggested that the decision requires a careful consideration of the entire evolution of a particular concept: 'The ground for interpretations relating to the point of departure of a concept can only be shown a posteriori by the probability of the explanation based on the total evolution of that concept' [Piaget, 1937/1954, p. 221]. This methodological approach is often called 'inference to the best explanation' [Overton, 1998]. It entails generating the most coherent explanation possible, given all available evidence (i.e., both observational and conceptual evidence). In the present case, this methodology is particularly important in avoiding the confounding of the point of view of the infant's consciousness and the point of view of the adult observer [Montangero, 1991]. Given that the theory being constructed is a theory about the infant, the best explanation must be about the infant's consciousness, not the adult's. For example, from the adult's perspective, infants' behavior suggests various practical spatial groups [e.g., postural and kinesthetic space; see Piaget, 1937/1954, pp. 101–113]. However, when these behaviors are placed within a developmental sequence and analyzed from the point of view of the infant's consciousness, it becomes unlikely that infants are aware of the spatial groups they are using:

> Action creates space but is not yet situated in it... the observer locates the subject as well as the objects in a single space and describes the movements of object and subject in relation to each other. If from this point of view external to the action one moves to that of the subject himself, things change entirely [Piaget, 1937/1954, pp. 104–105].

To build a theory of development that is about the infant's point of view of the world, it is necessary to articulate the most reasonable cognitive organization that underlies the infant's behavior. This organization can only be identified retrospectively, by interpreting any behavior in the context of the development of the concept under consideration. Thus, the contextualization of behaviors within a developmental sequence serves as a safeguard against the unwarranted ascription of competencies to infants from solely the adult observer's point of view, without considering the point of view of infant consciousness.

Meltzoff on Deferred Imitation and Recall

We have suggested that neither Mandler's research on concepts, nor Baillargeon's studies on object permanence, nor Leslie's studies on infants' comprehension of causality supports Mandler's claim that empirical findings provide evidence for the presence of representations in young infants. Meltzoff's studies on deferred imitation are cited by Mandler [1988, p. 123] as another source of evidence for representations in very young infants. In two studies, Meltzoff [1988a] examined immediate (study 1) and deferred (study 2) imitation in 9-month-olds. In each study, Meltzoff used one imitation group and three control groups. The infants in the imitation group viewed a model applying 3 simple actions to toys that were novel to them. For example, they observed a model shaking a plastic egg that made a rattling noise. Infants in the baseline control group did not observe modeled actions. The baseline control group was introduced to establish the probability that infants would produce the target actions spontaneously. In the adult-touching control group, the model approached and touched each toy but did not model the target actions. In the adult-manipulation control group the model manipulated the toy and produced the same consequences (e.g., noise) as in the imitation group, but did not produce the target actions. The latter two groups were introduced to control for the possibility that infants would produce the target action either because they were aroused by the adult approaching the toys, or because they heard the consequences of the model's manipulations.

Meltzoff [1988a] found that infants in the imitation group reproduced significantly more target actions than the three control groups combined both when the toys were handed to the infants immediately after the modelling period (study 1), and when the infants were given the objects 24 h later (study 2). Meltzoff interprets these findings as demonstrating that deferred imitation is already present in 9-month-old infants, a claim which would contradict Piaget's claims that deferred imitation emerges not until the 2nd year of life. Furthermore, Meltzoff [1990; see also Mandler, 1992a] maintains that his findings provide evidence for the presence of recall memory based on representations in 9-month-olds.

At issue here is the assumption that deferred imitation implies mental images and is thus a valid indicator for recall memory on the representational plane. Contrary to Meltzoff, Mandler, and Piaget [1945/1962, p. 70], we argue that deferred imitation provides evidence for observational learning but not for mental images or for consciousness of the past. We will first explain why deferred imitation does not imply mental images, and then provide a brief outline of memory development considered within the framework of the general action-theoretical proposal suggested in this paper.

Following Koffka [1921/1963], it is possible to distinguish between two types of imitation: (a) imitation of target actions that are already in the repertoire of an individual, and (b) imitation of target actions that involve either the extension of a familiar action scheme to new objects or completely new action schemes. Examples of the former type of imitation are instinctive imitation (contagion) such as the repetition of a bird's warning cry by other birds, or imitation of acquired actions such as the involuntary repetition of a melody one once heard [p. 307]. An example of the latter type of imitation is a child's dusting off a chair after having seen somebody else do so [p. 314]. A necessary condition for the latter but not the former type of imitation is that the target action is understood.

We argue that initial understanding is a necessary feature of both immediate and deferred imitation: once a target action is understood, it can be enacted whenever the proper cues (target object, place, presence of the model) are present. It is not necessary to assume that deferred imitation requires that infants form a mental image or are conscious of having perceived the imitated action in the past. Understanding the target action leads to a modification of the action scheme and memory of the past exists in nothing but the preservation of the modified scheme. Following this line of argument, Meltzoff's findings can be interpreted as follows: Infants assimilated the target action through observational learning, and reproduced it after a 24-hour delay because they recognized the toy and model and assimilated them to the scheme that had been activated earlier. This interpretation receives empirical support from the findings that immediate and deferred imitation performances of assimilable actions do not substantially differ [Abravanel, 1991; Mandler and McDonough, 1995], and that changing some features of the context and of the target object leads to a significant decrease of imitative performance [Barnat et al., 1996]. In conclusion, deferred imitation is more likely to be a measure of memory in the broad sense (preservation of the past as a change of functioning) than a measure of memory in the strict sense [conscious reference to the past; see Lockhart, 1984; Piaget and Inhelder, 1968/1973, and Stern, 1934/1938, for a discussion of the distinction between memory and learning].

Mandler and McDonough [1995] challenge the idea that mental representation might not be involved in deferred imitation. According to them, immediate and, a fortiori, deferred imitation of novel actions cannot be due to sensorimotor learning because sensorimotor learning is strenuous and time-consuming. This challenge can be answered as follows: Sensorimotor learning is a function of both the level of cognitive development during the sensorimotor period and the complexity of the task. In the course of sensorimotor development, learning becomes more flexible and smooth. As a consequence, infants become capable of immediately assimilating novel objects to familiar action schemes in situations in which the modeled action involves only a single scheme and does not require the coordination of different schemes [Piaget, 1945/1962, Obs. 36]. Meltzoff [1988a] used target actions that involve a single scheme (e.g., pushing, shaking). These action schemes are generally in the behavioral repertoire of 9-month-olds [Langer, 1980, p. 32; Piaget, 1936/1963; Uzgiris and Hunt, 1975; the fact that up to 33% of the infants in the baseline control groups in Meltzoff studies produced the target actions also indicates that these schemes were in the infants' repertoires]. Imitation of these modeled actions required infants to generalize a familiar scheme to new objects, which is well within the range of assimilability for infants at the ages tested by Meltzoff [Piaget, 1945/1962]. It is important to point out that familiarity with the modeled action *scheme* but not simply the novelty of either the modeled action or the target object determines whether a model can be imitated. Banging the head on the table is certainly a novel action [Meltzoff, 1988b]. The scheme of banging, however, is highly familiar to infants [Langer, 1980], and only needs to be transferred from one body part to another body part. On the other hand, unfamiliar action schemes such as suspending a toy bear by a string and jiggling it up and down are not imitated [Meltzoff, 1988b].

Mental images are also not necessary for the reconstruction of more complex action sequences that require the coordination of several action schemes [Abravanel et al., 1993; Bauer and Dow, 1994]. To imitate more complex action sequences, infants must understand the relationships between the action schemes being modeled. This understanding depends on infants' coordination capacities, and these belong to the operative rather than to the figurative aspect of knowing. Mental images are representative or figurative items which can only express meaning that has been constructed by the operative aspect of knowing. In addition, mental images alone cannot explain the emergence of a consciousness of the past because mental images must always be in the present. The important question, then, becomes: what type of knowledge organization is necessary to make it possible to use mental images in acts of remembering that refer to the past?

Consistent with our earlier claims, it is more plausible to believe that the development of consciousness of the past depends on the development of the operative aspect of knowing. This proposal provides a reasonable way of running to ground the usual regression that emerges in accounts of memory which dissociate memory development from general cognitive development, and attribute infants' performance failures to memory deficits [Schacter et al., 1986]. Such explanations 'end up explaining why the infant fails to retain perceived information in terms of failures of memory, that is, explaining a failure of memory by saying that it is a failure of memory. The argument is circular' [Russell, 1978, p. 134].

Tulving [1985, 1987] termed mnemonic acts that are accompanied by the consciousness of pastness *episodic memory*. In fact, episodic memory involves the awareness of two temporal modes: a past event is present in the present by being represented as an event that was perceived in the past [Marbach, 1993]. This complex organization of consciousness implies a consciousness of the temporal dimension of one's existence (i.e., a temporal structure or perspective) [Bieri, 1986; Fraisse, 1958/1963; Straus, 1958/1966]. What are the conditions for such a temporal perspective? The following considerations present an outline of these conditions (the influence of social factors on both memory development in general and the development of a temporal horizon in particular cannot adequately be addressed here) [see Halbwachs, 1925/1992, 1950/1980, and Snow, 1990].

First, let us deal with a common misunderstanding concerning the notion of memory traces and reactivation of past impressions [Straus, 1958/1966, 1970]. Traces are not sufficient conditions for a temporal perspective. Physical entities including the brain are subject to causal influences that change them and leave traces behind. For physical entities, however, traces are not memories; they are only states (i.e., results of earlier causal influences). The brain bears traces of past events, but the brain qua brain has no consciousness of the past as past.

> This table bears traces of my past life, for I have carved my initials on it and spilt ink on it. But these traces in themselves do not refer to the past: they are present; and, in so far as I find in them signs of some 'previous' event, it is because I derive my sense of the past from elsewhere, because I carry this particular significance within myself [Merleau-Ponty, 1945/1962, p. 413].

Consequently, simply reducing memory development to the maturation of brain areas, as Diamond [1990] proposes, does not provide an explanation for the emergence of a consciousness of the past [Straus, 1970].

Just as traces in the brain are not sufficient for consciousness of the past as past, neither can the reactivation of some past impressions and perceptions alone provide a consciousness of the past. For example, perceptions are ordered in time, but, as discussed earlier, the sequence of the perceptions is not the same as the perception of a sequence. The perceptions are displayed in the order in which they originated but they are not a representation of a temporal sequence [Piaget, 1937/1954, pp. 323, 325]. The simple reactivation of a past perception does not explain how this perception could refer back to the original perception; who could refer it back; or how a reactivated past perception could be distinguished from a reiterated perception. 'A preserved perception is a perception, it continues to exist, it persists in the present, and it does not open behind us that dimension of escape and absence that we call the past' [Merleau-Ponty, 1945/1962, p. 413]. Reactivating a former impression means experiencing the same feelings again. Remembering having experienced something has a completely different quality because the previous feelings are not reexperienced but cited: remembered frost does not bite, and a remembered steak provides a poor meal [Straus, 1970].

An organism limited to the reactivation of past impressions would be a sensorimotor organism. At the sensorimotor level of functioning, present perceptions are assimilated to sensorimotor schemes that embody the organism's history. These schemes, however, affect the present perception 'only implicitly, through the intermediate of a schema of action' [Piaget, 1945/1962, p. 277]. The schemes may endow the present perception with a feeling of familiarity, and, in this sense, the infant may recognize the present perception [Stern, 1914/1930, p. 110], but memory does not yet extend to events not actually perceived, and there is no conscious reference to the past.

Due to the further development of the practical concept of time during the sensorimotor period, infants become capable of organizing their action into increasingly complex temporal series. Although such a development is a prerequisite for the emergence of conscious reference to the past, the practical concept of time remains tied to the immediate situation, which precludes a conscious reference to the past. A consequence of the development of the practical concept of time consists in the construction of an objective temporal series through first-order practical operations. In the 1st year of life, infants construct subjective temporal series. For example, when infants perceive a rattle which they previously swung by shaking a chain attached to it, they will search for the chain and then pull it [Piaget, 1936/1963, Obs. 98; Rovee-Collier, 1990]. Practical memory at this stage remains linked to infants' actions, and infants do not take successive displacements of objects into account (A-not-B error). The subjective temporal series or subjective memory still dominates the search for the hidden object. With the construction of relations among objects themselves through first-order practical operations, infants acquire an objective temporal series, which encompasses the infants' actions [Piaget, 1937/1954]. During the 2nd year of life, the objective series will gradually come to regulate the subjective series, which explains why infants become capable of tolerating longer delays between hiding and search [Diamond, 1990], and succeed in more complex visible displacement tasks.

It also seems likely that first-order practical operations are related to infants' increasing capacities to recognize the absence of an experience that is normally associated with a given object or context. For example, a 16-month-old's behavior in front of a television that is turned off may indicate that he contrasts the current situation (television is off) with a situation he normally experiences (television on). This contrastive relation is the figure that appears in the background of a common characteristic shared by both situations [presence of the television; see Bonnet, 1983]. The further development of practical operations then leads to constructing more complex contrastive relations between the present situation and the absence of certain objects, events or activities usually associated with this situation [Bonnet, 1983]. Constructing contrastive relations between present and past situations does not imply that children locate their own experiences within a temporal horizon. Rather, at this developmental level, absence rather than pastness is experienced.

With the movement of consciousness to the representational level of knowing, children become capable of evoking absent objects and events by means of symbols and signs ['evocation memory', Piaget and Inhelder, 1966/1969; 'cued recall', Perner, 1992; Perner and Ruffman, 1995]. Children at this level differentiate between past, present and future, and express these distinctions linguistically [Nelson, 1984]. The ability to differentiate between past, present, and future, however, does not imply that children are able to locate events within the context of a personal history that extends over time. Rather, children draw temporal distinctions by contrasting their current cognitive content to the present situation. Although children at this level recall previous perceptions in a temporal sequence, this should not be confused with a representation of a temporal sequence. The representations are ordered in time because they follow the sequence of previous perceptions, and not because they reflect the representation of a temporal sequence.

To locate their experiences within a personal history, children must understand that their temporal relation towards the events in the world is continuously changing. They must realize that the events they represent as present or future now they will later remember as past, and that events they represent as past now they once experienced as present. They must establish what Stern [1934/1938] calls *mnemic continuity*: 'I am the *same one* who *now* remembers what I *then* experienced' [p. 250] – a competence that is emerging around the 4th year of life [Stern, 1914/1930, pp. 395–396]. The proposal here is that while the development of first- and second-order practical operations constitutes fundamental conditions for the consciousness of pastness, first-order representational operations are necessary to complete the picture as these are necessary for mnemic continuity. The judgment that a current mental content has been experienced before requires the construction of a conceptual relationship between past and present in the present. The past can only be represented in the present, although it is *not* the present [Cassirer, 1929/1957; Stern, 1934/1938]. Negated propositions, however, are judgments passed on judgments: 'A negation only exists as a function of a previous affirmation' [Piaget, 1936/1963, p. 235]. Thus, the competence to coordinate judgments through first-order representational operations is a prerequisite for the development of mnemic continuity. Thanks to this operative development, memory retrieval shifts from reliance on external cues to reliance on internal ones [free recall; Nelson, 1984; Perner and Ruffman, 1995; Stern, 1914/1930; Stern and Stern, 1909]. Representational operations at this level allow the construction of temporal series that are ordered according to subjective interest. The representation of a subjective temporal series is sufficient to order experiences that form a homogenous series, such as, for example, different sections of one's life, the successive stages in the growth of a tree, or the sequence of days. A subjective temporal series is no longer sufficient when heterogeneous sequences of events are related to each other. For heterogeneous series, it is necessary to reconstruct the sequence of the events by coordinating the order of succession of these events with the durations between the events [Fraisse, 1958/1963]. Piaget [1946/1969a] argues that more complex temporal operations on the representational plane are necessary to connect these heterogeneous series:

> If we think of several series of independent but overlapping events in our own past (for instance of important dates in our career, the dates of our publications, dates in private life and political events) we see that though all these series have remained very much alive in our memory, we must nevertheless use rational and hence operational reconstructions (1) to tell if a given event in one series came before an event in another series (even though the order of succession in each series is perfectly clear), and (2) to give an approximate evaluation (in terms of + or –) of the respective length of the intervals between two events in two distinct series [p. 252].

Such a concept of time is constructed through second-order representational operations, which correspond to Piaget's notion of concrete operations. Second-order representational operations coordinate the orders of succession with the intervals of duration between them [Fraisse, 1958/1963; Piaget, 1946/1969a]. The ensuing concept of time gives children a completely new self-understanding of their personal continuity in time, which is considered an important aspect of the organization of personal memories in autobiographical memories [Fivush et al., 1995; Neisser, 1988; Nelson, 1992]. This late onset of personal continuity in time does not imply that memories before the onset of concrete operations are inevitably lost. Memories will be recovered as autobiographical memories when they are stored as individualized schemas or unique events [Fivush et al., 1995].

In this section, we have argued that deferred imitation, as evidenced in Meltzoff's study, does not require mental representation. Rather, deferred imitation is a type of memory in the broad sense and consists in reproducing observationally learned actions in the presence of external cues. Next, we have argued that it is not mental image but an understanding of the self as being temporally extended (mnemic continuity) that constitutes the sufficient condition for the conscious recollection of the past. Mnemic continuity, in turn, depends on the development of first-order representational operations. A full-fledged autobiographical memory, however, does not emerge until second-order representational operations coordinate temporal duration and the orders of succession.

Conclusion

In this paper we have examined the development of representational thought from both the position of image-schema theory and from an action-theoretical perspective. Our analysis of Mandler's claim that sensorimotor knowledge is inaccessible to consciousness argued that this claim is untenable. As a consequence, it is not necessary to postulate a special mechanism that produces a special code in order to explain the emergence of representational thought. In addition, we have argued that image-schema theory faces severe conceptual and empirical problems that are resolved in an action-theoretical approach.

Empirically, our analysis has examined claims that research has established the precocious onset of representations. Our conclusion is that the empirical evidence fails to support these claims. Neither Mandler's studies on conceptual development, nor Baillargeon's experiments on object permanence, nor Leslie's studies on the understanding of causality, nor Meltzoff's study of deferred imitation provide evidence for early mental representation.

At several points, we have argued that, from an epistemological perspective, image-schema theory is deeply rooted in the representationalist tradition of empiricism. An important characteristic common to both Mandler's image-schema theory and empiricist representationalist approaches is the omission of the assumption of an embodied agent who is intentionally related to the world [Overton, 1997, 1998; Smythe, 1992b; Taylor, 1995]. As a consequence, within the framework of these approaches consciousness is not actively and meaningfully directed towards the world. From this basic omission two important incoherences follow. First, in these approaches subpersonal-level information processing and personal-level mental acts are confounded. Second, these theories collapse the distinction between signifier (i.e., representative item) and signified (i.e., meaning). We have shown that this collapse underlies Mandler's claim that the meaning of image-schemas resides in their own structure. The identification of the concepts of representative item and the meaning expressed through these items – 'one of philosophy's mortal sins' [Perner, 1991, p. 60] – is also entailed in Mandler's claim that with the emergence of representative items, their meaning, too, must be stored as a symbolic code: 'That is while one is developing symbols and has some crude approximation to them but not yet the real thing, does the knowledge being partially or imperfectly symbolized get lost, does it get integrated with sensorimotor schemes, or what?' [Mandler, 1988, p. 119]. However, in order to be expressed on the representational plane, meaning does not require a special representational code such as image-schemas; a system of differentiated signifiers is enough.

Mandler's image-schema approach has been contrasted with a contemporary action approach to illustrate the manner in which meta-theoretical contexts influence the theoretical, methodological, and empirical debate [Overton, 1998; Sigel, 1983]. An action framework results in an orientation toward cognition and development that differs markedly from the empiricist epistemological frame adopted by image-schema theory. For an action approach, the starting point of cognitive research is not the split-off world of objects but the relational world of subject and object. This is the active, embodied infant who in transaction with the physical world and social-cultural world grows through the action of constructing both self and the known world. In the Kantian-Hegelian tradition, this approach emphasizes the structuring, meaning-giving quality of our mind-in-transaction. In attributing a major role to the social-cultural, co-constructive nature of all knowledge [Piaget, 1965/1995], this approach is at odds with the basic assumption shared by empiricist and nativist cognitive developmentalists that some solitary split-off information processer can generate representations and meanings. Further, rather than drawing on innate constraints, an action approach postulates intrinsic constraints, that is, constraints that follow from the processes by means of which the operative systems develop [Campbell and Bickhard, 1992; Langer, 1986; Overton, 1991b]. These constraints are then

> posed by the transformational process itself. Given the initial system, there can be few ways in which it can be transformed, the fewer the higher the integration of the system. Understanding the mechanisms of transformation thus translates into an understanding of transformed structures [Antinucci, 1990, p. 158].

Although transformational processes have not been directly addressed in this paper, the developmental sequences outlined for memory and conceptual development suggest that the fundamental transformational process consists of the conceptualization of the operative systems of a previous level of knowing within the framework of new knowing levels – a process that Piaget [1950, 1977] calls *reflective abstraction* [see Müller et al., in press].

Finally, in contrast to empiricist and nativist frameworks, this action approach cautions us not to overrate the importance of representative items. Representative items are only a tool for dynamic thought processes [Piaget, 1936/1963, p. 345, p. 352], and they are only as good as the intelligence they serve [Furth, 1969]. The thinking act, the intentional organizing activity of assimilation, gives meaning to symbols and signs [Bloom, 1993]. As a consequence, qualitatively higher forms of knowledge cannot be derived from representative items alone; they emerge from the development of the operative aspect of knowing. According to our proposal, the operative aspect of knowing also constructs representative items. Once constructed, representative items, in turn, open up new possibilities for further operative development. In keeping with this idea, we have described developmental sequences in the domains of conceptual development and memory development. The developmental sequences proposed in this paper are in need of further conceptual elaboration and systematic empirical validation. We believe, however, we have demonstrated that an action framework provides a more fertile ground for research on cognitive development than do empiricist models.

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