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### Conceptual Development in Infancy: The Case of Containment

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**H**ow do children develop the concepts that are expressed by the individual terms of human languages—concepts of objects such as *dog*, of events such as *lunch*, of actions such as *jump*, and of spatial relationships such as *on*? The most popular accounts of this ability root the development of concepts either in language itself or in perception. On the first of these accounts, children construct concepts such as *dog* or *on* by observing commonalities in the events to which speakers refer when they say *dog* or *on*. On the second of these accounts, the child's perceptual systems naturally are attuned to such commonalities. Accounts that appeal both to language experience and to perceptual biases also have been offered (e.g., Smith, Jones, & Landau, 1996).

Jean Mandler (1988, 1992, 1998) proposed an alternative to all such theories of conceptual development. In her view, concepts develop from a foundational system that is distinct both from the child's perceptual capacities and from language. This foundational system has five principal properties. First, it is a primitive system with its own developmental origin and initial course. Second, it is a categorical system that

groups together perceptually diverse entities and treats them as equivalent. Third, it is an accessible system that can be used for a variety of purposes including thinking, recalling, and acting in multiple ways. Fourth, it is primarily a spatio-temporal system that operates by detecting the locations and motions of objects in relation to one another. Fifth, it is a conscious system, distinct from the unconscious mechanisms that give rise to the child's sensory, motoric, and linguistic representations.

In this chapter, we consider all these claims in the context of research on infants' representations of objects. Our review of this research leads us to argue that four of Mandler's claims are correct: Infants indeed have a conceptual system that is primitive, categorical, accessible, and attuned to spatio-temporal relationships among objects. We remain neutral concerning Mandler's claim that this system operates consciously. Finally, we argue that the conceptual system studied by Mandler serves not only to categorize the spatial relationships among objects but also to represent the unity and boundaries of objects, their identity through time, and their behavior. This system is domain-specific: It applies to inanimate, manipulable objects but not to other important, perceptible entities in the child's environment such as people. It is one of a set of systems of core knowledge.

To make our discussion more manageable, we focus on the development of a small set of concepts that capture spatial relationships between distinct objects, particularly the relationship of containment. We begin by considering the infant's ability to distinguish containment (the relationship expressed in English by "in") from a different spatial relationship expressed in English by "behind" and referred to by Baillargeon (1998) and others as occlusion.<sup>1</sup> We first ask whether young infants represent the distinction between containment and occlusion prior to language. In light of evidence that they do, we further ask whether this distinction is represented within a system that is categorical and accessible. Then we consider the development of a further distinction that is not captured by the lexicon of English but is captured by simple morphemes in certain other languages: the distinction between tight-fitting and loose-fitting relationships between objects. We

<sup>1</sup>Although we follow Baillargeon's terminology and refer to this relationship as occlusion, note that this term is somewhat misleading. Because occlusion occurs when objects enter into a variety of spatial relationships, including containment, not all occlusion relationships are captured by the "behind" concept. Moreover, because an object is not occluded when it moves behind a transparent object, some relationships captured by the "behind" concept do not involve occlusion. Here we discuss only the simple case studied by Hespos and Baillargeon (2001), in which one object is placed behind a second, opaque object and therefore is occluded by it, and we refer to this case alone as a relation of "occlusion."

ask whether young infants who are exposed only to English make this spatial distinction. In light of evidence that they do, we conclude by asking how infants' ability to distinguish tight from loose-fitting relationships between objects relates to their ability to represent individual objects and reason about their motions.

### CONTAINMENT AND OCCLUSION: A CONCEPTUAL DISTINCTION

Recent research provides evidence that 2½-month-old infants can distinguish between containment and occlusion events and are sensitive to some of the constraints that these different relationships place on the behavior of objects (Hespos & Baillargeon, 2001). Infants were shown an event where a small cylindrical object was lowered either behind or inside a container; next, the container was moved forward and to the side revealing the object behind the container. There is nothing surprising about this outcome for the behind condition. In the inside condition, however, the outcome appears to adults to be impossible, because the contained object should have remained inside and moved with its container. If infants had expectations similar to adults' expectations for these two events, they were expected to look longer at outcome for the inside condition. The results confirmed this prediction. These findings suggest that infants as young as 2½ months of age have different expectations about containment and occlusion events.

Is the distinction between containment and occlusion categorical and conceptual for infants, or does it reflect perceptual sensitivity to continuous stimulus variations? This is a question that Mandler has asked repeatedly in other contexts: For example, do babies group diverse animals together because they look similar or because they are represented as members of the same kind (e.g., Mandler, 1992)? To address this issue, Mandler presented infants with superficially very different but conceptually similar entities, asking whether infants would respond similarly in the face of this perceptual diversity. The approach of Hespos & Baillargeon (2001b) is close in logic to Mandler's: They presented infants with perceptually very similar but conceptually different spatial relationships, asking whether infants would respond differently to those different relationships.

For example, one series of experiments tested whether 4- to 8-month-old infants could assess how much of a tall object should be hidden when lowered either behind an occluder or inside a container. In the container condition, infants were presented with events in which a tall object was lowered out of view into a container either of equal height (consistent) or of half its height (inconsistent). Similarly, in the

occluder condition, infants were shown the same object hidden behind either a tall or short occluder. To make the occluder and container events perceptually as similar as possible, the occluders were constructed by removing the bottom and back half of the containers, so that they formed rounded occluders (see Fig. 13.1). These events were perceptually similar once the object was fully hidden, but they were conceptually different for adults, because the object was hidden inside a container in one and behind an occluder in the other.

The results showed that infants detected the violation in the occlusion events at 4½ months of age. In contrast, infants failed to detect the violation in the perceptually matched containment events until 7½ months of age. These findings suggest that containment and occlusion are categorically distinct classes of events for infants, despite their perceptual similarity, and that representations of objects and inferences about their behavior depend in part on this conceptual distinction.

#### LOOKING AND REACHING TO CONTAINED VERSUS OCCLUDED OBJECTS: AN ACCESSIBLE DISTINCTION

Is the conceptual distinction between occlusion and containment an accessible one for infants? One hallmark of an accessible representation is that it can guide diverse actions including visual exploration, manual exploration, communication, and any other actions in one's repertoire. To investigate whether the containment or occlusion distinction is accessible to young infants, therefore, Hespos and Baillargeon (2002) asked if the same distinction that guides infants' preferential looking in the aforementioned experiments also would guide their predictive reaching in a different experimental context.

In these experiments, infants of 5½ and 7½ months of age were presented with a tall frog and were encouraged to play with it. After a few seconds, the frog was removed and the infants were presented with two occluders or containers that had frog legs wrapped around the sides of them so that the frog's feet were sticking out in front and could be grasped directly. As in the preferential-looking studies, the occluders and containers were perceptually identical to one another, except that the container had a continuous back and therefore surrounded the frog. In addition, the pairs of occluders and containers were identical except for their height; one was tall enough to conceal the entire frog behind it, whereas the other was one third the needed height. After the infants' attention was drawn to each display, the apparatus was moved toward the infants, whose reaching was observed.

Infants of both ages reached significantly more often to the frog's legs that protruded from behind the tall occluder than to those pro-

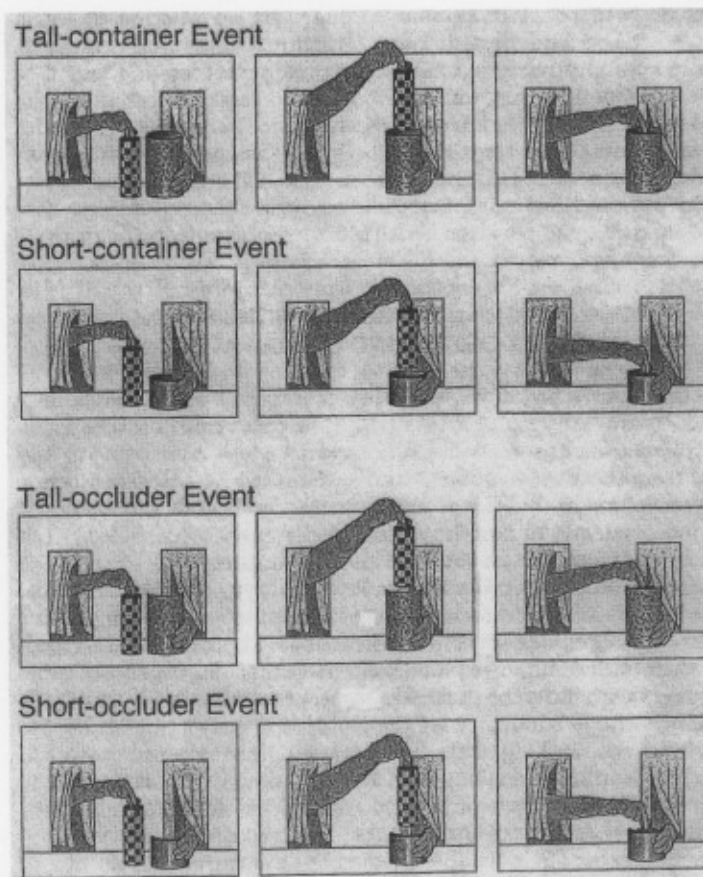


FIG. 13.1 Test displays used in studies of infants' developing distinction between containment and occlusion (after Hespos & Baillargeon, 2001b).



truding from behind the short occluder, although, in a control condition (with no initial exposure to the frog), they showed no intrinsic preference for the tall display. These reaching patterns provide evidence that the infants appreciated that only the tall occluder could conceal the frog. In contrast, infants reached more often for the frog inside the tall container at 7½ but not 5½ months of age. These experiments therefore provide evidence that infants exhibit the same developmental pattern in an object-retrieval task as in a preferential-looking task: The same developing representations of object occlusion and containment appear to guide both visual exploration and manipulation of objects for young infants. Taken together, these findings suggest in turn that the developing conceptual distinction between in and behind is available to guide diverse actions in infancy. This conceptual distinction appears to be an accessible one, consistent with Mandler's arguments for an accessible, developing, conceptual system in infancy.

#### CONCEPTS AND LANGUAGE: TIGHT-FITTING AND LOOSE-FITTING CONTAINMENT

Because children do not begin to use terms such as *in* and *behind* until well after the 1st year, and because all the children in the aforementioned experiments were well under 1 year of age, it is tempting to conclude from the aforementioned studies that the categorical distinction between in and behind is a primitive distinction that develops prior to and independently of language. Nevertheless, two recent sets of findings appear to cast some doubt on this conclusion.

First, research by Jacques Mehler, Peter Jusczyk, and others provides evidence that infants learn a great deal about their native tongue long before they begin to speak. Within the first days of life, neonates recognize their native language and discriminate this language from other languages with different rhythmic properties (Mehler et al., 1988). By 6 months of age, infants relate the words "mommy" and "daddy" to their referents, looking at the appropriate parent when each word is spoken (Tincoff & Jusczyk, 1999). By 7½ months, infants are able to learn to recognize new words within a single session, after only brief exposure to the word (see Jusczyk, 1997). Given the frequency of spatial terms such as *in*, in the spoken language that surrounds the infant, therefore, we cannot exclude the possibility that the 7½-month-old infants in Hespos and Baillargeon's (2002) experiments have learned something about its meaning.

Second, research by Choi and Bowerman (1991) yielded provocative findings concerning the effects of language on conceptual development, based on an interesting difference between the spatial vocabular-

ies of different languages. Not all natural languages have words that express the containment concept expressed in English by "in." In Korean, for example, morphemes appended to verbs of motion express a different distinction; the distinction between moving an object into a tight-fitting relationship with a second object and moving it into a loose-fitting relationship. The tight fit and loose fit distinction cross-cuts the English distinction between containment ("in") and support ("on"): whereas English speakers put the apple "in the bowl" (containment), the book "on the table" (support), and the ring "on the finger" (support), Korean speakers describe both the apple and bowl and the book and table as entering into loose-fitting relationships, whereas a book placed in its jacket and a ring placed on a finger enter into tight-fitting relationships. Importantly, Choi and Bowerman (1991) showed that adult speakers of English and Korean categorize events such as those just described differently from one another, in ways that reflect the categorical distinctions of their language. Moreover, Korean children appear to learn the morphemes that express the tight and loose distinction as quickly as English children learn "in" and "on," and they make few errors in applying these terms. Korean children do not go through a stage in which they try to fit the terms of their language into the spatial categories of containment and support to which American infants are sensitive. Together, with the findings of Jusczyk and others described earlier, these findings raise the possibility that language guides the development of spatial concepts from a very early point in development, contrary to Mandler's thesis.

There is, however, an alternative interpretation of Choi and Bowerman's (1991) findings, first suggested by Mandler (1998): "The fact that there is more than one way to express various spatial relationships does not mean that language itself is teaching relations previously unanalyzed by the language learner .... Rather, it seems more likely that different languages teach children different ways to express what they have already noticed through perceptual analysis" (p. x). On this view, she continues, "there is a universal set of relational concepts that preverbal children everywhere have analyzed before learning language. Bowerman's (1989) analyses indicate that this set is larger than that expressed in any given language" (Mandler, 1998, p. 295). On this view, children may come to the task of learning language equipped with all the principal categorical distinctions that the early-developing parts of the lexicon express; not only the distinctions of English but those of Korean and other languages. If that is the case, then prelinguistic children would possess a richer set of conceptual distinctions than those expressed by any language, and learning a language would require that they select, from among the conceptual distinctions

in their repertoire, those distinctions that the language expresses. As a result of this selection process, adult speakers may show reduced sensitivity to conceptual distinctions that are not marked by their language.

If word learning proceeded as Mandler suggests, then the development of lexical semantics would resemble the development of phonology. We now know that infants come to the task of learning the phonological distinctions of their language equipped with all the principal phonetic distinctions expressed by natural languages. Over the course of experience with their ambient language, infants learn to select from among those distinctions the ones that their own language uses to convey differences of meaning. This selection comes to influence speech perception by adults, who remain sensitive to the distinctions expressed in their language but who are generally less sensitive to non-native distinctions. Young infants therefore show greater sensitivity than do their parents to distinctions among speech sounds that signal differences in meanings in unfamiliar languages but that signal no such differences in their native language (Werker & Tees, 1984). As in the case of speech perception, Mandler's suggestion implies, young infants may show greater sensitivity than their parents to conceptual distinctions that are captured by the terms of some unfamiliar languages but that are not lexicalized in the native language.

Experiments by McDonough, Choi, and Bowerman (1999) attempted to test both of these predictions by assessing the spatial categorizations of infants and adults in an English-language environment. Participants were presented with a set of complex and heterogeneous events in which two objects entered various spatial relationships. In Experiment 1, infants aged 9 to 14 months were familiarized with six different scenes in which objects entered into either a relation of tight-fitting containment (a relation expressed by "in" in English and by "kkita" in Korean), or a relation of loose-fitting support (a relation expressed by "on" in English and by "nohta" in Korean). Although each infant observed the same spatial relationship on every familiarization trial, the scenes were otherwise diverse and involved a variety of objects and motions. After familiarization, infants were tested with novel scenes exhibiting each of the two spatial relationships. If infants categorized the events on the basis of their spatial relationships, they should have looked longer at the test event that exhibited the novel spatial relationship. Infants at 14 months showed this test preference, providing evidence that they categorized the spatial relationships in a manner consistent with many natural languages including both English and Korean. In contrast, 9-month-old infants looked longer at the test scene that exhibited the familiar spatial relationship, and 11-month-old infants showed no consistent preferences.

In Experiment 2, infants of the same ages were familiarized with six different scenes in which objects entered into either a relation of tight-fitting containment or a relation of loose-fitting containment: two spatial relationships that are described similarly in English but differently in Korean. Like the youngest infants in Experiment 1, infants of all ages in Experiment 2 looked longer at the familiar spatial relationship. All these findings suggest that infants show some sensitivity to both of the contrasting spatial relationships, because in the absence of any such sensitivity infants should have looked equally at the two classes of events. Nevertheless, the direction of sensitivity corresponded to that which is typically found in categorization research only for the oldest infants presented with a contrast that is lexicalized in English. The authors suggested that abilities to categorize spatial relationships begin to develop before language but are fragile until children begin to learn the spatial terms of their language. Experiments with adults supported this conclusion. English-speaking adults, tested in the same manner as infants, showed a preference for the novel test events of Experiment 1 but showed no such preference among the events of Experiment 2. Similar results were obtained in a different categorization task with adults presenting the same stimuli. Like infants, adults appeared to categorize readily only those spatial relationships that corresponded to the terms of their language.

Although the findings of McDonough et al. (1999) appeared to provide some support for the thesis that spatial categorization depends in part on the acquisition of language, the authors noted that they are open to other interpretations. In particular, infants may have been confused or distracted by the wide variation among the events that were presented to them, especially at the younger ages. More generally, early-developing categorization abilities may reveal themselves more clearly when infants are presented with simpler events that exhibit a minimal contrast between two conceptual categories, as in Hespos & Baillargeon's (2001a, 2001b) studies of containment and occlusion. That is what our experiments attempted to do.

In the first experiment (Hespos & Spelke, 2001), we tested 5-month-old U.S. infants' categorization of tight-fitting versus loose-fitting containment relations using a habituation-dishabituation paradigm. First, infants saw a narrow cylindrical object lowered into a series of loose-fitting, medium-sized containers on a series of trials until their looking time declined (see Fig. 13.2a). Next, the infants were presented with six test trials in which the same cylindrical object was lowered, in alternation, into a wide container ( $1\frac{1}{2}$  times wider, hence also a loose fit) and into a narrower container ( $1\frac{1}{2}$  times more narrow, a tight fit). If infants make a language-independent categorical distinction be-

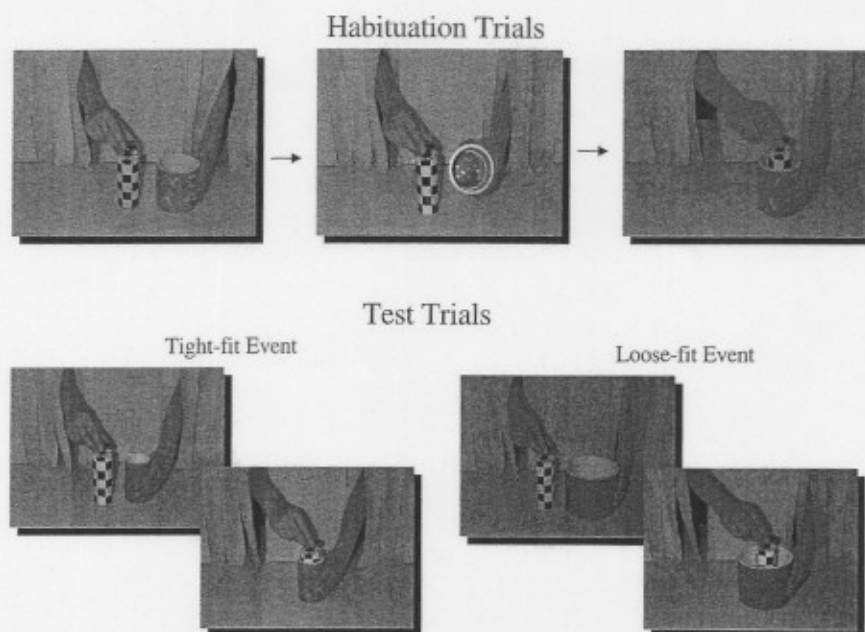
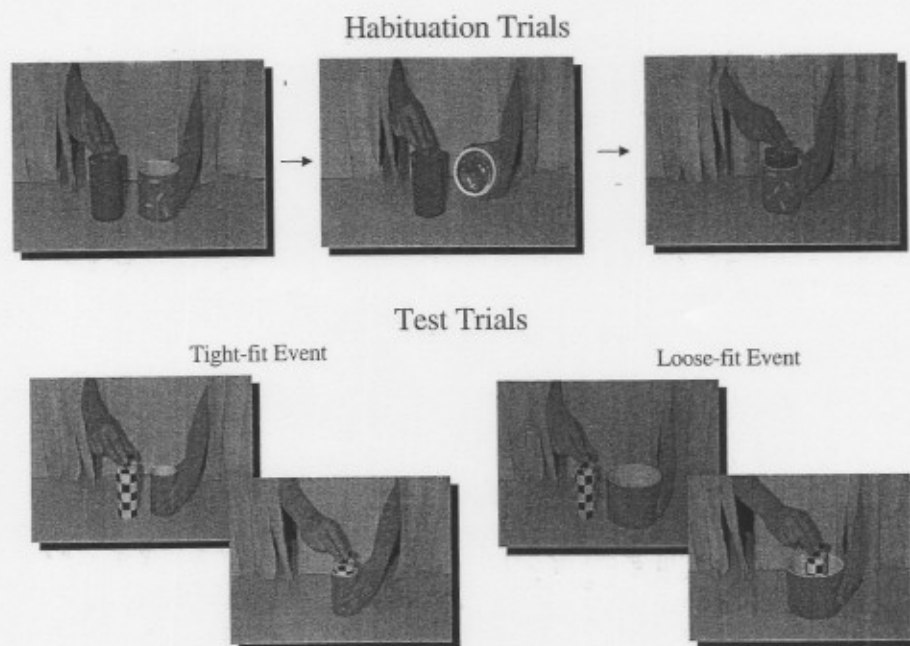


FIG. 13.2 Displays used in two studies of infants' developing distinction between tight-fitting and loose-fitting containment (after Hespos & Spelke unpublished). Infants were tested with loose- and tight-fitting events involving large and small containers after habituation to (a; this page) a loose-fitting event or (b; next page) a tight-fitting event involving a different, intermediate-sized container.





tween tight- and loose-fitting containment events, then they were expected to look significantly longer at the tight-fit trials. Our results confirmed this prediction.

Because the containers differed in size for the tight- and loose-fitting test events, it was possible that the results from the first experiment stemmed from an inherent preference for perceptual aspects of the tight-fitting event. To test this possibility, a second experiment compared infants' looking times to the same test events after habituation to an event in which a medium-sized object was lowered into the same medium-sized container as in the first study: a "tight-fit" event. The infants in this experiment showed the opposite pattern of behavior, looking longer at the loose-fit test event (see Fig. 13.2b). Together, these findings provide evidence that infants categorized the containment events as tight- or loose-fitting and mapped the categorical distinction seen during habituation trials onto the events that they saw during test trials.

Infants living in an English-speaking environment therefore are sensitive to the categorical distinction between tight-fitting and loose-fitting containment relationships, as Mandler had speculated. When exposed to continuous variation in the size of a contained object relative to its container, infants make the categorical distinction captured by the Korean morphemes "kkita" and "nehta." We conclude that sensitivity to this distinction develops in the absence of any relevant linguistic experience, prior to and independently of the language the child will learn.

In two respects, our findings resemble the findings of studies of phonetic discrimination in speech perception. First, we found that infants parse a continuum of spatial variation into categories of spatial relationships between objects, just as prior studies have found that infants parse a continuum of acoustic variation into categories of speech sounds (see Jusczyk, 1997). Second, we found that infants are sensitive not only to the spatial distinctions that are lexicalized in their native language but also to spatial distinctions that are lexicalized in other, non-native languages. Similarly, studies of speech perception have found that infants are sensitive to the phonological distinctions of non-native languages as well as to the phonological distinctions of their native language.

These findings raise the question whether the development of spatial concepts and of speech perception are similar in a third respect: Over the course of development, do speakers lose sensitivity to the conceptual distinctions that are not captured by the lexical semantics of their native language, just as they lose sensitivity to phonetic distinctions not captured by their native language phonology? To begin to address this question, we presented all the same containment events to two groups of English-speaking adults. Adult participants first were shown

the same habituation trials as the infants: one group was shown the loose-fitting containment event of our first experiment and the other group saw the tight-fitting containment event of our second experiment. Then both groups of adults were shown the two test trials consisting of the narrow and wide test events that the infants observed. After each test event, participants were asked to rate the similarity between the test event and the habituation events that they had seen. Finally, participants were asked to rank the test trials in similarity to the habituation trials. In contrast to the infants' patterns of preferential looking, the adults rated the two test events as equally similar to the habituation event. The adults, therefore, did not appear to make the same categorical distinction as the infants.

So far, we've discussed experiments that support three of Mandler's claims, providing evidence for an early-developing system of conceptual representation that is categorical, accessible, and primitive in the sense that it develops prior to and independently of language. Now we turn to Mandler's last two claims, that the system that gives rise to infants' early-developing conceptual distinctions is primarily attuned to spatio-temporal properties of objects and relationships among objects, and that this system is conscious in a way that distinguishes it from any of the infant's other systems for representing the environment.

#### **SPATIAL CONCEPTS AND OBJECT REPRESENTATIONS IN INFANCY**

Mandler (1988, 1992, 1998) proposed that infants' earliest concepts develop through a process of perceptual analysis, and that this process initially focuses primarily on the locations and motions of objects. For example, infants conceptualize some objects as animals by noticing their patterns of self-propelled, irregular, and contingent motion; they conceptualize other objects as furniture or kitchen things by noting their characteristic locations and functions; and they conceptualize spatial relationships between objects as containment by noticing the motion of one object from a position outside to a position inside another object. Because the process of perceptual analysis focuses first on large-scale spatial and kinetic relationships, infants categorize objects at the global levels of animals and furniture before they categorize objects at finer levels such as dogs and cats, although infants' perceptual systems are highly sensitive to the different appearances of dogs and cats (Quinn & Eimas, 1996). Thus, Mandler claims, infants' concepts depend on a process of spatio-temporal analysis that is distinct from the perceptual processes by which infants detect the fine-grained colors, shapes, and other properties of objects.

The cases discussed by Mandler are not the only cases, however, in which infants appear to be especially sensitive to spatio-temporal information. Infants also rely primarily on spatio-temporal information when they perceive the unity and boundaries of objects, when they reach for objects and extrapolate their motions, and when they follow objects through time and determine relations of numerical identity and distinctness (i.e., whether an object seen now is the same one as a given object seen in the past). For example, infants perceive the unity and connectedness of a center-occluded object by detecting the common motion of its visible surfaces (Kellman & Spelke, 1983; Johnson & Náñez, 1995) but not by detecting the common coloring of its visible surfaces, even when that coloring is highly salient and synchronously changing (Jusczyk, Johnson, Spelke, & Kennedy, 1999). How do these abilities relate to the ability to form spatial concepts?

Mandler discussed the infant's capacity for object representation in two different ways. On one hand, she drew from findings, such as those previously discussed, the conclusion that infants are especially sensitive to spatio-temporal information about objects, and she suggested that this sensitivity may explain why their earliest-developing concepts depend on such information. On the other hand, she argued that the processes of perceptual analysis that give rise to the first true concepts are conscious processes, whereas the processes that give rise to object representations are not (Mandler, 1998). In Mandler's view, object perception is an encapsulated and unconscious process, whereas concepts such as animal and containment are accessible and conscious.

Are the processes by which infants categorize spatial relations among objects—relations like containment and tight-fit—qualitatively different from the processes by which infants represent objects in the first place? To approach this question, we need first to consider further what are the processes of object representation. One of us has argued (Spelke, *in press*) that object representation depends on a system of core knowledge, with four central properties. First, the system gives rise to representations that are abstract and largely independent both from sensory systems and from response systems. On the sensory side, object representations are amodal and persist even in the absence of sensory support, when objects are occluded. On the motor side, object representations guide diverse actions including visual exploration, manipulation, and locomotion. Second, the system is domain-specific: It serves to represent objects but not to represent other perceptible entities such as persons, collections, or nonsolid substances (see Chiang & Wynn, 2000; Huntley-Fenner & Carey, 2001; Woodward, Phillips, & Spelke, 1993). Third, the system is informationally encapsulated: It operates on information about the spatio-temporal relationships between visible surfaces but not

on information about other surface properties such as color and detailed shape, although those properties are detectable by infants and used for other purposes. Fourth, the system provides the representations that are the building blocks for learning and cognitive development. It provides the initial set of concepts that allows children to develop systematic knowledge of their surroundings and to develop abilities to communicate that knowledge by language.

All of these properties, we believe, are true of the conceptual system that Mandler has described. Contrary to Mandler, we propose that a single system of representation underlies both the infant's capacity to represent objects as unitary and persisting and the infant's capacity to categorize objects and spatial relationships in the ways that Mandler has described. But how can our proposal and Mandler's be distinguished empirically? Mandler has articulated one set of predictions that separate the two views: On her view, infants should be conscious of the processes by which they form concepts, whereas they should not be conscious of the processes by which they form representations of objects. Consciousness is an elusive phenomenon to study at any age, however, and it is especially difficult to study in infants. Here, we propose and test a different prediction that may separate the two views. On our view, the very same principles that govern infants' construction of representations of the unity, identity, and behavior of inanimate, manipulable objects also should govern infants' construction of categorical distinctions among sets of objects and spatial relationships. On Mandler's view, in contrast, there is no reason to expect such a convergence.

Specifically, one of us has argued that young infants build representations of objects in accord with six constraints on object motion:<sup>2</sup> cohesion (objects do not spontaneously break apart as they move), boundedness (distinct objects do not spontaneously merge as they move), continuity (objects do not move on paths with gaps in space or time), solidity (distinct objects do not occupy the same place at the same time), no action at a distance (objects do not influence one another's motion when they are separated in space), and action on contact (objects do not move independently when they are in contact). If early-developing concepts of objects and their spatial relations are products of the same system, then they should be guided by the same constraints.

In light of this prediction, consider the distinction between the spatial concepts in and behind studied by Hespos and Baillargeon (2001a). These two spatial relationships limit the relative motions of objects in very different ways, given the aforementioned constraints. Because of the solidity

<sup>2</sup>These six constraints can be reduced to the three spatio-temporal principles of cohesion, continuity, and contact (Spelke & Van de Walle, 1993). For these purposes, however, it is more useful to consider the six constraints on motion.



and the action on contact constraints, an object inside a container will move when and where its container moves. Because of the no action at a distance constraint, an object that is behind and spatially separated from a screen will not move when and where its occluder moves. We have seen that infants as young as 2½ months are sensitive to these differing limits and make accurate predictions about object motion in accord with these constraints (Hespos & Baillargeon, 2001a; see also, Aguiar & Baillargeon, 2000; Wilcox, Nadel, & Rosser, 1996).

Now consider the distinction between tight-fitting and loose-fitting relationships between objects. When two objects fit tightly together, such as a ring on a finger or a cylinder in a cylindrical container just wide enough to hold it, then almost any motion of one object will induce an exactly parallel motion in the other object.<sup>3</sup> The constraints of solidity and action on contact ensure that these objects will move together unless one acts specifically to separate them. In contrast, when two objects fit loosely together, such as an apple in a bowl or on a table, the motions of the two objects are only partly constrained by one another. Because the objects are solid, the apple cannot move laterally through the side of the bowl or downward through the surface of the table; because the objects are in contact, motions of the bowl or table will influence the motion of the apple. In neither case, however, will the motions of two loose-fitting objects be strictly parallel. If a bowl containing an apple is suddenly moved, for example, the apple and bowl will undergo both common and relative motions, with the apple both moving with the bowl and rolling against it.

Because tight- and loose-fitting support place different constraints on the motions of objects, it is possible that the principles governing infants' representations of objects and their motions could also lead infants to categorize these spatial relationships differently, into the categories of support, containment, tight-fit, and loose-fit that are lexicalized in various languages. However, do infants in fact respect these principles in their spatial categorizations? Our last experiments were undertaken to address this question.

In the first experiment, we used a preferential-looking paradigm to test 5-month-old infants' expectations about how motion affects loose-fitting containment relations. First, infants saw a narrow cylindrical object lowered into a wide container until their looking time declined. Next, the infants were presented with six test trials that

<sup>3</sup>With a suitable action, of course, one can remove the ring from the finger, and with purely vertical motion, one can lift the cylinder from its container. In both cases, however, the motions that will serve to separate the objects are highly nonaccidental; random motions of either object will almost always induce a corresponding motion in the other object.

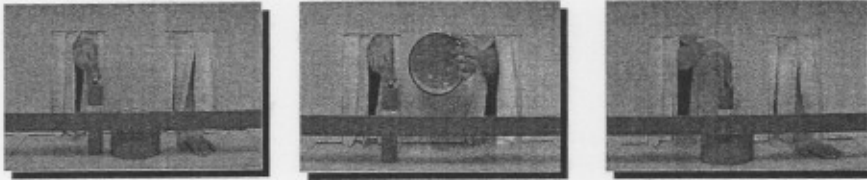
alternated between a move-separately event and a move-together event (see Fig. 13.3a). In the move-separately event, the cylindrical object was lowered inside the wide container and then the container remained stationary and the object moved back and forth inside the container (consistent). In the move-together event, the cylindrical object was lowered inside the wide container and then both the object and container moved horizontally as a unitary object (inconsistent). If infants expected the loose-fitting container to allow the object to move with some independence, then they were expected to look longer at the move-together event. Our results confirmed this prediction: Infants looked significantly longer at the move-together than at the move-separately events.

In a second experiment, we similarly tested infants' expectations for the effects of motion on tight-fitting containment relations. Infants saw the same cylindrical object lowered into a narrow container during the habituation and test trials. In the test trials, infants saw the object inside the container moved back and forth horizontally (see Fig. 13.3b). On alternate trials, the object and container moved together (consistent) or separately (inconsistent). If infants appreciated that a tight-fitting container more strongly constrains the motion of its contained object, then infants were expected to show the opposite looking preference from those in the loose-fitting condition and look longer at the move-separately event compared to the move-together event. The results confirmed this prediction.

These experiments reveal a close linkage between infants' ability to categorize spatial relationships between objects and their sensitivity to the ways in which the motions of objects in these relationships are constrained. As in other studies of object perception and object representation, infants' sensitivity to object motions is captured by a small set of constraints including solidity, no action at a distance, and action on contact. The same constraints on object motion therefore account both for infants' representations of objects and infants' categorization of spatial relationships between objects.

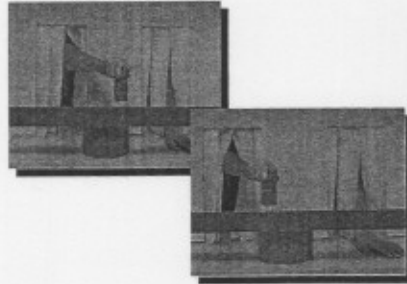
How does this system compare to the conceptual system that Mandler described in her writings? We already noted that the system has four properties which Mandler emphasized: It is primitive (that is, not derived from other systems or processes like sensory-motor integration or language learning), categorical, accessible to multiple response systems, and focused on spatio-temporal information. It may or may not have the fifth property Mandler described: the property of being a conscious system. Although accessibility and consciousness are related properties, they are not the same. Accessibility is a property of functional cognitive architecture: A system of representation is accessi-

### Habituation Events



### Test Events

#### Move-Separately Event



#### Move-Together Event

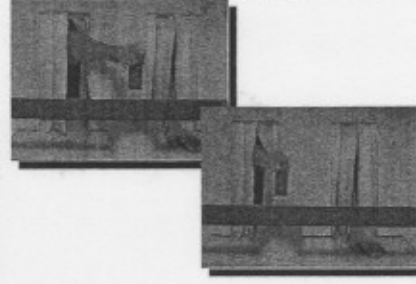
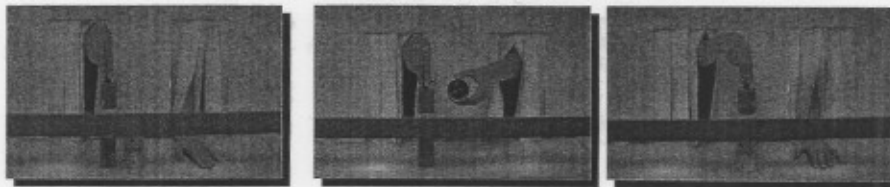


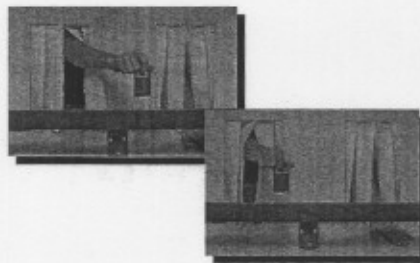
FIG. 13.3 Displays used in studies of infants' developing reasoning about the behavior of tight-fitting vs. loose-fitting containers (after Hespos & Spelke, unpublished). After an object was placed in either (a; this page) a loose-fitting container or (b; next page) a tight-fitting container, infants were tested with events in which the object moved laterally and the container alternately moved with the object or remained in place.

### Habituation Events



### Test Events

#### Move-Separately Event



#### Move-Together Event

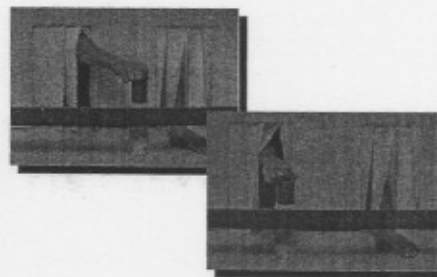


FIG. 13.3b

ble if its outputs are available to a wide range of response systems, regardless of whether the perceiver is aware of those outputs. Consciousness, in contrast, is a property of human experience: A system of representation is conscious if we are aware of its operations and outputs, regardless of our abilities to act on those representations. The subjective nature of conscious experience makes it difficult to determine whether and when infants are conscious, and we remain neutral on this question.

Contrary to Mandler, we argue that the spatio-temporal system of object representation has a sixth property. It is a domain-specific system; one among many. Evidence for the domain-specificity of this system comes from a consideration of the spatio-temporal constraints that guide it. Constraints such as action on contact and no action at a distance apply to the motions of inanimate, material bodies. They do not, however, apply to the motions of other perceptible entities, including animals and people (Spelke, Phillips, & Woodward, 1995). Infants, moreover, apply different principles when they reason about inanimate object motions on one hand and about human actions on the other: whereas inanimate object motions are seen as subject to the constraints of contact mechanics, human actions are seen as goal-directed (Woodward, 1998), intentional (Meltzoff, 1995), and socially responsive (Johnson, Slaughter, & Carey, 1998). Findings such as these suggest that infants are not endowed with a single process of perceptual analysis giving rise to a single, unified conceptual system but rather with a collection of such systems, each giving rise to a set of concepts within a particular domain. At the foundation of human cognition are multiple systems of core knowledge.

### CONCEPTUAL BEGINNINGS AND COGNITIVE DEVELOPMENT

We emphasized in this chapter that infants have early developing, primitive conceptual systems, and that these systems both precede and guide the development of language. It does not follow from this view, however, that cognitive development is a trivial process, or that language development fails to affect it. Indeed, we believe the core knowledge thesis may lead to the opposite conclusions.

If infants begin with a set of distinct, domain-specific systems of core knowledge, then they have much work to do over the course of cognitive development: They must come to relate these systems to one another, and to the world that the child perceives. The world of objects is not packaged neatly into domains that match the infant's core systems. For example, children must learn that there are classes of objects—animals—whose behavior is both goal-directed and subject to mechanical

constraints: objects that cross-cut the infant's distinction between intentional beings and inanimate manipulables. Children also must learn that there are other classes of objects—tools—whose properties follow not only from mechanical constraints but from human intentions: objects that are designed to serve human purposes. Such discoveries, we suggest, require that information from distinct core systems of representation be combined together in new ways. The child's developing language may be central to this developmental process, in two ways.

In writing about the relationship between language and thought, Mandler is quite open to the possibility that these developing functions mutually influence one another, and she proposes one way in which language can exert this influence. Although initial concepts, constructed by perceptual analysis, guide the first steps of word learning, the structure of the language to be learned may in turn guide the later elaboration of those concepts (e.g., Mandler, 1998). Words, first acquired in relation to concepts that are constructed by perceptual analysis, may in turn come to influence the process of perceptual analysis itself and the concepts to which it gives rise. For example, a language like Korean, with terms that distinguish tight- from loose-fitting relationships between objects, may call Korean speakers' attention to the details of those relationships, leading to new perceptual analyses of the relationships between objects and to an elaboration of the tight-loose conceptual distinction. Although the capacity for perceptual analysis is innate and universal, on Mandler's view, the particular directions that this analysis takes may be influenced by language and by other aspects of experience.

Elsewhere, one of us suggested a further way in which language may influence the child's developing concepts (Hermer-Vazquez, Spelke, & Katsnelson, 1999; Spelke & Tsivkin, in press). As the child comes to master the combinatorial syntax and compositional semantics of her native language, that language may serve as a medium for conjoining concepts from diverse domains and constructing new concepts that cross-cut those domains. In contrast to core-knowledge systems, language is a domain-general system of representation: it allows us to talk about anything we can conceive, regardless of the domain in which those concepts are couched, and it allows us to combine distinct concepts at will. Outside of language, representations of inanimate objects and of persons may be products of core systems that show little interaction. With language, however, we can easily relate them together, entertaining thoughts such as "Mary is a robot" or "This computer is malicious." We even may learn words for concepts whose features reside in different categories, such as names for tools or animals. Once the child has learned words and expressions that capture core concepts,



therefore, the child may be able to use the combinatorial resources of his or her language to express new concepts with components in distinct core domains.

### CONCLUSION

The above suggestions are speculative, but we may close on firmer ground. However much children's concepts and thinking change over the course of development and learning, these concepts are built on foundational systems that first emerge in infancy. Because many of our foundational concepts are clearest during the infancy period, studies of conceptual development in infants may allow cognitive scientists to approach many difficult questions concerning the structure and content of human knowledge at later ages. It is not easy to study conceptual development in infancy, because it is difficult to determine whether any given behavior pattern observed in infants results from representations that are perceptual or conceptual, implicit or explicit, primitive or derived. Fortunately, Jean Mandler has helped us all to think about these distinctions and to craft experiments that bring us closer to understanding the nature of infants' representations and the origins of their concepts.

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## 14



## Memories for Emotional, Stressful, and Traumatic Events

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This chapter presents an essay on the nature, organization, and early emergence of emotional memories. Specifically, I focus on the understanding process that guides and regulates the formation of emotional memories. I describe the mental inferences and evaluations of an event that lead to the experience of emotion, the types of evaluations children make before they experience specific emotions, and the courses of action they choose, once they express an emotion. I focus on the role that preferences, goals, and violations of expectation play in evoking emotion and planning behavior.

One of my goals is to be able to specify, in fairly precise terms, the nature and origins of very young children's skill at thinking about, remembering, and learning about events that evoke emotion. Research carried out from 1980 to 2000 has changed significantly our conception of the infant and toddler's capability to understand, remember, and respond to events and other people in their world. I argue that from the very beginning, emotional understanding is goal- and preference-based. That is, when young children experience and express emotion, they do so because they have some ability to recognize and respond to events that indicate a change in a goal that they value.