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6 Perception of Unity, Persistence, and Identity: Thoughts on Infants' Conceptions of Objects

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In this chapter, I propose that humans begin life with a conception of material objects. That conception leads infants to perceive certain objects as unitary and bounded. That conception also leads infants to perceive an object as persisting when it moves and changes in certain ways, and to predict whether it will persist over future transformations. Finally, that conception sometimes allows infants to decide whether an object seen now is identical to, or distinct from, one seen in the past.

The conception is this: In the world are things that are wholly interconnected and separate from each other; these things can move through any place not occupied by other things, provided that they move continuously over space and time; and these things persist, maintaining their internal unity and external boundaries, during their unimpeded movements. This conception may underlie not only infants' first perceptions of objects but also their earliest learning. Despite all that humans learn about objects, this conception may continue to stand at the center of our thinking about material objects and physical causality.

This chapter focuses on research of several kinds. It begins with experiments on infants' perception of visible objects as unitary and bounded, for these experiments first led to the view that infants conceive of objects as movable and enduring. Then it turns to experiments on infants' notion that an object persists as it moves, in or out of sight. Although such studies are few in number, they too suggest that young infants conceive of objects as movable and persisting. Finally, the chapter considers infants' knowledge of the identity of an object over successive encounters. The findings of many experiments have been taken to indicate that infants have a different notion of identity (and hence a different conception of objects) than adults. I will suggest, however, that these findings are consistent with the hypothesis that infants and adults have a common notion of physical identity. Since no existing experiment appears to distinguish between these interpretations, some experiments will be proposed.

The chapter closes with a brief discussion of the development of knowledge of objects. In that context, I consider some of the puzzles that surround our intuitions as adults about object unity, persistence, and identity.

UNITY

When we as adults encounter any visual scene, we perceive a layout of persisting objects: Things like rocks, cats, and typewriters. We effortlessly break the scene into stable entities with internal unity and external boundaries. Perceiving objects is no simple accomplishment, however, for the boundaries of things are not reflected straightforwardly in the structure of light at the eye. Any natural scene consists of a three-dimensional arrangement of surfaces. Most of these surfaces are partly hidden behind other surfaces, and almost all of them are adjacent to other surfaces. To perceive objects, we need to decide whether and how adjacent surfaces are connected, and whether and how partly hidden surfaces continue in the places where we cannot see them.

Adults appear to solve these problems in a variety of ways. We sometimes group surfaces into objects in accordance with our knowledge of particular kinds of objects and their characteristic properties. After identifying an object on a table as a telephone, for example, we may judge that the dial and the receiver are parts of it whereas the table surface is not. We also group surfaces into objects in accord with certain general principles of organization, as described by the Gestalt psychologists (Koffka, 1935; Wertheimer, 1923/1958). For example, we may group together surfaces that have aligned edges (principle of good continuation), surfaces that are homogeneous in color and texture (principle of similarity), and surfaces that combine to form objects of simple shapes (principle of good form). Finally, we group surfaces into objects by detecting the spatial arrangement and movements of surfaces in the layout. Surfaces are perceived to lie on a single object if they are connected, directly or via other object surfaces, and if their movements preserve the connections between them.

With a number of colleagues, I have attempted to investigate the origins of these abilities in human infancy. We began by studying infants' perception of partly occluded objects. In these studies, 4-month-old infants were presented with a three-dimensional object whose center was hidden: For example, a tall, thin rod positioned behind a shorter block (Fig. 6.1). We have asked whether, and under what conditions, infants perceive the top and bottom of such an object as connected behind the occluder.

Some of the experiments used a habituation procedure, developed in collaboration with Phillip Kellman (Kellman & Spelke, 1983). Infants were presented

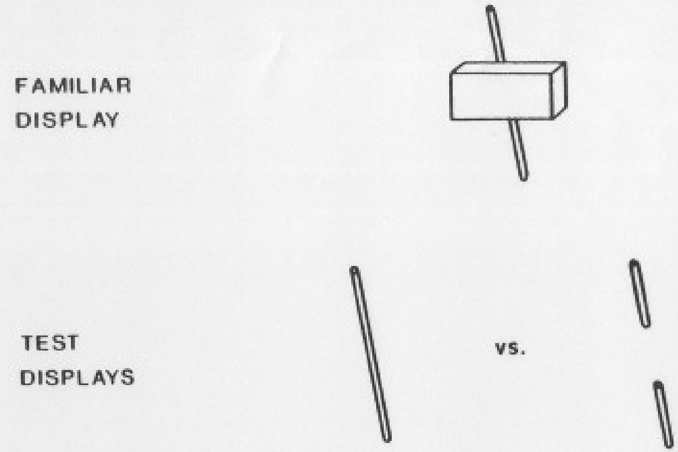

FIG. 6.1. Displays for one experiment on perception of partly occluded objects, using the habituation method (Kellman & Spelke, 1983).

with the partly hidden object repeatedly until their looking time declined, and then they were presented with two fully visible displays in alternation. One test display consisted of a single connected object; the other display consisted of two smaller objects separated by a gap where the occluder had been (Fig. 6.1). Infants were expected to look longer at the test display they perceived as more different from the original, partly hidden object. If they perceived the original object to continue behind the occluder, for example, they should have looked longer at the display with the gap.

Other experiments used a briefer procedure, developed with Hilary Schmidt and Timothy Hrynick, which we call the "disocclusion method" (Schmidt & Spelke, 1984; Termine, Hrynick, Gleitman, & Spelke, 1984). Infants were allowed to look at a partly hidden object for a few seconds, and then the occluder was removed before their eyes to reveal either a complete object or two smaller objects with the gap (see Fig. 6.2). If infants had perceived a connected object behind the occluder, they were again expected to look longer at the display with a gap, because this display was novel and possibly surprising.

With either method, it is necessary to conduct a variety of experiments to ensure that infants will look at the complete and broken objects about equally in the absence of any occlusion, that infants discriminate among all the displays, and that infants attend to the visible surfaces of the partly hidden objects. With the habituation experiments, it is also necessary to ensure that infants will generalize habituation from a display of two objects to a display containing one of those objects, and will dishabituate—increase their looking—when a display containing a different object is presented. Since all these assumptions were found to be correct (see Kellman & Spelke, 1983; Schmidt & Spelke, 1984), I will focus on the findings of the principal experiments.

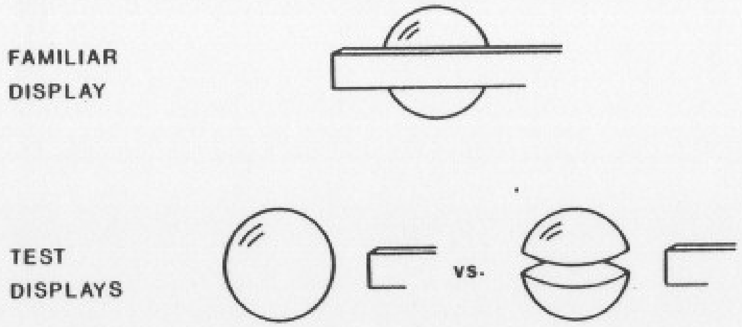

FIG. 6.2. Displays for one experiment on perception of partly occluded objects, using the disocclusion method (Schmidt & Spelke, 1984).

When a partly hidden object is stationary, infants of 4 months do not appear to perceive it either as a single, complete object or as two separate objects. This is so regardless of the object's properties (Fig. 6.3). For example, infants do not perceive three rods arranged in the shape of a triangle as continuing behind an occluder. Adults perceive a compelling connection in this case, in accordance with the principles of similarity, good continuation, and good form (Kellman & Spelke, 1983; Michotte, Thines, & Crabbe, 1964).[1] Moreover, infants do not perceive a solid, regular sphere or cube as continuing behind an occluder, again in contrast to adults (Schmidt & Spelke, 1984). Finally, infants of 4 months do not perceive a photograph of a face as connected behind a block that occludes the ears and nose. Five-month-old infants, in contrast, perceive a unitary face (Schwartz, 1982).

When a partly hidden object moves in certain ways, however, 4-month-old infants perceive the object as a single unit behind its occluder (see Fig. 6.4). Infants perceive the unity of a rod that moves back and forth in a linear translation behind a stationary block, its center never coming into view. They also perceive the unity of a rod that moves in depth; translation in depth appears to be as effective as translation in the frontal plane. The unity of an object is not perceived if it is stationary against a stationary background and only the occluder moves, or if the object and the occluder move together. The experiments suggest that infants perceive partly hidden objects in accordance with a common movement principle (Spelke, 1982; see also Wertheimer, 1923/1958), and that the critical conditions for common movement are that an object change position in the three-dimensional layout, relative to its occluder and relative to the background.

Studies of perception of moving objects provide further evidence that infants do not perceive in accordance with the principles of similarity, good continuation,

[1]The findings of the experiment with infants do not accord with the findings of an experiment by Bower, 1967a, using a similar display.

FIG. 6.3. Displays, methods, and findings of experiments on perception of partly occluded stationary objects by 4-month-old infants. **a.** Reported in Kellman and Spelke (1983). **b.** Reported in Schmidt and Spelke (1984). **c.** This experiment used a slide photograph of a face, rear-projected on a translucent screen behind a three-dimensional occluder. Reported in Schwartz (1982).

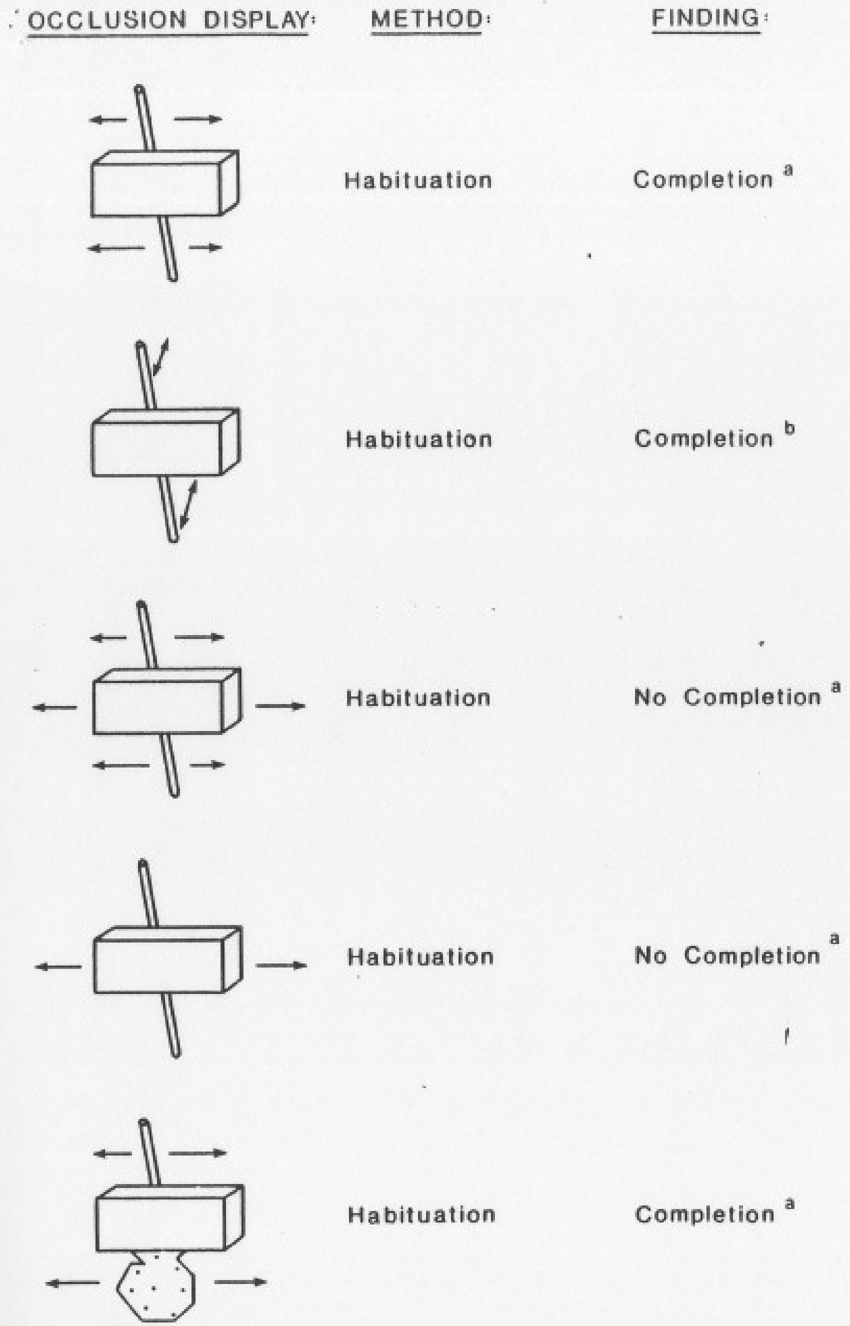

FIG. 6.4. Displays, methods, and findings of experiments on perception of partly occluded moving objects by 4-month-old infants. Arrows indicate the extent and the direction of motion. a. Reported in Kellman and Spelke (1983). b. In this experiment, the motion is in depth. Reported in Kellman and Spelke (1984).

and good form. Perception of the unity of a moving object is not affected by the similarity of its visible surfaces in color and texture, the alignment of its edges, or the simplicity of its overall shape. In contrast, adults perceive the ends of a moving object as more strongly or definitely connected if they are aligned and similar (Kellman & Spelke, 1983). Infants of four months appear to perceive partly hidden objects by detecting the movements of visible surfaces but not by analyzing the colors or forms of surfaces.

The next experiments focused on infants' perception of stationary objects that are adjacent or separated in depth. A number of experiments using looking time and reaching methods have investigated whether 3-month-old infants perceive two objects as distinct when they are touching and/or when one stands in front of the other (von Hofsten & Spelke, 1984; Kestenbaum, Termine & Spelke, 1984; Prather & Spelke, 1982). One experiment conducted with Penny Prather (Prather & Spelke, 1982) will serve to illustrate our findings. In this experiment, we made use of the finding that infants can be habituated to the number of objects or forms in a visual display (Starkey, Spelke, & Gelman, 1980; Strauss & Curtis, 1981). If infants are presented with a succession of different displays of three objects, they will subsequently look less at new displays of three objects than at new displays of two or four objects. Accordingly, Prather and I attempted to induce habituation to displays of one or two objects—solid, rectangular blocks of various sizes and shapes—and then we presented displays of one block, of two blocks that were separated in the frontal plane, of two adjacent blocks, and of two blocks separated in depth (Fig. 6.5). Looking times to the first two test displays should have indicated whether the infants detected, and dishabituated to, a change in number. If they did, looking times to the adjacent objects and to the overlapping objects should have indicated whether each of these displays was perceived as one unit or two.

Only a minority of the infants appeared to dishabituate to a change in number. Among this minority, most of the infants who were habituated to one-object displays looked longer at the blocks separated in depth than at the adjacent blocks; most of the infants who were habituated to the two-object displays looked longer at the adjacent blocks. These findings suggest that the adjacent blocks were perceived as one object and that the blocks separated in depth were perceived as two objects. Observations of infants' reaching for objects (von Hofsten & Spelke, 1984) and of infants' habituation and dishabituation to objects that change position (Kestenbaum et al., 1984) support the same conclusions. Infants evidently do not perceive adjacent objects by analyzing the alignment of their edges or the simplicity of their shapes, in accordance with the principles of good continuation and good form. Infants do appear to perceive objects by detecting the spatial connections and separations of surfaces in a three-dimensional scene. Two objects separated in depth are two objects, whether or not their images overlap at the eye.

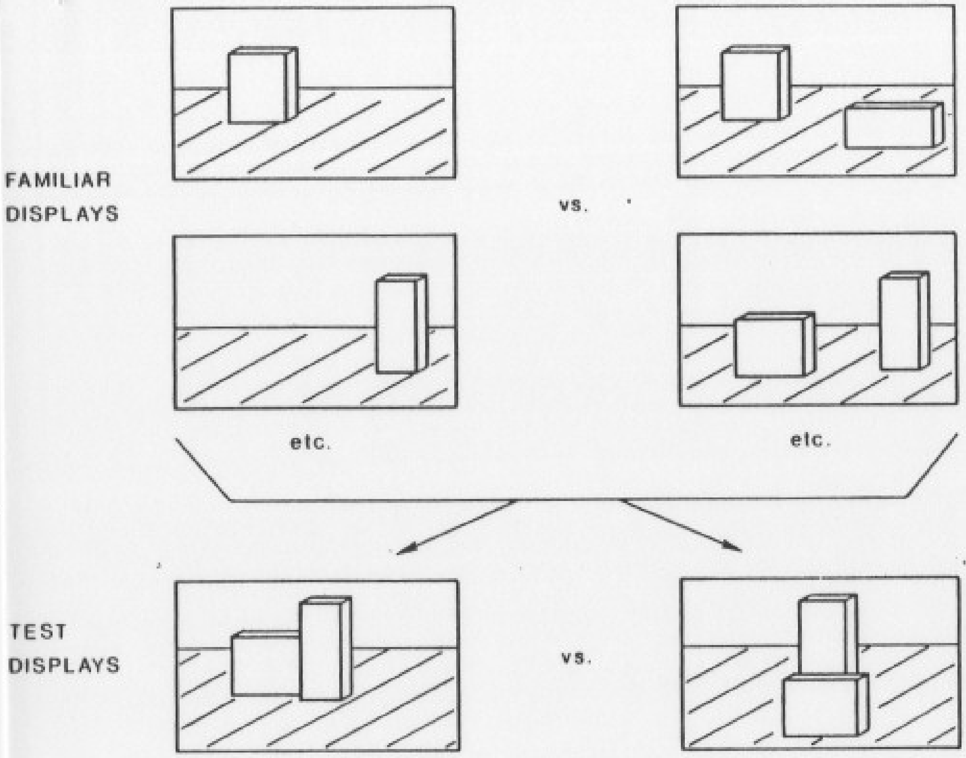

FIG. 6.5. Displays used in an experiment on perception of adjacent objects and of objects separated in depth (Prather & Spelke, 1982).

I discuss further studies of object perception in the next section, but those described already suggest a general account of infants' perception of visible objects (Spelke, 1982). In brief, infants appear to perceive objects by analyzing the spatial arrangements and the movements of surfaces, in accord with two principles. According to the "connected surface principle," any two surfaces lie on the same object if they are touching in the three-dimensional layout, either directly or indirectly through other object surfaces. Two surfaces lie on separate objects if they are separated by empty space. According to the "common movement principle," two surfaces lie on the same object if they undergo the same three-dimensional translation relative to the other surfaces in the scene. Two surfaces lie on separate objects if one moves independently of the other. No other principles are needed to account for the abilities described thus far.

This account is still quite vague, because the existing experiments on object perception leave many questions unanswered. For example, we do not know how extensively surfaces must touch for infants to perceive them as connected. Would an infant perceive a collection of objects as one unit if they touched at

isolated points, as do beads on a string? We also do not know how uniformly two surfaces must move for infants to perceive them as a unit. Would an infant perceive different surfaces as parts of one object if they underwent separate jointed motions, as do the limbs of a walking person? Finally, it is not clear what infants would perceive if the connected surface and the common movement principles were placed in conflict. Is a flock of geese one object for an infant, when its spatially distinct members move in harmony? Is a bicycle one object, with its spatially connected but separately moving parts? In these cases, human adults are prey to conflicting impressions. We can see a necklace either as a unitary object or as a collection of distinct beads; we can see a bicycle either as one object or as an arrangement of separate wheels, pedals, and gears. These problematic cases are especially interesting, and I will return to them.

What capacities give rise to the connected surface and the common movement principles? It is possible that the principles arise from the activity of specifically sensory mechanisms, attuned to certain relationships in a visual array. But I am intrigued by a different possibility, that the infant's perception is guided by a conception of physical objects. Infants may group together surfaces that touch and move together because they conceive of the world as consisting of units that are internally cohesive and separately movable. Infants may fail to group together surfaces that form units with smooth contours and a homogeneous color because they do not conceive of the world as consisting of units that are regular in shape and coloring.

On this view, developmental changes in object perception could result from the growth of conceptions of objects. Adults, unlike infants, may perceive a blue cup and a red plate as two distinct objects when one sits on the other, and as complete objects when each is stationary and partly hidden, because of what we know about plates and cups, and because we know that many objects, particularly artifacts, tend to be homogeneously colored and textured, smoothly contoured, and simply shaped. Children may attain this knowledge as they begin to categorize objects and to learn about their characteristic properties.

PERSISTENCE

Objects often move and change: Matches are struck, balls are bounced, paper is cut, bread is toasted and eaten. As adults, we can often predict whether a given object will persist over a given transformation by using knowledge of particular kinds of objects and events. Knowledge of the properties of particular sorts of objects allows us to predict, for example, that a nail will survive a long fall onto a rock, whereas a crystal vase will not. Knowledge of the effects of particular sorts of transformations allows us to predict that a teacup that will break if it is struck by a hammer but not if it is filled with tea. Some of our predictions about objects, however, may depend on more general notions. We know that all objects persist when they move freely through unoccupied spaces: No unimpeded movement, by itself, will destroy an object's integrity.

If infants conceive of objects as unitary and persisting over displacements, they too should predict that an object will retain its unity and its boundaries as it moves from place to place, provided that no other events occur during these movements. Infants should even expect an object to persist when it travels completely out of view.

Several experiments have probed these expectations by following the logic of an early study by Bower (1965). Bower had investigated whether infants expect a two-dimensional visual form to cohere as it moves. Infants of 1 to 9 months were presented with pictorial displays in which adults perceive a certain organization. Two of the displays consisted of stationary dots or lines; adults group together elements in these displays in accordance with the principles of proximity, good continuation, closure, or good form. The third pattern consisted of two lines moving in a uniform translation; adults perceive the lines as a unit in accordance with the principle of common fate. After the infant subjects viewed a display for 20 seconds while sucking spontaneously on a nipple, there began a new movement that either preserved or broke apart the configurations that adults perceive. If infants perceived the original grouping, and if they expected a group of elements to persist as a unit, they were expected to be surprised by the movement that broke this grouping. A decrease in spontaneous sucking served as the index of surprise. By this measure, infants as young as 2 months were more surprised by the movement that broke the organization in the common fate display than by the movement that preserved this organization. Not until 9 months did the infants appear more surprised by movements that broke the other configurations. Bower's experiment provides additional evidence that young infants organize visual scenes into units in accordance with the principle of common fate and not in accordance with the other gestalt principles. The experiment suggested, moreover, that infants expect a perceived group of elements to retain its unity when it is displaced.

Wendy Smith Born and I used a variant of this method to investigate whether infants expect a three-dimensional object to persist, maintaining its unity and boundaries, over its movements (Spelke & Born, 1984). In the first experiment, 3-month-old infants were presented with a large cylindrical object suspended in front of a uniform background surface. The object and the background differed in color and texture and were well separated in depth (Fig. 6.6). By the connected surface principle, infants should have perceived the object as unitary and separate from the background. Did they expect the object to retain its unity and its distinctness as it moved?

To address this question, the display was presented without movement for 30 seconds, and was then moved in one of two ways. In one condition, the object moved forward as a whole. In the other condition, half the object and an adjacent piece of the background moved forward, leaving the rest of the object

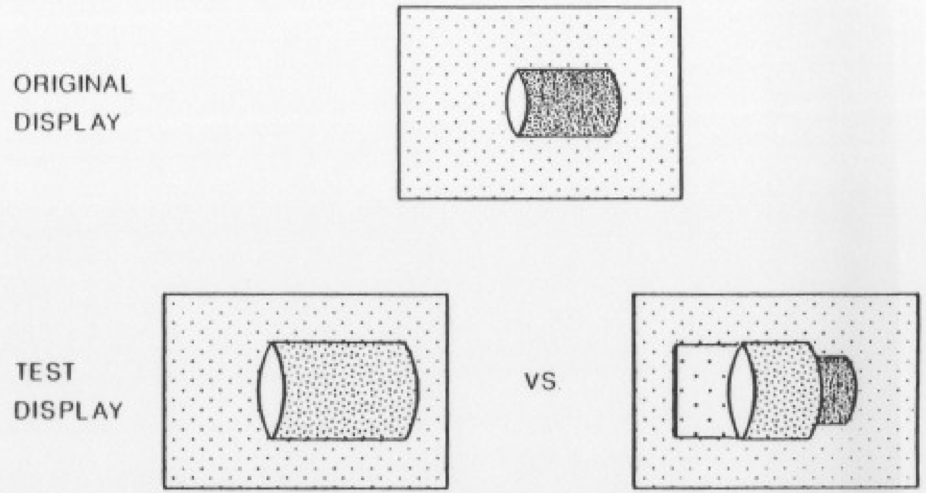

FIG. 6.6. Displays used in an experiment on perception of the unity and persistence of suspended objects (Spelke & Born, 1984). The object and background surface were in the position depicted in the upper drawing during the stationary periods. During the object movement and the broken movement periods, the surfaces moved from that position to one of the two positions depicted in the lower drawings.

and background behind (Fig. 6.6). Infants were presented with both kinds of movement in a counterbalanced order; they were videotaped, and an observer judged when the babies looked most surprised or puzzled (see Spelke & Born, 1984, for details). Infants were judged to be more surprised or puzzled during the movement that broke up the object than during the movement of the object as a whole. This experiment provides evidence that the infants perceived the object as unitary and distinct from the background, and that they expected the object to retain its unity as it moved.

This interpretation was supported by our next experiments. The second experiment differed from the first only in one respect: Infants were presented with the cylindrical object in front of a background of the same color and texture. If infants perceive objects by analyzing the spatial arrangements of surfaces and not by analyzing surface colors and textures, then the infants in this study should have been as surprised by the breakup of the object as were those in the first study. The results of the two experiments were indeed the same.

The findings of the third experiment complemented those of the second. Infants were presented with a single planar surface consisting of two regions: a region of the same two-dimensional shape, size, color, and texture as the object in the first study, and a surrounding region of the same shape, size, color, and texture as the background. The object region either moved as a whole or split in two, half of it moving with a piece of the background region. The infants were judged to respond equally to the two types of movement. They evidently did not organize this surface into areas of homogeneous color and texture.

A second series of experiments, with 6-month-old infants, focused on perception of adjacent objects (Spelke, Born, Mangelsdorf, Richter, & Termine, 1984). Infants were presented with two adjacent objects that differed in color, texture, size, and shape, and that were arranged so that no surfaces or edges of one object were aligned with those of the other (Fig. 6.7). In one condition, the two objects moved forward together. In a second condition, one object moved forward while the other remained at rest. Most of the infants were judged to be more surprised when one object moved alone than when the two objects moved together. They apparently perceived the two adjacent objects as one unit, for they seemed to expect this unit to move coherently.

Despite these findings, a final experiment suggests that the boundary between two adjacent objects has some privileged status for a 6-month-old. Infants were presented with two different breakings of the same configuration of adjacent objects. Either one object moved relative to the other, or half of one object moved together with the other object (Fig. 6.8). The infants were judged to be more surprised by the latter movement. Six-month-old infants may perceive two adjacent objects as one unit, but they are less surprised if this unit breaks in two at the objects' boundary than if it breaks at some other place. Their perception of the object is affected by the colors, textures, and shapes of surfaces. This

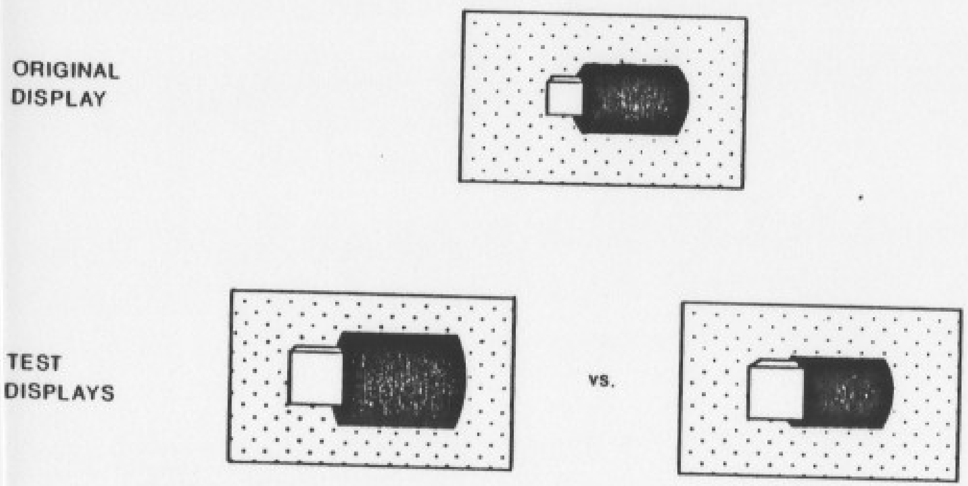

FIG. 6.7. Displays used in an experiment on perception of the persistence of adjacent objects (Spelke, Born, Mangelsdorf, Richter, & Termine, 1984). The objects were in the position depicted in the upper drawing during the stationary periods. During the movement periods, the object(s) moved from that position to one of the two positions depicted in the lower drawings.

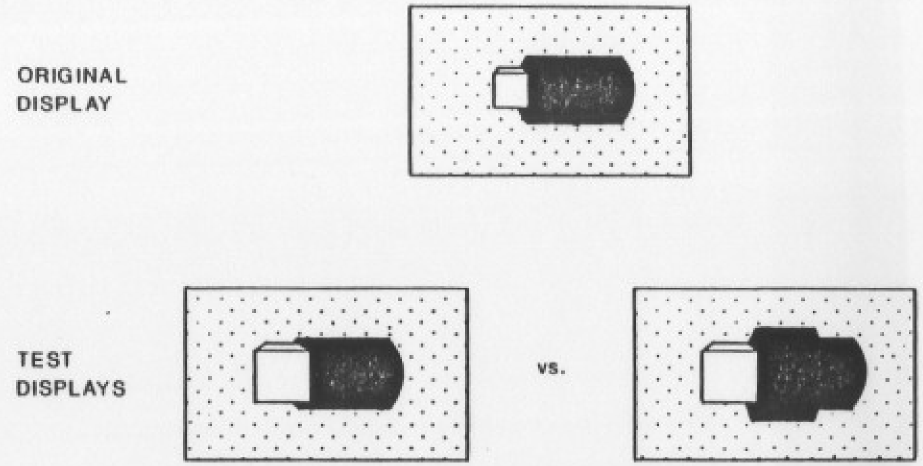

FIG. 6.8. Displays used in an experiment on perception of the boundary between two adjacent objects. (Spelke, Born, Mangelsdorf, Richter, & Termine, 1984). The objects were in the position depicted in the upper drawing during the stationary periods. During the movement periods, the object(s) moved from that position to one of the two positions depicted in the lower drawings.

experiment, like other recent experiments (Bertenthal, Campos, & Haith, 1980; Bresson & de Schonen, 1976–1977; Piaget, 1954; Wishart, 1979), suggests that adherence to the static gestalt principles begins to emerge near 6 months of age.

In summary, infants appear to organize visual scenes into units by detecting the spatial separation of surfaces. They are less apt to organize scenes into units by analyzing the colors or textures of surfaces, the alignments of surfaces and edges, and the shapes of objects. Most importantly, infants appear to expect the units they perceive to retain their coherence and their boundaries as they move. These experiments provide evidence that infants conceive of objects as unitary, as separately movable, and as persisting over their movements.

Experiments have not investigated whether infants expect objects to cohere over other visible transformations: for example, whether infants would be surprised if an object shattered, or failed to shatter, when hit. We also do not know whether infants expect objects to retain other properties through time: for example, whether infants would be surprised if an object suddenly changed its shape or color. As adults, we are sometimes surprised by these events and sometimes not, depending on the particular object and transformation that are involved. The breaking of a doll is less surprising if it is kicked than if it is kissed; a gradual, spontaneous change in shape is more remarkable in a dish than in a dog. It is possible that humans begin life with knowledge of certain kinds of objects and transformations. Infants may distinguish rigid from nonrigid objects, for example, and expect only the latter to deform when squeezed (Gibson, 1982). Nevertheless, it is likely that most expectations about objects and their transformations develop through learning. Infants may learn about particular kinds of object transformations as they perceive objects and follow them through time.

Let us turn to objects that move fully out of view. Do infants expect an object to persist over this change? Most psychologists believe that they do not. According to Piaget (1954), a young infant has no notion that objects endure when out of sight. When an object is occluded and disoccluded, a young infant's experience is of a tableau that is destroyed and created anew. Infants slowly construct a conception of persisting objects over the first 18 months, as they develop the capacity to act on objects in a coordinated manner.

Piaget's proposal is supported by observations of infants' search for hidden objects. A very young infant does not search visually for an object that moves behind a screen (Nelson, 1971; Piaget, 1954), and an infant under about 8 months of age will not remove a cover in order to retrieve an object that is hidden beneath it (Piaget, 1954). The ability to find hidden objects seems to emerge in a succession of stages over the course of infancy (Harris, 1975; Piaget, 1954).

Nevertheless, it is not clear that the development of search for objects results from changes in the child's conception of objects. Reaching and visual following may improve with age, because children become increasingly capable of organizing different actions together in means-ends sequences (Piaget, 1952), and increasingly adept at keeping track of objects and their displacements (Harris, 1975; see also Cornell, 1979; Harris, 1983; Ninio, 1979). It would be desirable, therefore, to investigate infants' knowledge of hidden objects using methods that do not involve visual or manual searching. Two such studies have been conducted, to my knowledge, and both suggest that infants do expect objects to persist when they are fully occluded.

Bower (1967b) trained infants of 2 months to suck for reinforcement in the presence of an object, and then he made the object disappear either by gradual occlusion or by a magical, gradual or sudden dissolving. The infants were expected to continue sucking only if they perceived that the object was still present. Infants continued sucking after a gradual occlusion, but not after one of the other modes of disappearance. Bower concluded that infants perceived the object as persisting when it was occluded but not when it was dissolved.

How did the infants react to the magical events: Were they surprised to see an object dissolve, like Alice's cheshire cat? This question has not been answered. In a further experiment (Bower, 1967b), infants exhibited no drop in spontaneous sucking—one possible index of surprise or interest—during the magical disappearances. No other observations of surprise reactions have been reported.

The second experiment was conducted in collaboration with Renée Baillargéon (Baillargéon & Spelke, in preparation). Baillargéon asked whether infants will make an inference about the possibility or impossibility of an event by drawing

on knowledge about a hidden object. If infants could be shown to make this inference, it would follow that they knew the hidden object continued to exist in the place where it was hidden. Five-month-old infants were presented with a bright yellow block standing on a table, fully in view behind a screen that lay flat on the table. The screen then began to rotate about its far edge, moving upward and toward the block. The screen began to occlude the block as it rotated upward, and the block was fully occluded when the screen had rotated about 70°. By the time the screen had rotated about 120°, it should have made contact with the hidden object. On half the trials it did this, and it stopped moving. On the other trials it continued its rotation through the space that the hidden block should have occupied (Fig. 6.9). If the infants knew that the block continued to exist out of view behind the screen, and if they knew that two physically distinct objects cannot occupy the same place at the same time, then they should have been surprised by the complete rotation but not by the arrested rotation.

Baillargéon assessed infants' surprise by embedding these events in a habituation study. Infants were habituated to a succession of events in which the screen rotated through the full 180° with no block present. After habituation, infants in one group were presented with the same screen with a block behind it, as described. The screen rotated either 120° or 180° on alternating trials. Infants in a second group were presented with the block beside the screen, out of the path of the screen's rotation. The screen moved 120° or 180° on alternating trials, but it never occluded the block or made contact with it. Infants who saw the block next to the screen looked equally long at the display during the equally possible 120° and 180° rotations. The infants who saw the block behind the screen, however, looked longer during the impossible 180° rotation. Although the 180° rotation was superficially the same as the original, familiar event, the infants responded as if this event was novel and/or surprising. It apeared that the infants knew that the block was behind the screen, constraining the screen's movement.

These experiments suggest that infants perceive an object to persist when it moves behind another object. It is not clear whether infants, like adults, expect an object to persist when it disappears in other ways: for example, when it is placed inside a box. It seems possible that infants do not have this expectation,

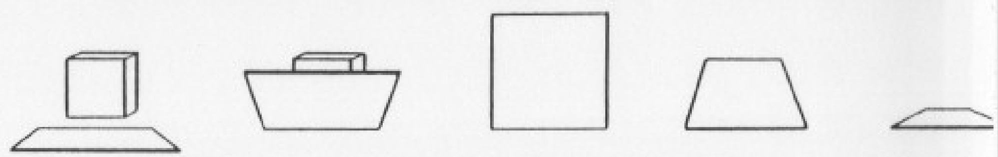

FIG. 6.9. Display used in an experiment on perception of the persistence of a hidden object (Baillargéon & Spelke, in preparation). The screen moved from the first position to the fourth position and back again (normal movement) or from the first position to the fifth position and back again (impossible movement).

for objects sometimes persist when they enter other objects and sometimes do not. Our ability, as adults, to predict the fate of objects that enter caves, mailboxes, incinerators, and mouths probably depends on what we learn about particular kinds of objects and events.

To summarize this section, young infants appear to expect objects to persist under certain conditions. When an object moves within the visual field, infants expect it to move as a whole; they seem to be surprised if a movement changes its boundaries. When an object moves out of sight behind another object, infants expect it to continue to occupy some place; they seem to be surprised if something else moves through the space that the object should occupy. These reactions could stem from an underlying conception of objects as coherent, as separately movable through unoccupied space, and as persisting over their movements.

IDENTITY

When infants encounter an object, do they ever have the notion that the very same object has been encountered in the past? If so, under what conditions does an infant perceive that objects, seen at different times, are identical or distinct?

As adults, our attributions of identity are as commonplace as they are difficult to understand. Sometimes we decide questions of object identity by drawing on knowledge of the stable and variable characteristics of particular kinds of objects. Such knowledge informs us, for example, that a sparkling blue Volkswagen seen today can be the same car as one seen last week if the old car was colored green, but not, most likely, if it was in the shape of a Cadillac. Sometimes we are guided by knowledge about the characteristic life spans of different kinds of objects. We know that an elderly gentleman might be the same individual as a young man encountered many decades ago, but that his bulldog and his lit cigarette almost certainly were not present at that first encounter. Sometimes we bring to bear knowledge about the similarities and distinctions among objects of a given kind. We know that we can identify most people on separate occasions by detecting their unique physical characteristics, but that we can identify few ballpoint pens in this way. Finally, we sometimes decide if an object seen now is identical to one seen in the past by tracing the path of the object in the interval between our encounters with it. If there is a path, continuous in space and time, between "that object then" and "this object now," and if a unitary object moved continuously through every point on that path, then the objects are one and the same. This decision depends on the notion that objects move separately, coherently, and continuously.

Many problems are raised by the view that identity judgments rest on judgments about the continuity of an object through space and time (see Wiggins, 1980). Nevertheless, such continuity seems central to our thinking. If there is a continuous path connecting a bulldog living now with a bulldog that lived in

1930, we would probably conclude that this is the same, extraordinarily old, dog. If there is no continuous path connecting a man seen today with a man seen yesterday, then we would probably conclude that they are distinct people, however, similar they appear. Dramatists sometimes mystify or amuse us by playing with these notions. Two people are presented at different times in the guise of one character, and then they are introduced at times and in places that tax our ability to connect these appearances by a single path. At some point, our imagination gives way, our perceptions shift, and we realize we have been watching two distinct characters all along (e.g., Bernard & Sullivan, 1867).

Young infants also have a basis for deciding questions of object identity if they conceive of objects as separately movable on continuous paths and as persisting over their movements. Infants should consider an object seen now as identical to one seen in the past whenever they perceive that some unitary, persisting thing has followed a continuous path from the first encounter to the second. Infants should consider the objects as distinct whenever they perceive that no such path unites them. On this hypothesis, the core of the adult's conception of object identity traces back to infancy.

No psychologist, to my knowledge, would agree with this conjecture. It is widely believed that humans begin life either with no notion of object identity or with a notion very different from that of adults. According to Piaget (1954), infants do not initially conceive of objects as persisting, external things, and so they could not found a notion of object identity on spatiotemporal continuity. Piaget asserts, in fact, that young infants have no notion of identity for physical objects. According to Bower (1974) and Moore and Meltzoff (1978), young infants have a notion of identity, but it is virtually opposite to the adult notion: An object is identified with a particular position or movement. If a car moved out of a garage and stopped at the end of a driveway, these authors propose infants would perceive at least three distinct objects: the car at rest in the garage, the car moving down the driveway, and the car at rest by the street (see Moore & Meltzoff, 1978). On this view, infants revise their identity concepts a number of times before embracing the notion that an object retains its identity as it moves.

A large number of experiments seem to support one or the other of these views, providing evidence for a radical developmental change in conceptions of object identity. I believe, however, that the findings of this research have been misunderstood. The research is fully consistent with the view that infants resolve questions of object identity by tracing the paths of objects through space and time.

In these experiments, infants are presented with one or two objects on two separate occasions. Reactions to the object(s) are observed, in an effort to determine whether, and under what conditions, infants treat the separate encounters as encounters with a single object. For example, infants have been presented with an object that moved smoothly behind a screen so that it disappeared at one edge of the screen and reappeared at the opposite edge. After infants observed this event repeatedly, a change was introduced: One object moved smoothly out of sight behind the screen, and a second object, of a different shape and color, reappeared at the appropriate time and place. If infants perceived these events as do adults, they were expected to react to the change in some way. Either of two kinds of reaction might be expected. First, adults perceive the first event as involving one object and the second event as involving two objects. Thus infants might perceive the event involving two objects as novel, and they should attend to it. Second, adults perceive the second event as surprising, because an object of one color and shape usually does not appear on the same path, moving at the same speed, as an object of a different color and shape. Infants might respond to the two-object event with signs of surprise.

Infants younger than 5 months show no signs of special interest or surprise when they watch these events. When a single object disappears and reappears, for example, infants are reported to follow the object smoothly. Until 5 or 6 months, infants follow events in the same manner when one object disappears and an object of a different shape and color reappears (Muller & Aslin, 1978; see also Bower, Broughton, & Moore, 1971). Infants also show no distinctive changes in heartrate while viewing events in which one object is substituted for another while the objects are out of sight (Goldberg, 1976), unless the objects are occluded for a very brief time (von Hofsten & Lindhagen, 1983).

In an ingenious experiment, Moore, Borton, and Darby (1978) investigated infants' reactions to a different kind of change in the original one-object event. After infants had viewed one object moving behind a wide screen on repeated trials, they were presented with two narrow screens separated by a gap. The object again disappeared behind the first screen and reappeared from behind the second screen on a series of trials. On half the trials, the object passed between the screens at the appropriate time; on the other trials, it did not. To an adult, the latter event seems to involve two objects and is surprising, because the objects look alike and their movements are coordinated. In contrast, infants of 5 months did not differentiate between the two events. They followed the disappearing and reappearing objects quite smoothly, whether or not an object appeared between the two screens.

These experiments all suggest that infants perceive objects moving in and out of view differently from adults. Infants do not appear to be surprised by events that adults find surprising, and they react similarly to events that adults see as different. It does not follow, however, that infants lack a notion of identity based on spatiotemporal continuity, for the infants in these experiments were presented with events in which it is impossible to determine whether one object has moved continuously. When a white sphere disappears behind a screen and a red cube emerges, adults think it likely that two distinct objects are involved: one that came to a halt behind the screen, and a second that originally stood at rest behind the screen and moved into view. It is possible, however, that a single object

moved continuously behind the screen, changing its size and shape as it moved. When a white sphere disappears behind a screen and a white sphere emerges, we think it likely that only one object is present, but it is possible, again, that there are two distinct spheres. All of these possibilities are consistent with the notion that objects move continuously through space and time. If some of these events surprise us, it is because they violate other notions, such as the notion that inanimate objects tend to move on straight paths at uniform speeds, and the notion that inanimate objects do not often change color or shape. Infants may fail to be surprised when objects are substituted or move strangely, because they lack our knowledge of the ways in which these objects are likely to behave. Like adults, however, infants may conceive of objects as moving continuously through space and time and as persisting over these movements.

How reasonable is the hypothesis that infants judge object identity by tracing an object's continuous movement but not by noting its shape and color? I think it is highly plausible. Consider the quandary of an infant who encounters an object on two separate occasions, and who seeks to decide whether she is encountering one object or two. One cannot make this decision in any general way by analyzing an object's physical attributes. For example, the infant's breakfast plate this morning may look indistinguishable from her dinner plate last night, and yet it is not necessarily the same object. Moreover, her groggy, bed-clothed father may look very different this morning than during the previous evening, yet he is one object all the same. To determine the identity of objects in these cases, one must bring to bear knowledge about particular kinds of objects, their constant and variable attributes, and their unique distinguishing characteristics. Infants seem quite likely to lack this knowledge. If so, they would only be able to decide questions of identity by tracing an object's path of movement.

I suggest, therefore, that there has been no test of the hypothesis that infants attribute identity to an object by tracing its movements through space and time. It should be possible, nevertheless, to test this hypothesis with experiments quite similar to those just described. For example, one could present infants with a variety of object-screen events and investigate linkages between perception of the number of objects in a display and perception of the patterns of movement of those objects. Infants should perceive the object that reappears at one side of an occluder as identical to the object that had disappeared at the other side if, and only if, they also perceive that something moved continuously behind the occluder from one side to the other.

As a second example, one could present infants with an event that is truly inconsistent with the notion that objects move continuously. Infants could be shown that only one object is present in a display. Then a barrier could be introduced and positioned so that the object could not move continuously across the display. Finally, a screen could be lowered in front of the barrier and the standard event could be presented. If infants expect objects to move continuously, they should be surprised when the object disappears at one side of the screen and reappears at the other side. To my knowledge, no such studies have been reported (but see Baillargéon, forthcoming).

To summarize this section, I have presented a hypothesis concerning infants' notions of object identity. Infants perceive an object to maintain its identity if it is displaced as a unit and if its displacement is continuous in space and time. Spatiotemporal continuity may provide infants with their only notion of identity for physical objects. With growth, children will acquire more specific knowledge about particular sorts of objects and transformations, and will thus extend their ability to decide whether an object seen now is identical to one seen in the past. Nevertheless, infants begin with a conception of identity that is shared by us as adults.

THE GROWTH OF CONCEPTIONS OF OBJECTS

This chapter has focused on infants' conceptions of objects, and on the ways in which these conceptions might serve as a basis for perceiving objects, for predicting their future states, and for tracing their identity through time. In closing, I consider how our first notions of objects might figure in the conceptions of unity, persistence, and identity that we hold as adults.

Our conceptions of objects are puzzling. In some circumstances, we have strong and clear intuitions about the boundaries of objects and about the conditions under which objects persist. When we see a car cross a field, we have no doubt that the car is a unitary object, whereas the collection consisting of the wheels of the car and all the grass that touches them is not. We strongly suspect that this car will continue to persist as it moves, provided no other events intervene. As the car advances, we perceive one car that retains its identity over the displacement and not, for example, a succession of different cars, each replacing the one that came before.

Our intuitions falter, however, when they are pursued further. Would we say that the car is one object or many: Is each wheel, for example, a separate object? Would we say that the car persisted if it was burned to a point at which it became undrivable? unrecognizable? Would we say that the car persisted while it was disassembled for repairs or after the mechanic had replaced its tires? its body? every one of its parts? Pressed with such questions, our thinking seems neither clear nor consistent. We are not certain how to answer these questions about cars, and we might answer similar questions quite differently if we were asked about cats or kings. In view of these complexities, some philosophers have concluded that humans have no underlying notions of the persistence and identity of objects (e.g., Hume, 1738/1962). Other philosophers have concluded that we have different notions of persistence and identity for each sort of object in the world, one notion for cups and a different notion for carrots (e.g., Wiggins, 1980). These arguments may apply to our conceptions of the unity of objects as well.

Although I can offer no serious analysis of human notions of unity and identity, I suggest that the preceding conclusions are partly wrong. Human adults have a notion of the unity, persistence, and identity of physical objects that is clear and general. The usefulness of this notion is limited, however: It only serves to single out certain kinds of things in certain kinds of situations. Adults overcome its limitations by calling on special notions about objects of particular kinds. Most, and perhaps all, of these special notions are acquired over the course of development. The general notion, in contrast, is given to humans at the beginning of life. Guided by the general notion, humans formulate their clearest and most certain intuitions about objects. Guided by the special notions, humans extend these intuitions beyond their original limits, at the cost of some certainty and perhaps some coherence.

To see how this mixture of general and specific conceptions might come about, let us return to human infants. Infants, I have suggested, are born with the conception that the world consists of unitary, bounded things that maintain their unity and boundaries over displacements. This conception provides them with a basis for perceiving unitary objects in certain visual scenes, for predicting that such objects will persist under certain conditions, and for determining in certain cases whether an object encountered now is identical to one encountered before. The usefulness of this conception is limited, however, in two general respects.

First, most visual arrays do not provide sufficient information for an infant to decide where an object's boundaries are, whether the object will survive a particular kind of transformation, and whether it is identical to an object seen in the past. If infants are guided only by the conception I have described, they will not perceive the boundaries of stationary, partly hidden objects, and they will perceive the wrong object boundaries when two objects are adjacent, either if the objects are stationary or if they move together. Infants also will not be able to predict whether an object will persist when it enters another object or when it is hit. Finally, infants will not be able to decide questions of object identity, unless they can trace an object's path while it is out of view.

Children could overcome these limitations by learning about the likely characteristics of particular kinds of objects and events. They may learn that any artifact is likely to have uniform coloring and a regular shape (see Brunswik, 1956), and that it is not likely to change color and shape as it moves. They also may learn that a particular sort of object—a car—is likely to have attached wheels and bumpers (see Hirsch, 1976), and that a particular kind of event—an explosion of a certain force and proximity—is likely to blow the car to bits. This learning will allow children to apply their original conception more effectively to the world (Spelke, 1982).

The second limitation of the infant's conception is more serious: That conception does not apply to all things that human adults consider objects. Attached objects, for example, would not qualify as objects if an object must be separately movable. An infant would have no basis for singling out a tree as distinct from the ground, or a mountain as distinct from its neighboring valleys. Unstable or unconnected configurations would also not qualify as objects if an object must be unitary and coherent. An infant could not treat a pile of leaves, a teardrop, or a cloud as one unit.

Similar problems are raised by the notion that an object persists and retains its identity if, and only if, it moves continuously and coherently. There are events that might lead an adult to say that an object has lost its identity even though it remains unitary: for example, the death of a man, the burning of a car, or the melting of a vase into a lump of glass. There are also cases in which an adult might say that an object retained its identity while losing its unity. A pipe is not said to go out of existence, for example, when it is taken apart for cleaning. Finally, there are events in which objects are transformed more radically and yet are considered to persist in some sense. A branch may fall from a tree, or a ship's planks may be replaced one by one, without ending the existence of the tree or ship (see Hobbes, 1650/1839; Hume, 1738/1962).

Because the original conception does not cover these cases, humans may overcome its limitations by enriching that conception with specific notions about objects of particular sorts. How children develop these specific notions, and come to consider an object as "a cat" or "a vase' as well as "an object," is a question fraught with problems (see Armstrong, Gleitman, & Gleitman, 1983). The development of such concepts, however, allows children to extend their notions of unity, persistence, and identity. Children may learn to identify trees in the ground and to perceive their persistence as trees over transformations such as the removal of branches. They may also learn that a pipe continues to exist as a pipe when it loses its integrity as a spatially connected object. But children extend their conceptions, I believe, at a price. The adults' notions of the unity, persistence, and identity of particular sorts of objects do not seem as certain, as clear, or as consistent as the infant's original, more general conception.

In brief, I suggest that we as humans have a general, unlearned conception of objects. Throughout life, we conceive of objects as spatially coherent, as separately movable, and as persisting over their unimpeded movements. But human adults also have many specific, acquired conceptions of particular kinds of objects. Our general and specific conceptions sometimes conflict, and when they do, our judgments about objects become uncertain and confused. This confusion does not reflect the absence of general notions of unity, persistence, and identity. It reflects, instead, our imperfect attempts to extend our general conception beyond its natural bounds.

If these speculations are correct, they would seem to reverse one standard description of cognitive development. On the standard view, humans begin life with highly sketchy and unstructured notions of the world. As we encounter the regularities of the environment and come to act on the world in increasingly systematic ways, we construct representations that are more complete and balanced. On the view I have suggested, humans begin life with at least one notion that is already as coherent as it will ever be: the notion of a physical object. As we attempt to use this notion in order to find objects in particular scenes, however, we discover that we can perceive objects more quickly and effectively by acquiring and using more specific knowledge: knowledge of the likely characteristics of objects of particular kinds. As we confront the complexities of the environment and come to act in increasingly diverse ways, we also develop a need to consider new kinds of things as objects, and to follow new and more specific principles for singling them out and tracing them through time.

These enriched conceptions seem to suit the concerns of human adults rather well. I am not certain, however, that human notions of unity, persistence, and identity ever again attain the coherence of the conception with which we began.

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