Infants' Understanding of the Physical World

A major focus of the research carried out in our lab is infants' understanding of the physical world. As adults, we possess many expectations about how objects move in space and interact with other objects. Which of these expectations do infants share, and how do they attain them? In an attempt to answer these questions, we have been studying infants' understanding of five different types of physical events: *support*, *occlusion*, *collision*, *uncovering*, and *containment* events. The results obtained in each project are detailed below.

Support events

Our experiments on infants' reasoning about support events have focused on simple problems involving a box and a platform. Our results indicate that, by 3 months of age, infants expect the box to fall if it loses contact with the platform (see Figure 1A) and to remain stable otherwise. At this stage, *any* contact between the box and the plat-form is deemed sufficient to ensure the box's stability.

Three developments take place between 3 and 12.5 months of age. First, infants become aware that the *type* of contact between the box and the platform must be taken into account when judging the box's stability. Infants initially assume that the box will remain stable if placed either on the top or against the side of the platform. By 4.5 to 5.5 months of age, however, infants come to distinguish between the two types of contact and recognize that only the former ensures support (see Figure 1B). The second development is that infants begin to appreciate that the *amount* of contact between the box and the platform affects the box's stability. Initially, infants believe that the box will be stable even if only a small portion (e.g., the left 15%) of its bottom surface rests on the platform (see Figure 1C). By 6.5 months of age, however, infants expect the box to fall unless half or more of its bottom surface lies on the platform. Finally, the third development is that infants come to recognize that the overall *shape* of the box affects its support. Prior to 12.5 months

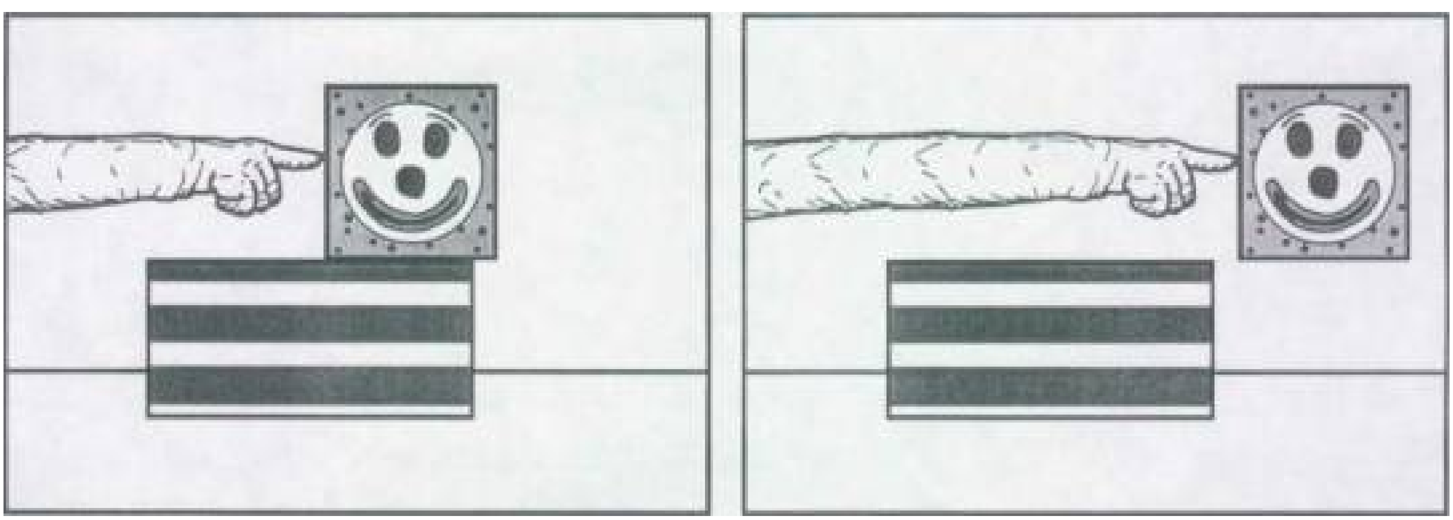


Figure 1A

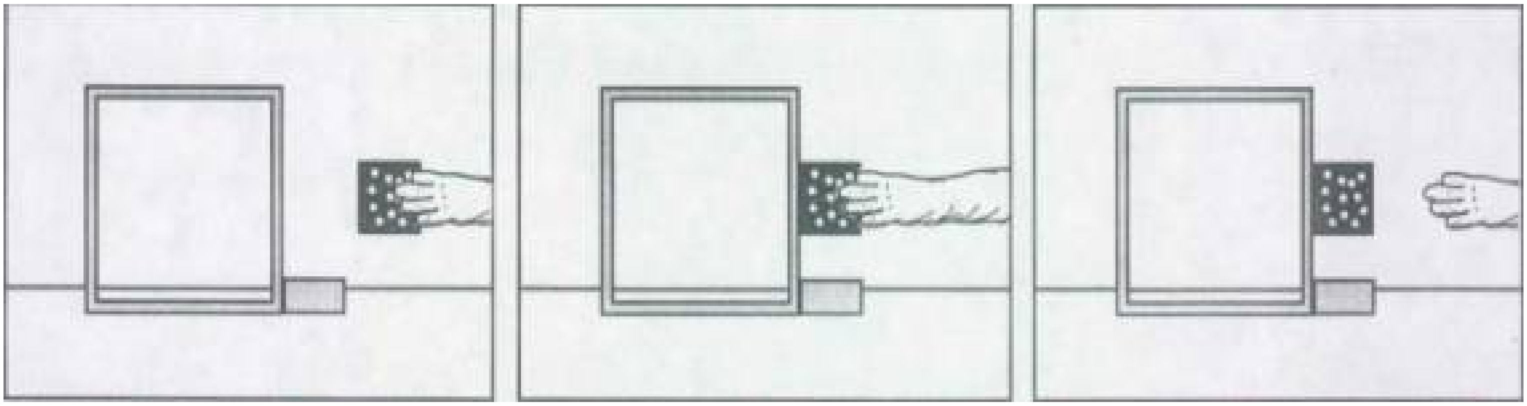


Figure 1B

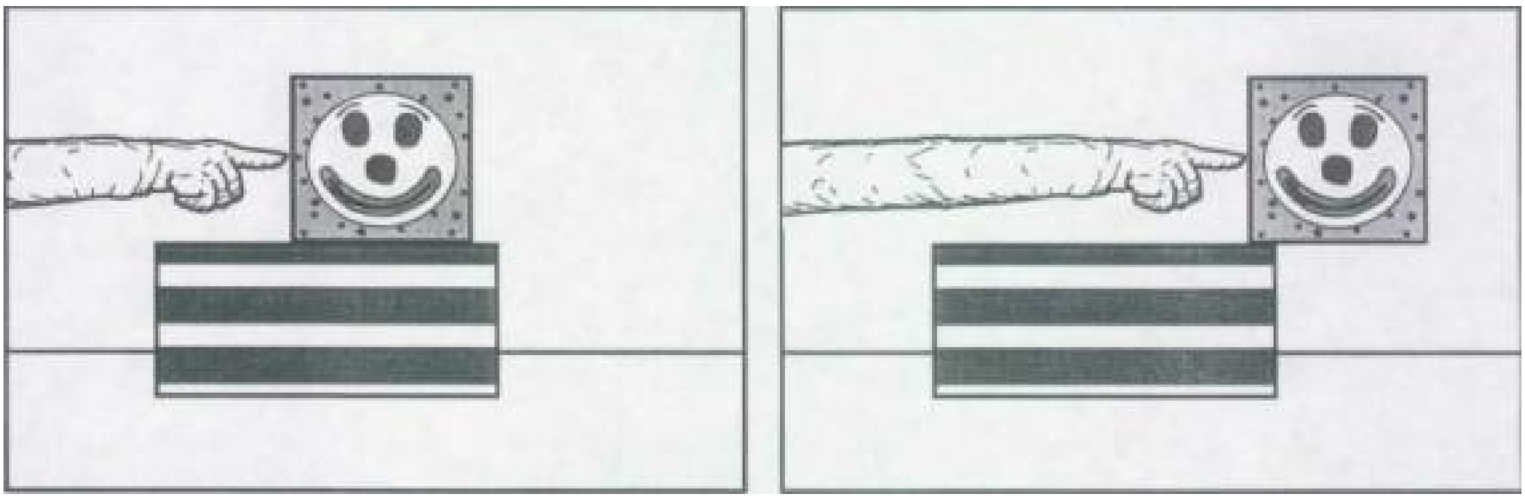


Figure 1C

of age, infants treat symmetrical and asymmetrical boxes alike: they assume that an L-shaped box will be stable as long as half or more of its bottom surface lies on the platform (see Figure 1D). At about 12.5 months of age, infants begin to take into account a box's overall shape or weight distribution in making judgments about its support; they judge the L-shaped box to be stable when the heavier but not the lighter portion of the box rests on the platform.

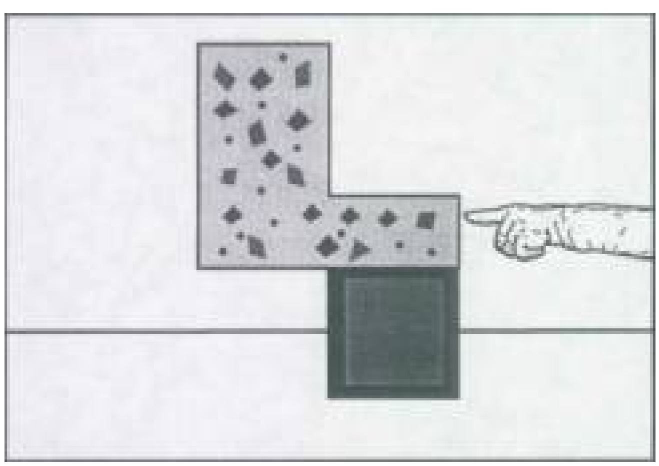


Figure 1D

Further results: Why does infants' knowledge of support events develop according to the sequence described above? We suspect that what infants learn when depends on the nature of the data available to them. Thus, it seems likely that 3-month-old infants have already learned that objects fall when released in midair because this expectation is consistent with countless observations (e.g., watching their caretakers drop peas in pots, toys in baskets, clothes in hampers) and manipulations (e.g., noticing that their pacifiers fall when they open their mouths) available from birth. Similarly, we assume that it is not until 6.5 months that infants begin to appreciate how much contact is needed between objects and their supports because it is not until this age that infants engage in the type of manipulations required to learn about this variable. Researchers have reported that the ability to sit without support emerges at about 6 months of age; for the first time, infants may have the opportunity to sit in front of tables (e.g., on a parent's lap or in a high-chair) and to deposit objects such as cups, spoons, and rattles on the tables. In the course of these manipulations, infants may note that objects tend to fall unless a significant portion of their bottom surfaces is supported.

In the natural course of events, infants would be unlikely to learn from observation alone that the amount of contact between an object and its support matters, because caretakers rarely deposit objects on the edges of surfaces (it is only by accident that we release objects on the edges of tables and counters). But what if we deliberately *showed* infants that objects fall when supported only at their edges? Would they be able to learn about this variable from observation alone? To explore this question, we have begun a "teaching" experiment with 5-month-old infants. Infants first receive training trials in which whey watch a hand place a box on a platform. On half of the trials, the box is placed on the edge of the platform and falls when released; on the other trials, the box is placed fully on the platform and remains stable when released. Following these training trials, we test to see whether infants have developed an expectation that objects fall when only a small portion of their bottom surfaces is supported. Our results so far are extremely encouraging and suggest that we *can* teach infants this fact about support!

Emboldened by these results, we have begun a second teaching experiment in which we attempt to teach 11-month-old infants that asymmetrical boxes are not like symmetrical boxes, and that when judging the stability of an asymmetrical box one must take into account the entire box, not just its bottom surface. Though preliminary, our results are here again very encouraging.

Now you see it, now you don't:

Occlusion events

Our experiments on occlusion or hiding events have focused on simple problems involving a toy (a Minnie Mouse doll) that moves back and forth along a track; portions of the track are hidden either by two screens placed a short distance apart (see Figure 2A) or by a single screen with a large door-way in its center (see Figure 2B). Our results indicate that, by 2.5 months of age, infants are surprised, as Minnie moves from one end of the track to the other, if she fails to appear between the two screens; infants show no surprise, however, if Minnie does not appear in the screen doorway. These results suggest that infants at first expect objects simply to be hidden *behind* occluders and to be visible *between* occluders; at this stage infants are still unable to take into account the structure of occluders (e.g., the presence of doorways or windows) to predict whether objects should be visible at any time during

Possible Event **Impossible Event**

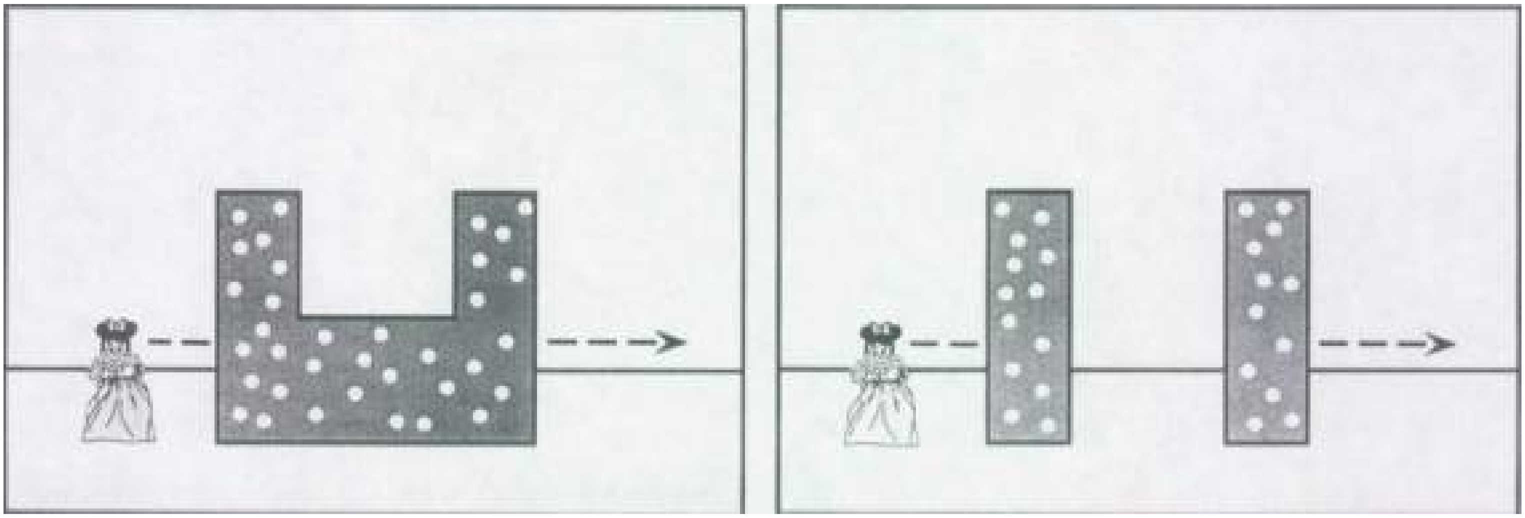


Figure 2A

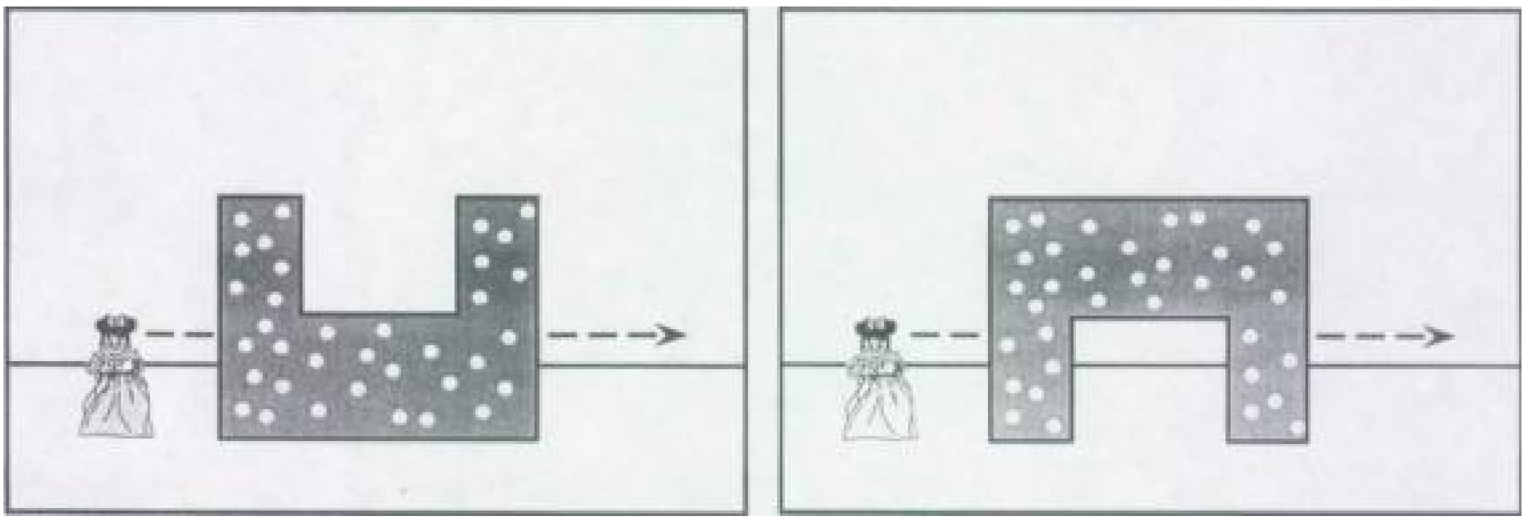


Figure 2B

their passage behind the occluders. By 3 months of age, however, infants are already able to consider occluders' structure in making predictions: the 3-month-old infants we tested were clearly surprised when Minnie failed to appear in the screen doorway.

Further results: In addition to testing 3-month-old infants in our doorway task, we also tested 3.5-month-old infants. To our surprise, we found that these older infants were not surprised when Minnie failed to appear in the screen doorway. We eventually realized that these infants were not surprised by our impossible event because they immediately guessed how it was produced. Specifically, they understood that two identical Minnies were involved in the event, one traveling to the left and the other to the right of the doorway. It is rather odd to be cast by 3.5-month-old infants in the position of inept magicians who fail to draw gasps of surprise from their audience because their tricks are too readily understood!

In addition to our Minnie studies, we have recently begun other studies that focus on a different aspect of infants' understanding of occlusion events. These studies ask whether 7.5-, 9.5-, and 11.5-month-old infants are able to judge how many objects can hide simultaneously behind one screen. In one condition, for example, infants see a large green ball move along a track and disappear behind the left edge of a screen; a few seconds later a large red box appears at the right edge of the screen. Our results show that infants show surprise at this event only when the screen is too narrow to allow the ball and the box to both stand side by side behind the screen. When the screen is fairly large, infants, like adults, immediately conclude upon seeing the box, that the ball stopped behind the screen. By 7 months of age, infants are thus able to use the width of two objects to determine whether they can simultaneously hide behind the screen.

What should they do when hit?
Collision events

Our experiments on infants' reasoning about collision events have focused on simple problems involving a moving object (a cylinder that rolls down a ramp) and a stationary object (a large wheeled toy bug resting on a track at the bottom of the ramp). Adults typically expect the bug to roll down the track when hit by the cylinder. When asked *how far* the bug will be displaced, adults are generally reluctant to hazard a guess (they are aware that the length of the bug's trajectory depends on a host of factors about which they have no information). After observing that the bug rolls to the middle of the track when hit by a medium-size cylinder, however, adults readily predict that the bug will roll farther with a larger and less far with a smaller cylinder made of identical material.

Our experiments indicate that, by 2.5 months of age, infants already possess clear expectations that the bug should be displaced when hit by the cylinder (see Figure 3A), and should remain stationary when not hit (e.g., when a barrier prevents the cylinder from contacting the bug; see Figure 3B). However, it is not until 5.5 to 6.5 months of age that infants are able to judge, after seeing that the medium cylinder causes the bug to roll to the middle of the track, that the bug should roll farther with the larger but not the smaller cylinder (see Figure 3C). Younger infants are not surprised to see the bug roll to the end of the track with either the larger or the smaller cylinder, even though (a) all three of the cylinders are simultaneously present in the apparatus, so that their sizes can be readily compared, and (b) the infants have no difficulty remembering that the bug rolled to the middle of the track with the medium cylinder. These results suggest that, prior to 5.5 to 6.5 months of age, infants are unaware that the size of the cylinder can be used to reason about the length of the bug's trajectory.

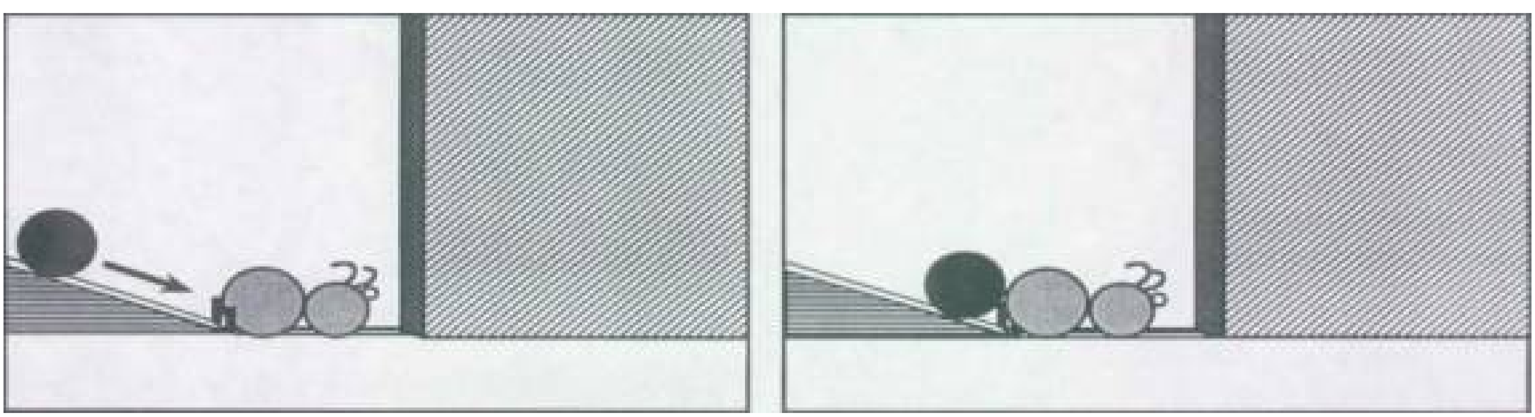


Figure 3A

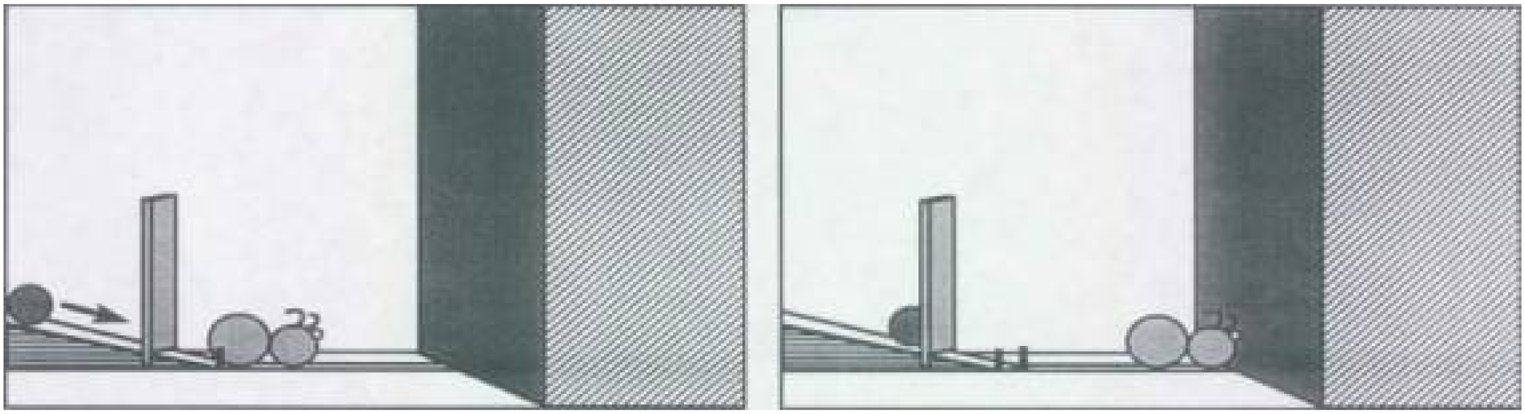
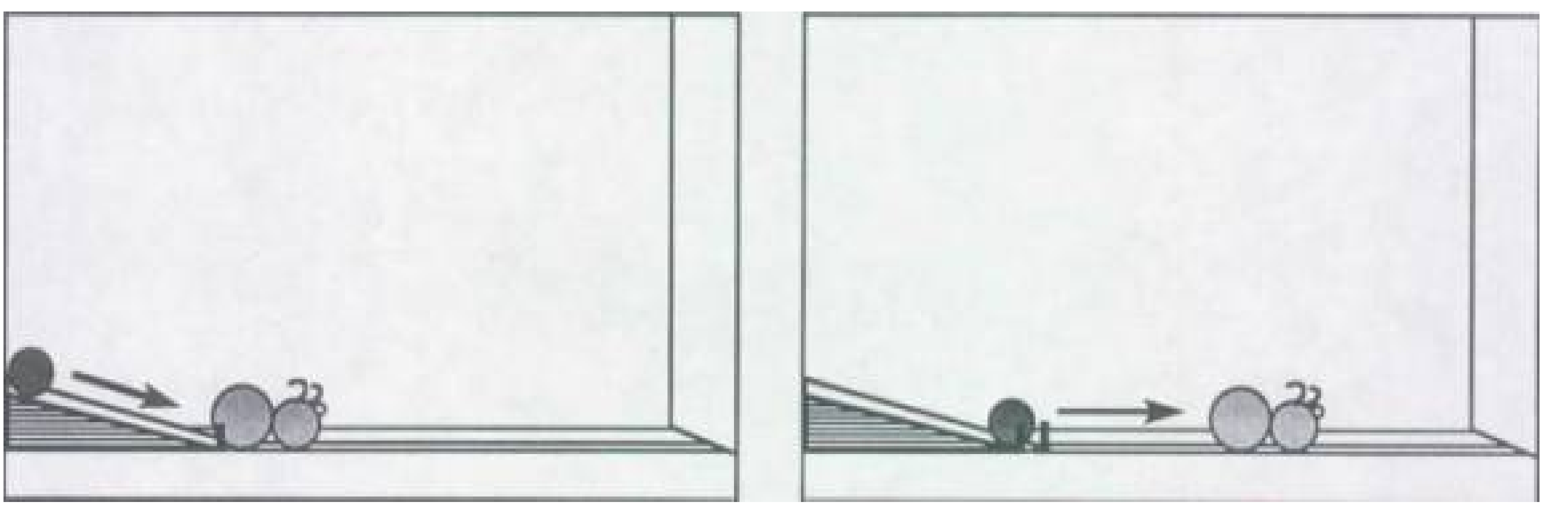


Figure 3B

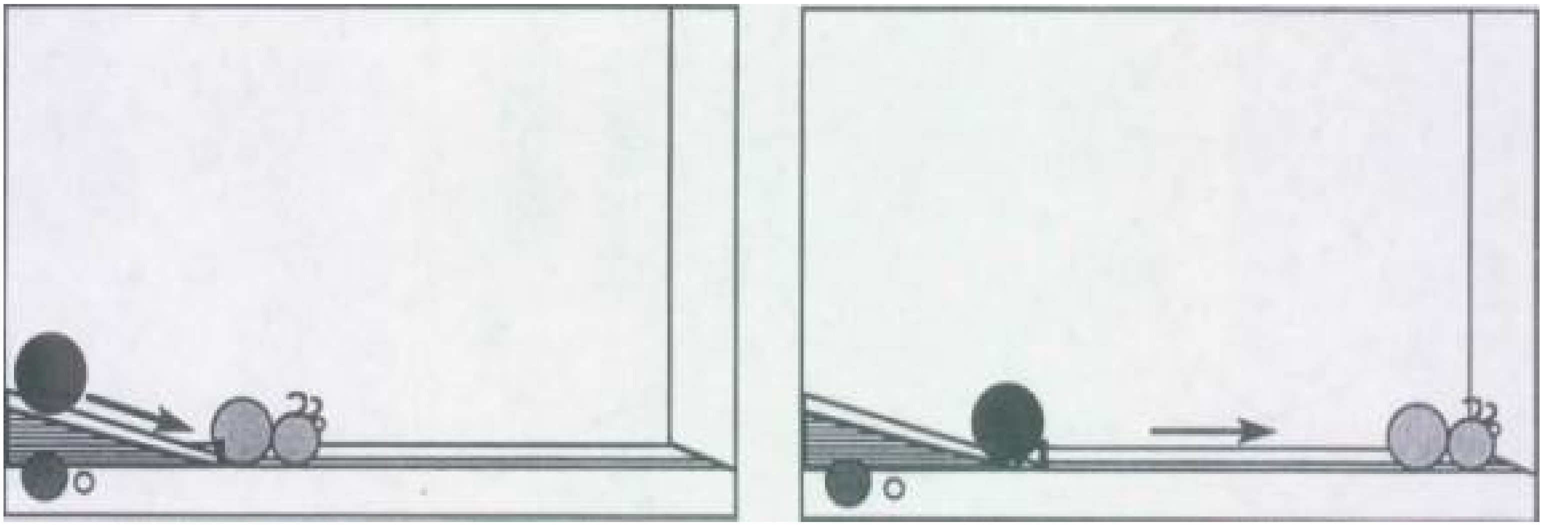
Further results: As was described above, it is not until 5.5 to 6.5 months of age that infants realize that the size of the cylinder affects the length of the bug's trajectory. One unexpected aspect of our results with this age group was that the infants were able to reason about the sizes of the cylinders only when all three were laid out side by side at the start of each event, making it possible for the infants to compare the cylinders' sizes in a singe glance. The infants failed the task when they were shown only one cylinder at a time and hence had to rely on their memory of the medium cylinder to determine whether the cylinder before them was smaller or larger than previously. By 7.5 months of age, however, infants no longer had difficulty remembering the size of the medium cylinder and correctly predicted how far the bug should roll with the small and the large cylinders regardless of whether the cylinders were laid out side by side.

Habituation Events



Test Events

Large-cylinder Event



Small-cylinder Event

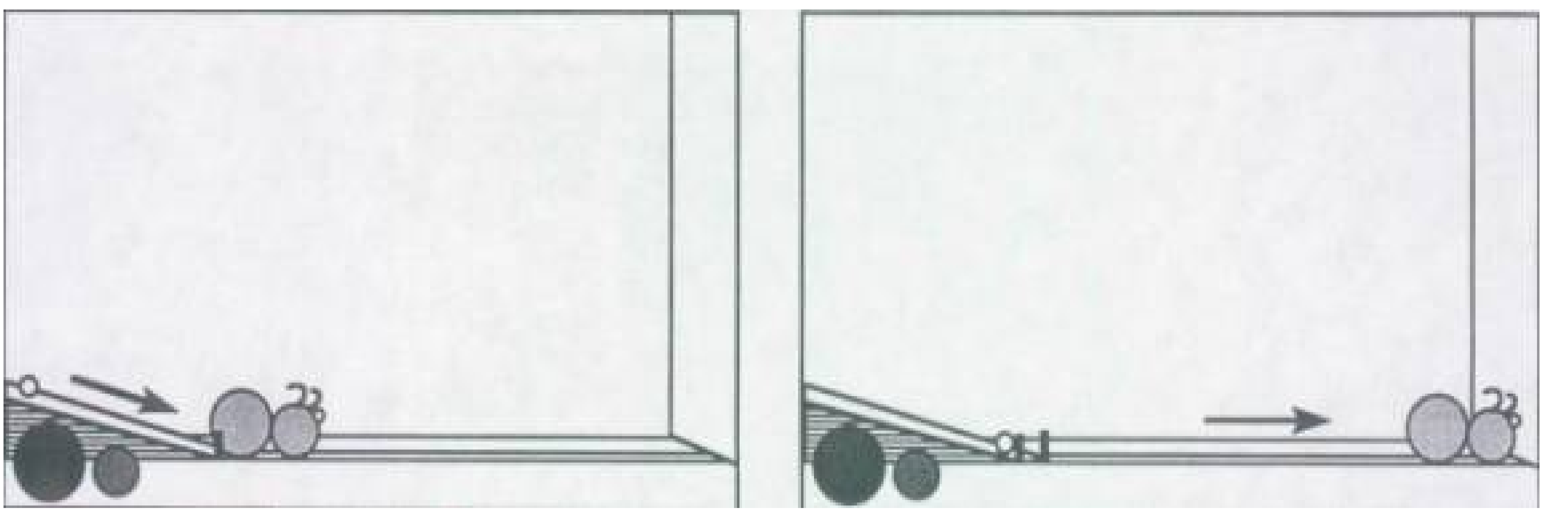


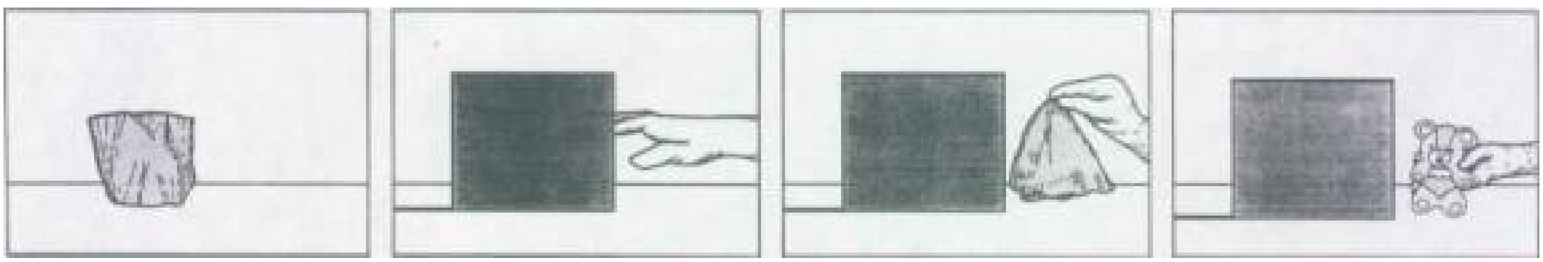
Figure 3C

What's hiding under them?
Uncovering events

Our experiments on uncovering events have involved problems in which a malleable cloth cover is removed to reveal an object. Our results indicate that, by 9.5 months of age, infants realize that the presence (or absence) of a protuberance in the cover signals the presence (or absence) of an object beneath the cover. Infants are surprised to see a toy retrieved from under a cover that displays a marked protuberance (see Figure 4A).

At this stage, however, infants are not yet aware that the size of the protuberance in the cover can be used to infer the size of the object beneath the cover. When shown a cover with a small protuberance, they are not surprised to see either a small or a large toy retrieved from under the cover. Furthermore, providing infants with a reminder of the protuberance's size has no effect on their performance. In one experiment, for example, infants saw two identical covers placed side by side; both covers displayed a small protuberance (see Figure 4B). After a few seconds, a screen hid the left cover; the right cover remained visible to the right of the screen. Next, a hand reached behind the screen's right edge twice in succession, reappearing first with the cover and then with a small (possible event) or a large (impossible event) toy dog. Each dog was held next to the visible cover, so that their sizes could be readily compared. At 9.5 months of age, infants judged that either dog could have been hidden under the cover behind the screen. At 12.5 months of age, however, infants showed reliable surprise at the large dog's retrieval.

Possible Event



Impossible Event

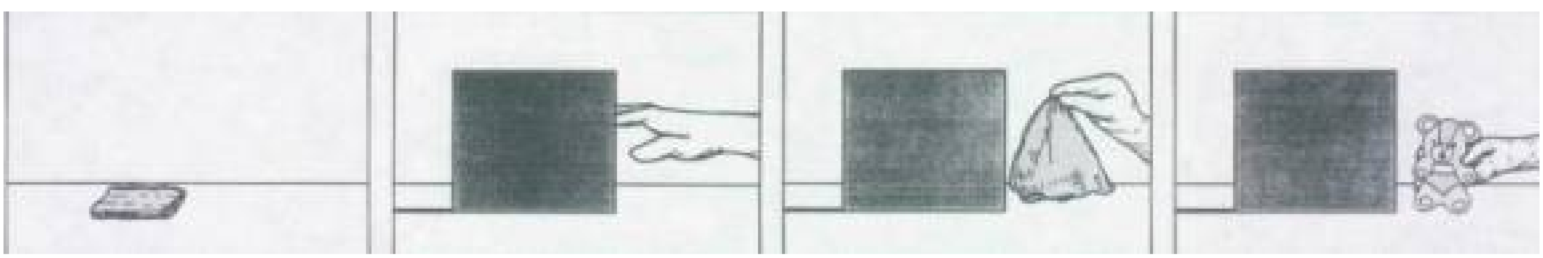
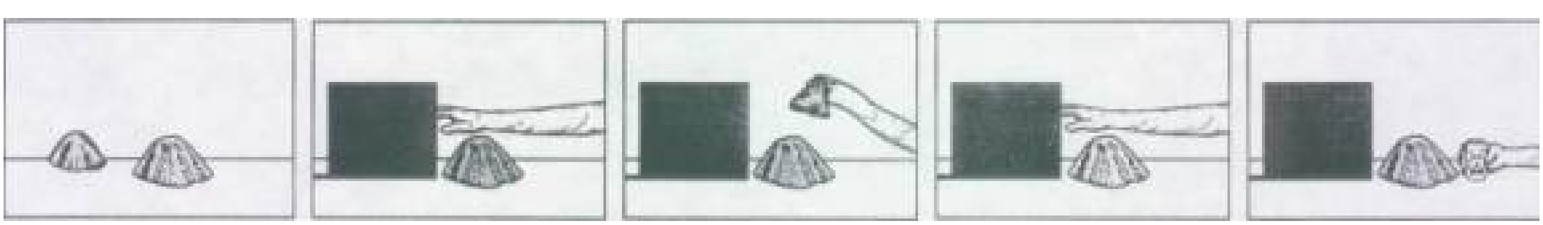


Figure 4A

Further results: We have just seen that 12.5-month-old infants are surprised when a large dog is retrieved from under a cover with a small protuberance and is held next to a second, identical cover. In subsequent experiments, we found that infants showed no surprise at the large dog's retrieval if the second cover was absent so that the infants were forced to rely on their memory of the cover behind the screen to judge whether it could have been hiding the large dog. Additional results revealed that by 13.5 months infants no longer require the second cover to succeed at the task: they have no difficulty remembering the size of the protuberance in the cover behind the screen and judging whether the small or the large dog could have been hidden beneath it.

Possible Event



Impossible Event

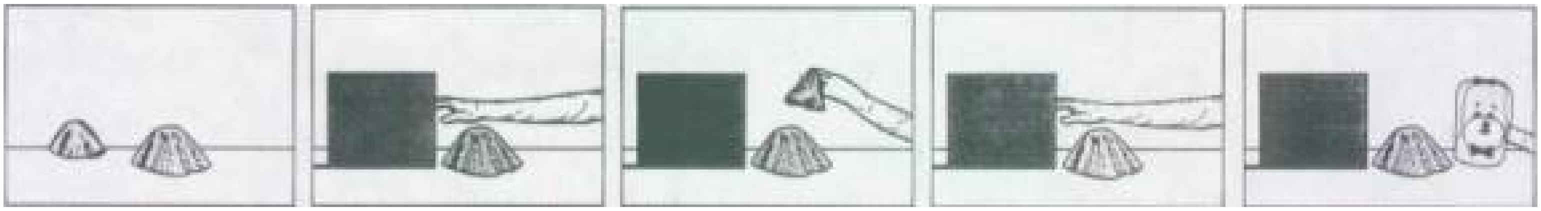


Figure 4B

Containment Events

Our experiments on infants' understanding of containment events suggest that, by 5.5 months of age, if not sooner, infants understand that an object can serve as a container only if (a) it is open at the top, to permit insertion, and (b) it is closed at the bottom, to provide support. However, at this stage, it is still unclear whether infants realize that the size of an object, relative to that of a container, can be used to predict whether the object can be inserted into the container. In one experiment, we found that 5.5-month-old infants are not in the least surprised to see a large, solid ball inserted into a much narrower container (see Figure 5). By 6.5 months of age, however, infants show surprise at such an event, suggesting that they are aware that the size of the ball relative to that of the container determines whether the one can fit into the other.

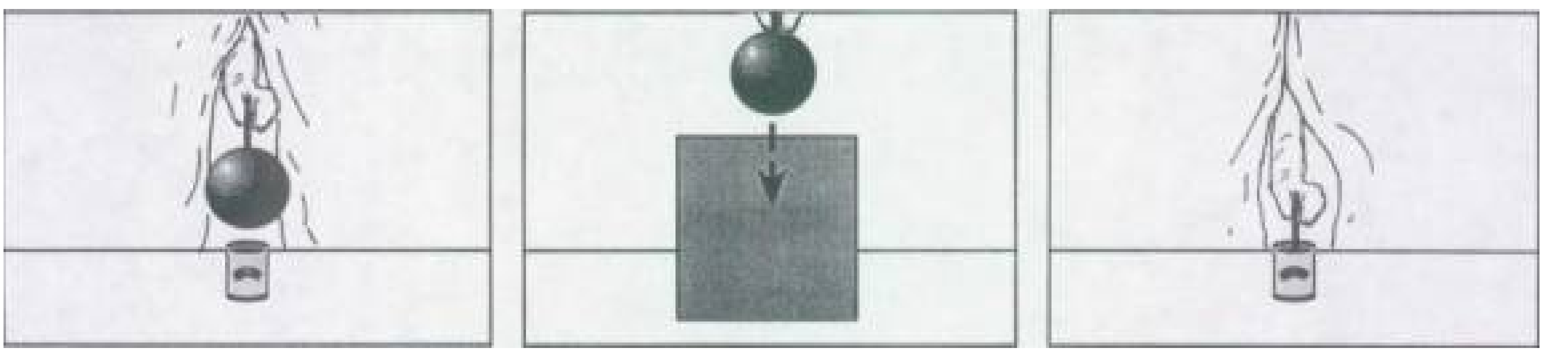


Figure 5

Further results: In the experiment described above, 6.5-month-old infants were able to compare in a single glance the size of the ball to that of the container. In another experiment, infants were prevented from doing so through the introduction of a spatial gap (e.g., the ball and the container were too far apart to be directly compared) or a temporal gap (the infants saw first the ball and then the container). Under these conditions, infants were no longer able to judge whether the ball could fit into the container, suggesting that being forced to rely on their memory of the ball's size impairs infants' performance in the task. By 8.5 months of age, however, infants are successful whether or not they are able to compare in a single glance the size of the ball to that of the container.

Infants' Categorizations of Objects

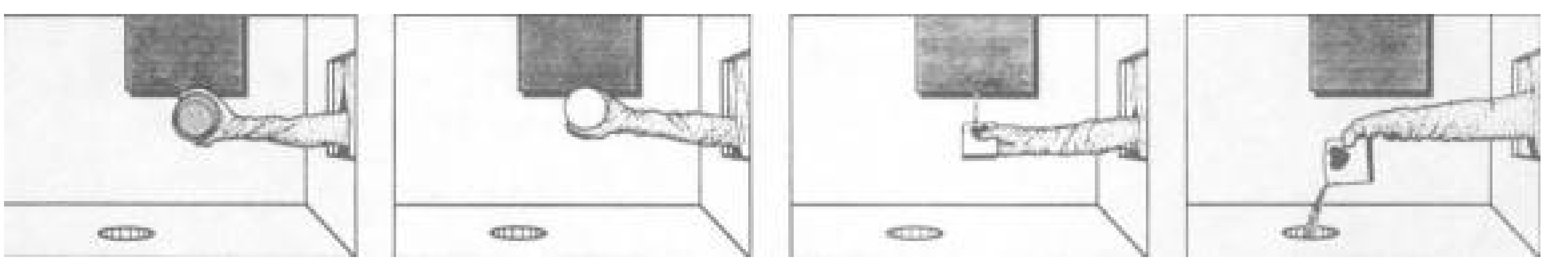
Another focus of the research going on in the lab has been infants' ability to categorize objects. As adults, we are able to group objects into perceptual or functional categories; for example, we would have no difficulty sorting objects on the basis of their size, shape, or color (perceptual categories), or on the basis of whether they could function as containers, doorstops, or hammers. Are infants, like adults, able to detect functional as well as perceptual similarities between objects? Two projects were conducted to address this question.

Sorting objects into those that can and cannot contain

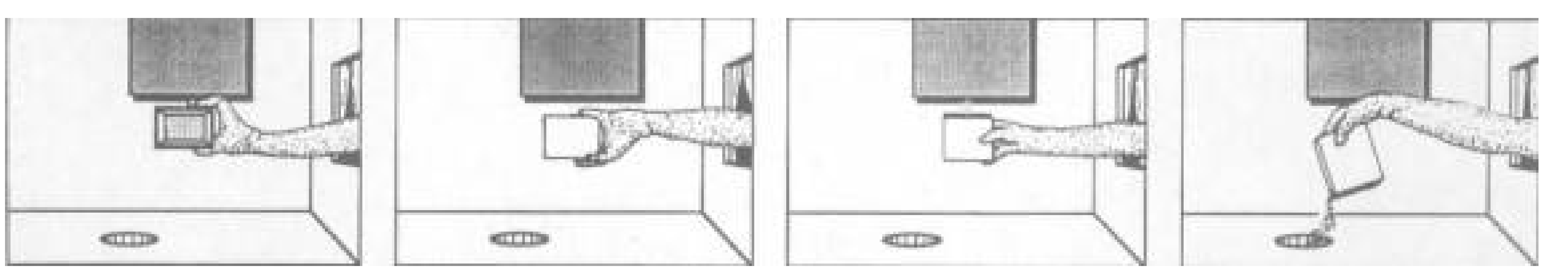
In a series of experiments, 5.5-, 8.5-, and 10.5-month-old infants watched three familiarization events in which salt was poured into a container; the infants could see a stream of salt enter the top of the container, and none fall out of the bottom (see Figure 6). A different container was used in each of the three familiarization events; all three were cylindrical, brightly colored, and decorated with geometric shapes. Next, the infants saw two test events that were identical to the familiarization events except that novel objects were used. One object was similar to the familiarization objects in function but not in appearance: it consisted of a rectangular box open at the top and covered with pastel contact paper. The other object was similar to the familiarization containers in appearance but not in function: it was cylindrical, bright yellow, and decorated with black diamonds; however, it appeared to have no bottom and hence should not have been able to contain the salt that was poured into it.

We found that the 10.5-month-old infants attended mainly to the functional properties of the test objects: they tended to focus on the fact that the tube could not function as a container, and to ignore the fact that the box differed in appearance from the familiarization containers. In contrast, the 5.5-

Familiarization Event



Box Event



Tube Event

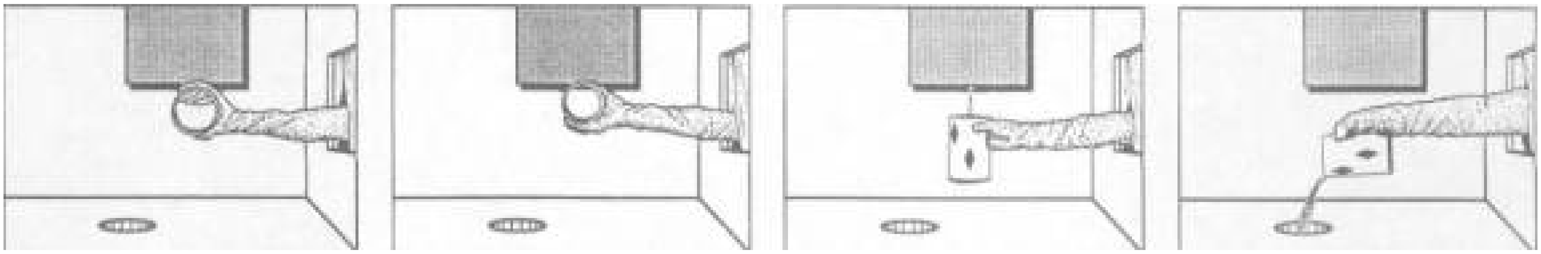


Figure 6

and 8.5-month-old infants tended to focus mainly on the perceptual properties of the test objects: they attended solely to the box's novel appearance, dismissing the fact that the tube lacked the necessary bottom to function as a container.

Why did the younger infants focus merely on the perceptual properties of the test objects? One possibility is that young infants are generally more likely to be captured by perceptual than by functional similarities among objects. Another possibility is that infants pay little attention to the functional properties of objects until they themselves start using the objects functionally. An infant who uses containers daily- to drink juice, eat cereals, or play with bathwater- may find the sight of a bottomless object containing salt far more interesting than a younger infant who rarely manipulates containers; it is not entirely surprising that such a younger infant would find marked perceptual differences between objects more salient than subtle functional differences.

Sorting objects into those that can and cannot permit insertion

In another series of experiments, 10.5-, 11-, and 11.5-month-old infants watched three familiarization events in which a rod was pushed through a box with a large hole at its center (see Figure 7). A different box was used in each of the three familiarization events; all three were rectangular, pastel-colored, and decorated with fringes. Next, the infants saw two test events that were identical to the familiarization events except that novel objects were used. One object was similar to the familiarization objects in function but not in appearance: it consisted of a cylindrical box with a large opening that was covered with brightly lined contact paper and colorful sequins. The other object was similar to the familiarization containers in appearance but not in function: it was rectangular, pastel colored, and decorated with a fringe. However, it had no opening so that the experimenter should not have been able to push a rod through it.

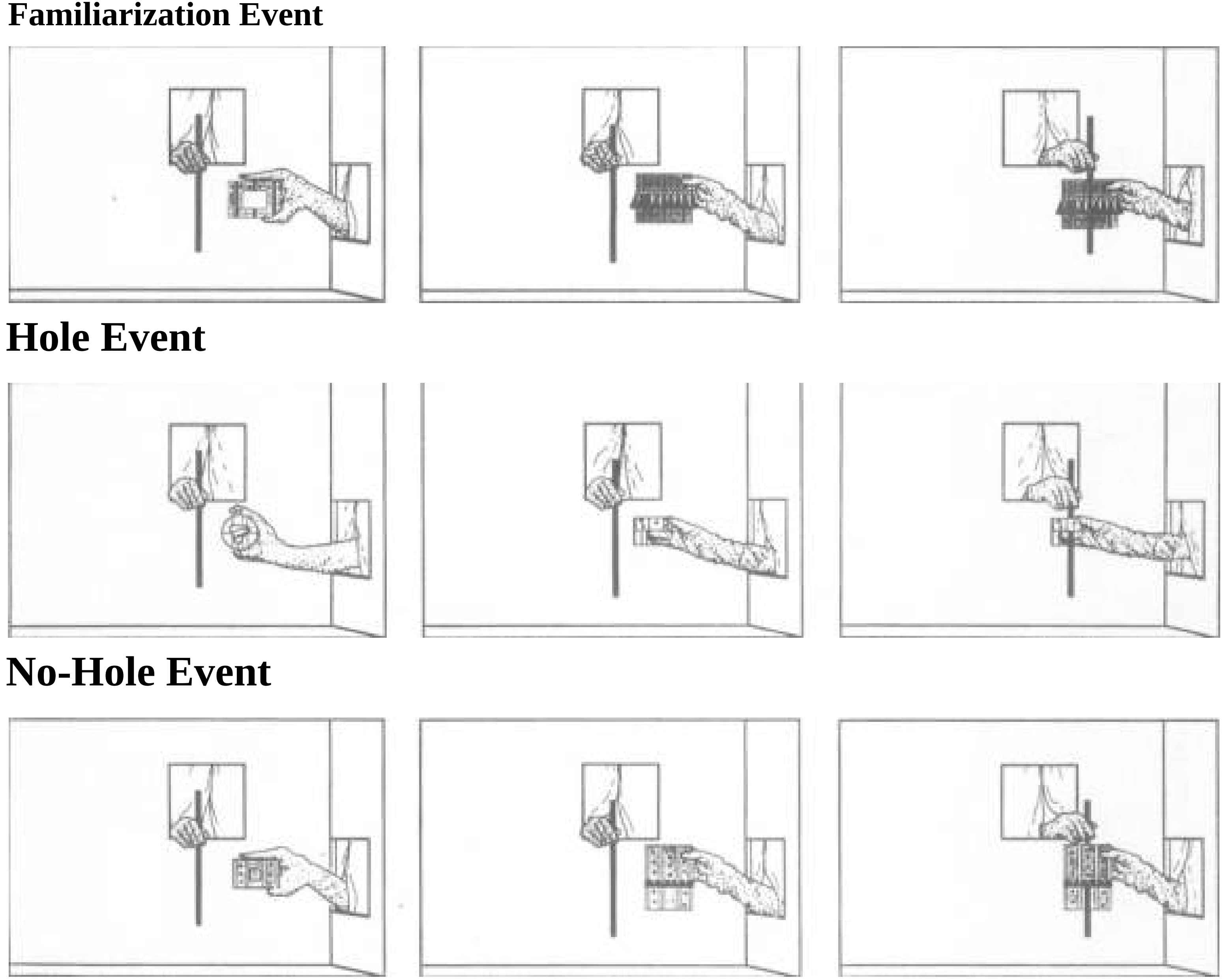


Figure 7

Our 11.5-month-old infants attended to the functional properties of the test objects: they tended to dismiss the fact that the cylindrical test box was novel in appearance, and to focus instead on the fact that the rectangular test box lacked an opening and thus should not have functioned as did the other boxes. Unlike these older infants, the 10.5- and 11-month-old infants were more likely to be captured by the novel appearance of the cylindrical test box; they showed little or no surprise at the rod's insertion into the closed, rectangular test box.

Why did the younger infants focus on the perceptual rather than on the functional properties of the boxes? One possibility was that these infants did not understand that a rod cannot be pushed through a box with no opening. However, a control experiment ruled out this interpretation. A second possibility, is once again, that infants attend to the functional rather than to the perceptual properties of objects only after they themselves begin to use the objects functionally. According to this view, the older infants we studied were interested in the rod's insertion into the closed box because they themselves have begun inserting toys into containers, and find such a possibility especially intriguing.

Follow-up results: In another series of experiments, we examined infants' responses to events in which a blue wooden rod was inserted into a block with a narrow hole at its center; the infants could see that the rod fit snugly within the hole. Next, the infants saw (a) a blue wooden rod much larger than the initial rod or (b) a plexiglass rod that differed in color, texture, and length from the initial rod, but was of the same diameter. Both rods appeared to fit through the hole of the block. The results indicated that 13-month-old infants were more interested in the large test rod, whose diameter should have prevented its insertion into the block, whereas younger infants preferred the plexiglass rod, which differed markedly in appearance from the familiarization rod. We suspect that this developmental finding reflects the fact that older infants are more likely to engage in manipulations in which objects of different sizes are pushed into openings.