Developmental Science 2:2 (1999), pp 115–163

ARTICLE WITH PEER COMMENTARIES AND RESPONSE

Young infants' expectations about hidden objects: a reply to three challenges

Renée Baillargeon

University of Illinois, USA

Abstract

In this article, I address three broad challenges that have been directed at claims that even young infants are able to represent and to reason about hidden objects. The first challenge is that such claims are static and non-developmental and as such represent an unproductive approach to the study of infant cognition. The second challenge is that claims that even young infants represent hidden objects typically go hand in hand with assertions that infants are born with a belief that objects exist continuously in time and move continuously through space, and there is no evidence to date to support such assertions. Finally, the third challenge is that reports that young infants represent hidden objects can all be explained more parsimoniously in terms of low level perceptual biases in infants' encoding and processing of events, or in terms of transient expectations formed during habituation trials and later extended to test trials.

Over the past 15 years, there have been many reports in the developmental literature indicating that even young infants are able to represent hidden objects. In particular, these reports suggest that infants aged 2.5 months and older believe that (a) a stationary object continues to exist and retains its location when occluded; and (b) a moving object continues to exist and pursues a continuous path when behind an occluder (e.g. Spelke, Breinlinger, Macomber & Jacobson, 1992; Wilcox, Nadel & Rosser, 1996; see Baillargeon, 1993, and Spelke *et al.*, 1992, for reviews of early reports). In this paper, I address three broad challenges that have been directed at these reports.

First challenge

The first challenge I will consider is the following: researchers have argued that the claim that even young infants are able to represent hidden objects is static and non-developmental, and as such constitutes an unproductive approach to the study of early cognition (e.g. Fischer & Bidell, 1991; Thelen & Smith, 1994; Haith & Benson, 1997; Munakata, McClelland, Johnson & Siegler, 1997; Mueller & Overton, 1998).

Do young infants' expectations about hidden objects undergo developmental change? Recent evidence from my laboratory suggests that the answer to this question is a resounding *yes*. This evidence comes from two distinct series of experiments. The first focused on infants' knowledge about occlusion events (Baillargeon & DeVos, 1991; Aguiar & Baillargeon, 1999, in press). Our results indicate that, although infants appreciate from a very early age that an object continues to exist *after* it becomes occluded, their ability to predict *when* the object should be occluded is initially poor and undergoes systematic development. The second series of experiments built on the first and compared infants' knowledge about occlusion and containment events[1] (Hespos & Baillargeon, 1999a, 1999b). Our findings

---

[1] In the present context, *occlusion* events are defined as events in which an object is hidden by a nearer object (e.g. a ball that rolls behind a screen), and *containment* events are defined as events in which an object is inserted into a container (e.g. a ball that is lowered into a canister). From an adult perspective, containment of course also involves occlusion. However, it should be noted that this occlusion is of a different form than that defined above: the contained object becomes hidden when lowered into, not behind, the container. As we will see, this distinction appears to be crucially important to infants.

Address for correspondence: Department of Psychology, University of Illinois, 603 East Daniel, Champaign, IL 61820, USA; e-mail rbaillar@s.psych.uiuc.edu

have revealed a striking décalage in infants' reasoning about these two types of events: infants can judge how much of an object should be hidden when lowered *behind* an occluder several months before they can judge how much of an object should be hidden when lowered *into* a container.

Experiments on occlusion events

The first series of experiments was suggested by experiments we have been conducting over the past eight years on the development of infants' expectations about support, collision and other physical events (see Baillargeon, 1994, 1995, 1998, for reviews). The results of these experiments have brought to light a general developmental pattern in infants' acquisition of knowledge about events. Specifically, it appears that, when learning about an event category, infants first form an initial concept centered on a simple, all-or-none distinction. With further experience, infants identify variables that elaborate and refine this initial concept, resulting in increasingly accurate predictions and interpretations over time. To illustrate this developmental pattern (see Figure 1), consider the results of experiments on infants' knowledge about support events (e.g. Baillargeon, Needham & DeVos, 1992; Needham & Baillargeon, 1993; see Baillargeon, 1995, and Baillargeon, Kotovsky & Needham, 1995, for reviews). By about 3 months of age (or perhaps sooner), infants have formed an initial concept of support centered on a simple *contact/no contact* distinction: they expect an object to be stable if released in contact with another object, and to fall otherwise. At this stage, infants detect the violation shown in the top row of Figure 1 but not those shown in the lower rows, because in each case the object is released in contact with another object. At about 4.5 to 5.5 months of age, infants begin to take into account the *type of contact* between an object and its support. Infants now expect an object to remain stable when released on but not against another object. At about 6.5 months of age, infants begin to consider the *amount of contact* between objects and their supports. Infants now expect an object that is deposited on a support to remain stable only if half or more of the object's bottom surface lies on the support. At this stage, infants detect the violation shown in the third row of Figure 1 but not that shown in the fourth row: infants expect the L-shaped box to remain stable because half of its bottom surface is supported. It is not until infants are about 12.5 months of age that they begin to attend to an object's *proportional distribution* and recognize that an asymmetrical object can be stable only when the proportion of the object that lies on the support is greater than that off the support.

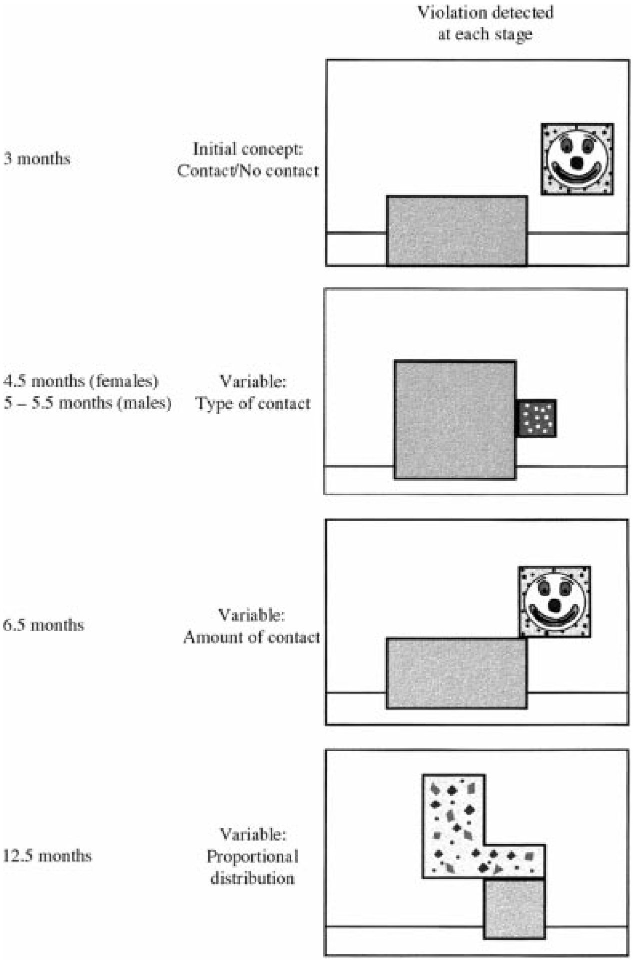


Figure 1 *Schematic description of the development of infants' knowledge about support events.*

Would the general developmental pattern identified for support, collision and other physical events also hold for occlusion events? To address this question, Andréa Aguiar and I carried out a series of experiments on the development of young infants' expectations about occlusion events (Aguiar & Baillargeon, 1999, in press). Before summarizing these results, I first illustrate our approach by describing two experiments we conducted with 2.5-month-old infants (Aguiar & Baillargeon, in press).

The infants in the first experiment were assigned to a two-screens or a connected-screens condition (see Figure 2). In both conditions, the infants were habituated to a toy mouse that moved back and forth behind a wide screen. Next, the infants saw two test events. In one (high-window event), a window was created in the screen's upper half; the mouse was shorter than the bottom of the window and did not become visible when passing behind the screen. The other test event differed for the two conditions. In the two-screens condition, all

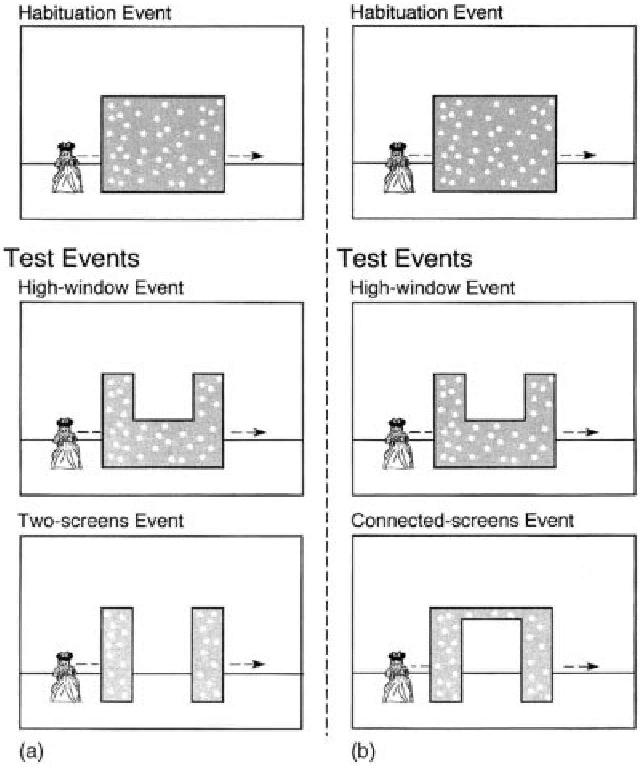


Figure 2 *Schematic drawing of the habituation and test events used in (a) the two-screens condition and (b) the connected-screens condition (Aguiar & Baillargeon, in press).*

of the screen's midsection was removed to create two separate screens (two-screens event). In the connected-screens condition, the two screens remained connected at the top by a short strip (connected-screens event). In each case, the mouse should have become fully visible when passing behind the screen(s), but it did not in fact do so.

The infants in the two-screens condition looked reliably longer at the two-screens than at the high-window test event. This result suggested that, when shown the two-screens event, the infants (a) believed that the mouse continued to exist after it disappeared from view; (b) realized that the mouse could not disappear behind one screen and reappear from behind the other screen without travelling the distance between them; and (c) expected the mouse to appear between the screens and were surprised that it did not.[2] These results confirmed previous findings by Spelke *et al.* (1992) and Wilcox *et al.* (1996) that 2.5-month-old infants represent occluded objects.

In contrast to the infants in the two-screens condition, those in the connected-screens condition tended to look equally at the two test events they were shown. Our interpretation for these results was that, at 2.5 months of age, infants possess only an initial concept of occlusion centered on a *behind/not behind* distinction: they expect an object to be hidden when behind an occluder, and to be visible otherwise. Thus, when the connected screens were used, the infants saw these as forming a single occluder and they expected the mouse to be hidden when behind this occluder. When the two screens were used, however, the infants expected the mouse to be hidden behind each screen but to be visible between them, because at that point the mouse did not lie behind any occluder.

Support for this interpretation came from an additional experiment (see Figure 3) in which 2.5-month-old infants were tested with the same procedure as in the two-screens condition, with one exception: at the start of each trial the screen or screens lay flat on the apparatus floor to reveal either one mouse (one-mouse condition) or two mice (two-mice condition). Like the infants in the two-screens condition, the infants in the one-mouse condition looked reliably longer at the two-screens than at the high-window test event, thereby confirming our results. In contrast, the infants in the two-mice condition tended to look equally at the two test events. These negative results suggested that the infants were able to use the information that two mice were present in the apparatus to make sense of the two-screens event: that is, they realized that no mouse appeared between the screens because the two mice travelled separate trajectories, one to the left and one to the right of the screens.

In subsequent experiments, we replicated the results of the two experiments I have just described using slightly different versions (see Figure 4) of the two-screens and connected-screens test events.

These and similar experiments with 3- and 3.5-month-old infants (Baillargeon & DeVos, 1991; Aguiar & Baillargeon, 1999) have led Andréa Aguiar and me to conclude that infants' expectations about occlusion events undergo rapid development between 2.5 and 3.5 months of age (this development is no doubt made possible in part by improvements in infants' visual abilities; e.g. Aslin, 1981; Banks, 1983; Slater, 1995). As

---

[2] When shown two events, one that is consistent with their physical expectations and one that is not, infants typically look longer at the inconsistent than at the consistent event. Infants' greater interest in the inconsistent event is often taken to indicate that they (a) detect the violation of their physical knowledge and furthermore (b) are surprised or puzzled by this violation. Although no formal evidence has yet been gathered involving facial or behavioral correlates of surprise and puzzlement, we have often observed such reactions in our laboratory, and for this reason find the use of the terms 'surprise' and 'puzzlement' appropriate. Readers uncomfortable with these terms might want to view them simply as short-hand descriptions for infants' detection of violations of their knowledge.

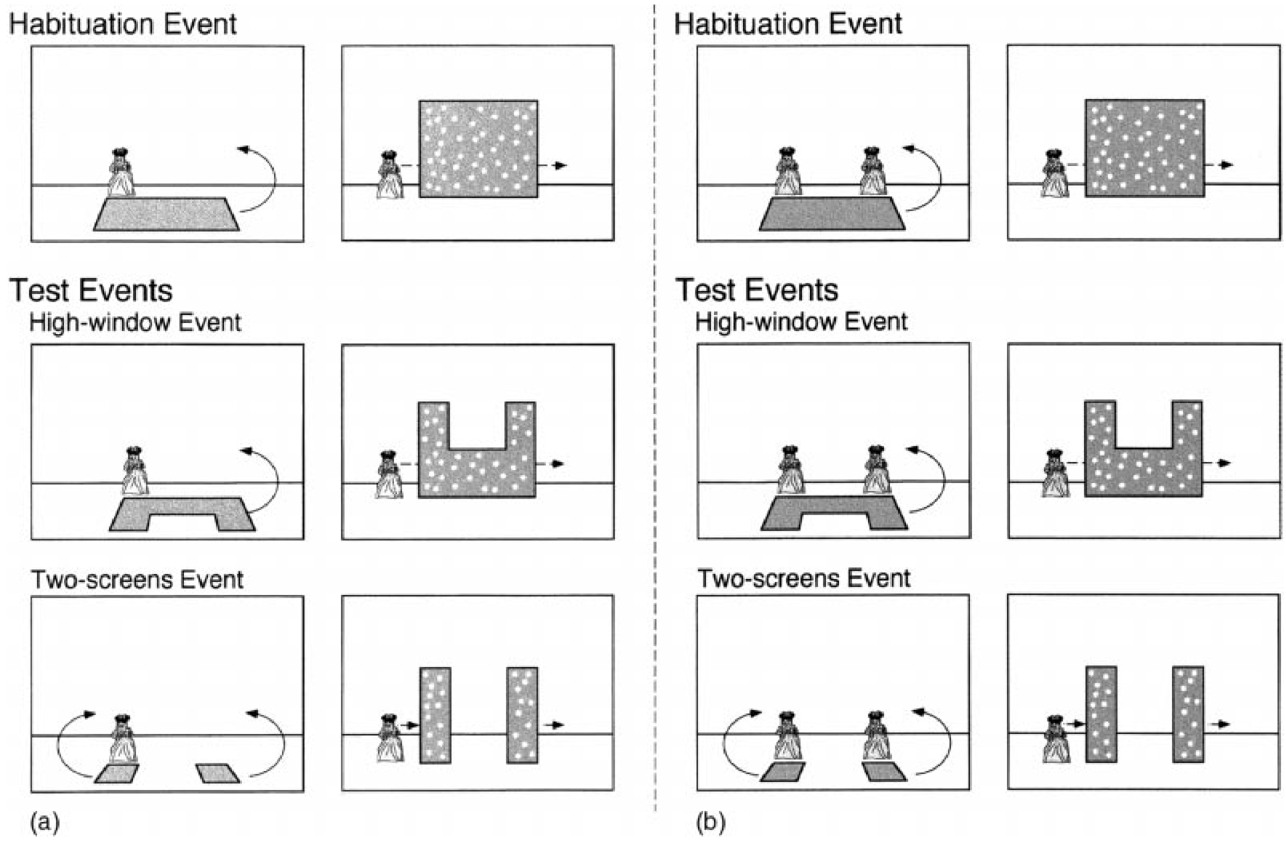


Figure 3 *Schematic drawing of the habituation and test events used in (a) the one-mouse condition and (b) the two-mice condition (Aguiar & Baillargeon, in press).*

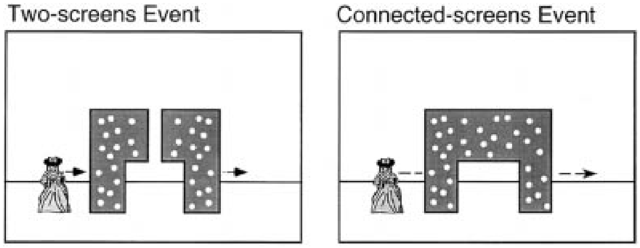


Figure 4 *Schematic drawing of additional two-screens and connected-screens test events (Aguiar & Baillargeon, in press).*

we just saw, infants' initial concept of occlusion (see Figure 5) appears to be that objects are hidden when behind other objects, and are visible otherwise. At this stage, infants detect the violation shown in the top row of Figure 5 but not those shown in the lower rows, because the two screens are connected at the top or the bottom to form a single occluder. By about 3 months of age, infants expect an object to remain hidden when passing behind an occluder with a continuous lower edge, and to become visible when passing behind an occluder with a discontinuous lower edge. Hence, infants now detect the violation shown in the middle row of Figure 5 but not that shown in the bottom row, because the screen presents a continuous lower edge. It is not until infants are about 3.5 months of age that they attend to the height of objects relative to that of occluders and expect tall objects to become visible when passing behind short occluders.[3]

The findings we have just discussed suggest two conclusions. First, although infants appreciate from a very early age that an object continues to exist *after* it becomes occluded, they are initially poor at predicting *when* the object should be occluded; however, their ability to do so improves rapidly as they identify

---

[3] We do not mean to imply, of course, that infants' knowledge about occlusion events is complete by 3.5 months of age. Infants also need to learn, for example, that the width of an object relative to that of an occluder determines whether the object will be fully or only partly hidden when behind the occluder (e.g. Wilcox & Baillargeon, 1998b); that the speed of an object and width of an occluder determine how soon the object will reappear from behind the occluder (e.g. Spelke, Kestenbaum, Simons & Wein, 1995a); that the width and speed of an object determine how long it will take to cross a narrow aperture in an occluder (e.g. Arterberry, 1997); and so on.

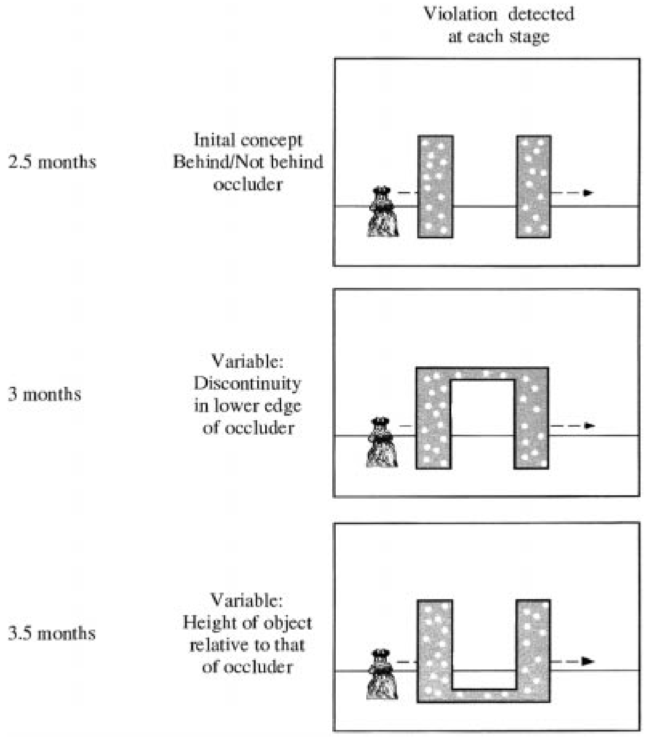


Figure 5 *Schematic description of the development of infants' knowledge about occlusion events.*

relevant variables. Second, the development of young infants' expectations about occlusion events follows the same general pattern – the identification of an all-or-none initial concept followed by that of a sequence of variables – that has been observed in infants' acquisition of knowledge about support, collision and other physical events (Baillargeon, 1994, 1995, 1998).

Experiments on containment and occlusion events

We saw in the preceding section that 3.5-month-old infants are able to reason about the height of an object relative to that of an occluder (Baillargeon & DeVos, 1991). Would young infants also be able to reason about the height of an object relative to that of a container? To answer this question, Susan Hespos and I conducted a series of experiments comparing infants' responses to perceptually similar occlusion and containment events (Hespos & Baillargeon, 1999a, 1999b). We reasoned that evidence of a décalage in infants' responses to these two types of events would suggest that infants acquire, not general physical principles that are applied broadly to all relevant events, but rather local expectations that are closely tied to individual event categories.

In the first experiment (Hespos & Baillargeon, 1999a), 4.5-month-old infants were assigned to a container or an occluder condition. The infants in the container condition (see Figure 6) saw two test events. At the start of each event, a hand grasped a knob attached to the top of a tall cylindrical object which stood next to a container. Next, the hand lowered the object into the container until only the knob protruded above the container's rim. The container used in the tall-container event was as tall as the object minus the knob; the container used in the short-container event was only half as tall, so that it should have been impossible for the cylindrical portion of the object to be fully lowered into the container. Prior to the test trials, the infants received familiarization trials in which the containers were rotated forward so that the infants could inspect them. The infants in the occluder condition (see Figure 7) saw identical events with one exception: the bottom and back half of each container were removed to create a rounded occluder.

As expected, the infants in the occluder condition looked reliably longer at the short- than at the tall-occluder test event, suggesting that they realized that the height of the object relative to that of each occluder determined how much of the object could be hidden behind the occluder. This interpretation was supported by a control condition in which a short object was used; the infants in this condition tended to look equally at the short- and tall-occluder test events.

In contrast to the infants in the occluder condition, those in the container condition tended to look equally at the short- and tall-container test events. Our interpretation for these results was that, at 4.5 months of age, infants have not yet learned that the height of an object relative to that of a container determines how much of the object can be hidden in the container.[4] This interpretation led to the intriguing prediction that infants should perform differently if the object were lowered *behind* rather than into the containers. The containers would then serve as occluders, and infants should now be able to detect the violation shown in the short-container test event.

This prediction was confirmed: when the object was lowered behind rather than into each container (see Figure 8), the infants looked reliably longer at the short- than at the tall-container event. This result, together with those of the container and occluder conditions, suggests that 4.5-month-old infants can reason about

---

[4] It could be suggested that young infants might simply have difficulty understanding the physical concept of containment. This seems unlikely, however. In additional experiments, Susan Hespos and I have found that 2.5-month-old infants already possess an initial concept of containment and recognize that (a) an object can be lowered into a container with an open but not a closed top and (b) an object hidden in an upright container must move with the container (Hespos & Baillargeon, 1999c).

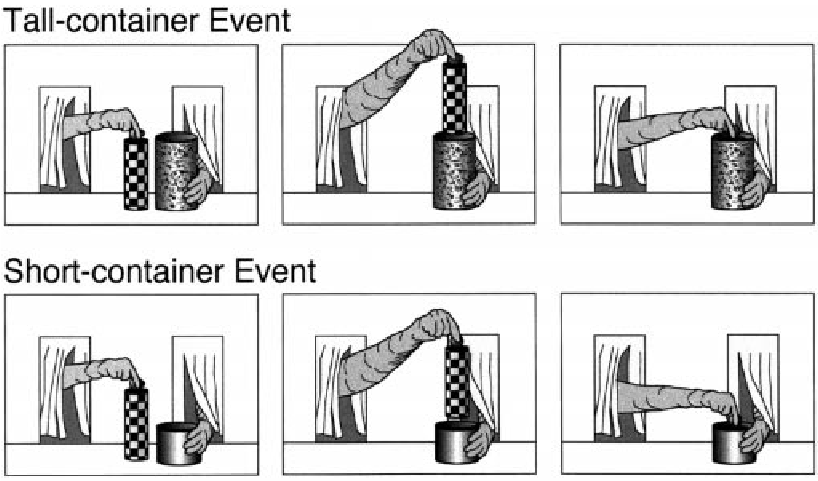


Figure 6 *Schematic drawing of the test events used in the container condition (Hespos & Baillargeon, 1999a).*

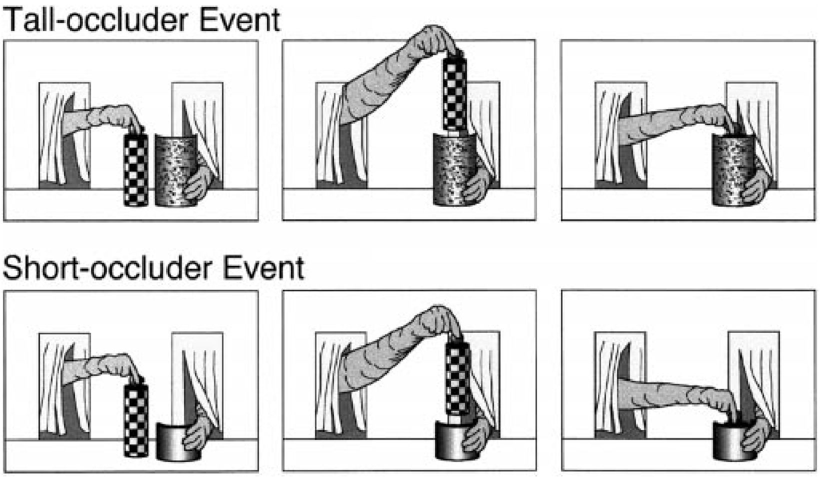


Figure 7 *Schematic drawing of the test events used in the occluder condition (Hespos & Baillargeon, 1999a).*

the variable 'height' in the context of occlusion but not containment events. In ongoing experiments with older infants, Susan Hespos and I are finding that it is not until infants are about 7.5 months of age that they identify 'height' as an important containment variable (Hespos & Baillargeon, 1999b).

Together, the results reported in this section suggest two conclusions. The first is that the knowledge infants acquire about occlusion events remains closely tied to these events; infants relearn in the context of containment events some of the same variables they have already identified for occlusion events, resulting in striking décalages in their reasoning.[5] The second conclusion, which follows from the first, is that infants view occlusion and containment as distinct event categories, and reason and learn separately about these two categories.

Second challenge

We saw in the previous section that infants' expectations about hidden objects undergo considerable development. At the same time, however, we must not lose sight of the fact that some ability to represent and reason about hidden objects has been demonstrated with both occlusion and containment events in infants as young as 2.5 months of age, the youngest tested to date. Thus, researchers have found that 2.5-month-old infants are surprised when (a) an object hidden behind one occluder

---

[5] The context-specificity in infants' knowledge revealed in this research echoes an emerging theme in the infant literature (e.g. Adolph, 1997), one that is strongly endorsed by Thelen and Smith (1994).

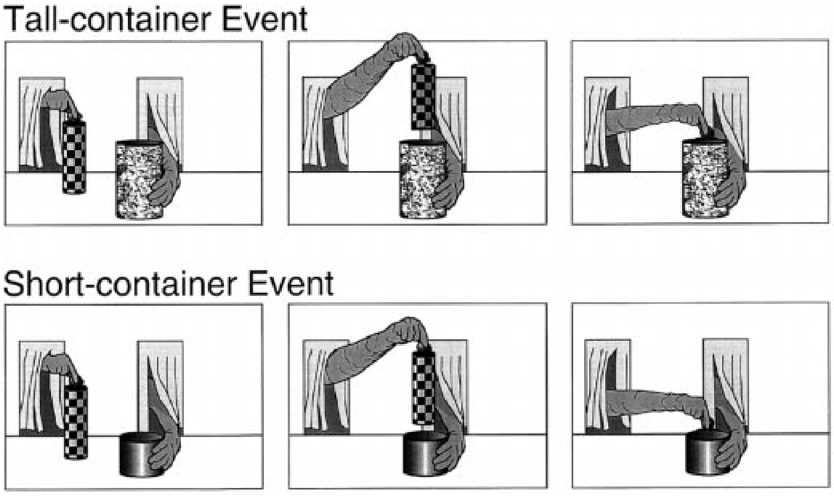


Figure 8 *Schematic drawing of the test events used in the container-as-occluder condition (Hespos & Baillargeon, 1999a).*

is retrieved from behind another occluder (Wilcox *et al.*, 1996); (b) an object follows a non-continuous path behind an occluder (Spelke *et al.*, 1992; Aguiar & Baillargeon, in press); and (c) an object hidden in a container fails to move with the container (Hespos & Baillargeon, 1999c). The second challenge I will address in this paper is that reports of young infants' successes with hidden objects typically go hand in hand with a claim that infants' reasoning about occlusion, containment and other physical events is constrained from birth by a belief that objects exist continuously in time and move continuously through space, and no evidence to date supports such a claim (e.g. Fischer & Bidell, 1991; Thelen & Smith, 1994; Haith & Benson, 1997; Munakata *et al.*, 1997).

What sort of empirical evidence would compel us as researchers to consider the possibility – first raised by Elizabeth Spelke (1994; Spelke *et al.*, 1992; Spelke, Phillips & Woodward, 1995b) – that a belief in continuity informs from the start infants' reasoning about occlusion, containment and other physical events? The findings summarized in the previous section bear directly on this question. First, they suggest that findings that very young, 2.5-month-old infants represent occluded objects (Spelke *et al.*, 1992; Wilcox *et al.*, 1996; Aguiar & Baillargeon, in press) cannot be taken as conclusive evidence for an innate belief in continuity. As we saw earlier, there are important developments in infants' knowledge about occlusion events between 3.5 and 3 months as well as between 3 and 2.5 months (Baillargeon & DeVos, 1991; Aguiar & Baillargeon, 1999, in press). In light of these results, it might be argued that further developments prior to 2.5 months could account for infants' ability to represent occluded objects at 2.5 months.

The findings presented in the first section also make a second point. Researchers with nativist inclinations have sometimes suggested that one would have strong evidence for an innate belief in continuity if one found that infants consistently detected any or all violations of this belief. Given the results we discussed earlier, however, it should be clear that such evidence is not going to materialize. Young infants often fail to detect marked continuity violations: for example, we saw that 2.5- and 3-month-old infants are not surprised when objects fail to appear in occluder openings (Aguiar & Baillargeon, 1999, in press) and that 4.5- to 6.5-month-old infants are not surprised when tall objects disappear in short containers (Hespos & Baillargeon, 1999a, 1999b).

What evidence, then, would compel us as researchers to consider the possibility that infants' event representations are constrained from birth by a belief in continuity? The approach that my colleagues and I are pursuing (Baillargeon, DeJong & Sheehan, 1999) is to try to uncover *how* infants learn about physical events. Finding out how infants learn, we believe, should also tell us what they *can* and *cannot* learn. Consider, for example, 2.5-month-old infants' expectation that a moving object continues to exist and pursues a continuous path when behind an occluder (Spelke *et al.*, 1992; Aguiar & Baillargeon, in press). If it turns out that infants' learning mechanisms can readily acquire such an expectation, then we will know that it is learned, and we will know how it is learned. On the other hand, if it turns out that such an expectation is something that infants' learning mechanisms are ill-equipped to learn, then we will be compelled to take seriously Spelke's (1994; Spelke *et al.*, 1992, 1995b) proposal that it reflects the presence of an innate belief in continuity.

I would like to emphasize that the proposal to study how infants acquire their physical knowledge is one that fits very well within many current undertakings in the field of infant cognition. Researchers with a wide variety of theoretical perspectives, and with a wide range of empirical interests, have been concerned in recent years with explaining how infants develop. This focus on the developmental process is apparent in the recent writings of Thelen and Smith (1994) as well as in the work of Arterberry (1997), Bahrick (1988), Karmiloff-Smith (1992), Mandler (1992), Mareschal, Plunkett and Harris (1999), Meltzoff and Moore (1998), Munakata (1998), Needham (1998), Oakes and Cohen (1995), Rochat (1992), Sitskoorn and Smitsman (1995), Spelke, Katz, Purcell, Ehrlich and Breinlinger (1994), Wilcox and Baillargeon (1998a), and Xu and Carey (1996), to name just a few. We often hear today that researchers in the infancy literature have become extremely polarized. From the present perspective, however, it appears that many investigators are engaged in the same effort, which is that of solving the puzzle of how infants progress from point a to point b. It does not matter in the least that researchers are exploring very different solutions to this puzzle: clearly, the wider the net that we cast, the more likely we are to bring to light bits and pieces of the correct, final solution.

The research that my colleagues and I have been conducting to investigate how infants acquire their physical knowledge (e.g. Baillargeon *et al.*, 1999) is based in part on the hypothesis that infants acquire initial concepts and variables when they are exposed to *contrastive evidence* for them: that is, infants must observe both that a certain outcome occurs when a condition is met, and that a different outcome occurs when that same condition is not met. Thus, in order to identify the variable 'height' in occlusion events, infants must observe *both* that short objects remain occluded when passing behind short occluders and that tall objects do not. Similarly, to learn about the variable 'width' in containment events, infants must observe both that small objects can be lowered into narrow containers and that wide objects cannot. Finally, to learn about the variable 'amount of contact' in support events, infants must see *both* that objects remain stable when released with their bottom surfaces fully supported and that they fall when released with only a small portion of their bottom surfaces supported.[6]

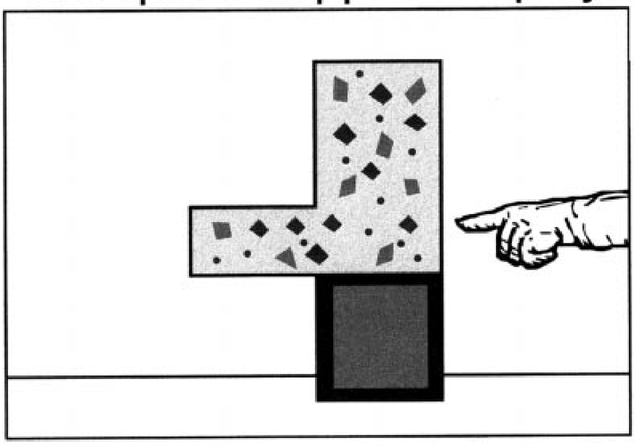
For some variables, such as 'height' in occlusion events, the contrastive evidence required for learning will be available to infants simply through observation (e.g. infants will see that a parent remains partly visible when stepping behind a counter, whereas a short sibling does not). For other variables, such as 'width' in containment events or 'amount of contact' in support events, the necessary contrastive evidence may become available only when infants engage in the relevant object manipulations. Caretakers rarely try to lower wide rigid objects into small containers or to deposit objects on the edges of surfaces; hence, infants may typically observe the outcomes of such manipulations only when they themselves produce them.

These speculations led us to undertake experiments in which we attempted to teach infants a physical concept they had not yet acquired, by presenting them with appropriate contrastive observations. Our experiments focused on the variable 'proportional distribution' in support events. We saw earlier that infants less than 12.5 months of age do not consider the proportional distribution of an asymmetrical object when judging its stability (see Figure 1). Part of the evidence for this conclusion was obtained with static displays involving an L-shaped box resting on a platform (see Figure 9); 12.5-month-olds looked reliably longer at the inadequate-support display than at the adequate-support display, whereas younger infants tended to look equally at the displays (see Baillargeon, 1995, for a review). These and other results suggested that infants less than 12.5 months of age expect any box – whether symmetrical or asymmetrical – to be stable as long as 50% or more of its bottom surface is supported. In our experiments, we attempted to teach 11.5-month-old infants to attend to an asymmetrical box's proportional distribution when judging its stability.

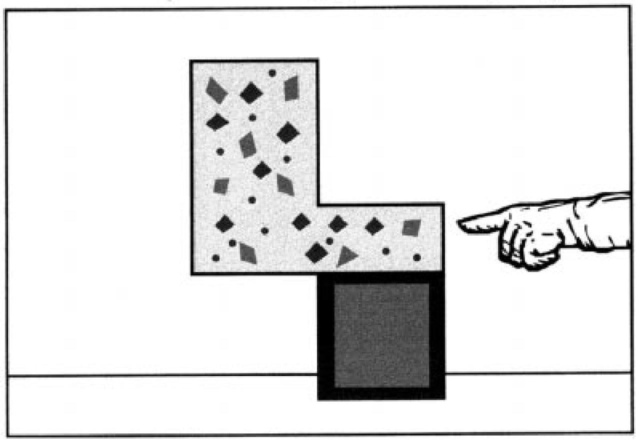
In our first experiment, 11.5-month-old infants were again shown the adequate- and inadequate-support L-box test displays. Prior to seeing these displays, however, the infants received two pairs of teaching trials (see Figure 10). In each pair of trials, the infants saw an asymmetrical box being deposited on a platform; the overlap between the box's bottom surface and the platform was always 50%, as in the L-box displays. In one trial, the smaller portion of the box was placed on the platform and the box fell when released (box-falls event). In the other trial, the larger portion of the box was placed on the platform and the box remained stable

---

[6] We are not suggesting that infants can acquire knowledge about physical objects only through exposure to contrastive evidence. There is ample evidence that infants can learn facts about individual objects simply through repeated exposure to these facts. For example, Kotovsky and Baillargeon (1994, 1998) found that infants readily learned that a medium cylinder would propel a wheeled toy bug to either the middle or the end of a track. Rather, what we are suggesting is that different learning mechanisms – with different evidence requirements and generalization gradients – may be involved in infants' acquiring expectations about entire event categories as opposed to individual event situations.



Adequate-support Display



Inadequate-support Display

Figure 9 *Schematic drawing of two of the static test displays used in experiments on infants' knowledge of the support variable 'proportional distribution' (see Baillargeon, 1995).*

when released (box-stays event). The two pairs of teaching trials were identical except that different asymmetrical boxes were used. For the infants in the 'Set A' condition (see Figure 10), the box used in the first teaching pair was shaped like an asymmetrical B on its side and was pink with yellow dots; the box used in the second teaching pair was a right triangle and was green with white flowers. The infants in the 'Set B' condition saw identical events except that the B-box was replaced with a right triangle of the same color and pattern as the B-box.

The infants in both conditions looked reliably longer at the inadequate- than at the adequate-support L-box test display. These results suggested that, when exposed to contrastive observations designed to highlight the variable 'proportional distribution', 11.5-month-old infants use these observations to acquire new knowledge about support that they would not otherwise have shown until 12.5 months.

In subsequent experiments, we began to systematically vary the content of our teaching observations, to see which ones resulted in learning and which ones did not. In one experiment, for example, the infants saw a single box, rather than two distinct boxes, in the two pairs of teaching trials. That is, the infants saw either the B-box *or* one of the triangles on all four teaching trials. We found that these infants, unlike those who saw two distinct boxes, gave no reliable evidence of learning. These results suggest that, at 11.5 months, infants must see at least two distinct objects behaving according to the same contrastive pattern in order to abstract a variable.

In another experiment, we asked whether 11.5-month-old infants would still show evidence of learning if taught with events depicting *reverse* outcomes – outcomes opposite from those that would normally occur in the world (see Figure 11). As in our successful teaching conditions, the infants were given two teaching pairs involving two distinct boxes; the only difference was that the outcomes were now reversed so that the box fell when released with its larger portion on the platform (box-falls event) and remained stable when released with its larger portion off the platform (box-stays event). We reasoned that if the infants merely abstracted the invariant relation embedded in the teaching trials, they should expect the L-box to fall when its larger portion was on as opposed to off the platform, and they should therefore look reliably longer at the adequate- than at the inadequate-support display. What we found, however, was that the infants tended to look equally at the two test displays. These results suggest that whether or not infants learn from teaching observations depends in part on how easily they can integrate the content of the observations with their prior knowledge.

We next conducted experiments with younger, 11-month-old infants. In contrast to the 11.5-month-olds, these infants showed reliable evidence of learning when given *three* but not two pairs of teaching trials (a staircase-shaped box was used in the third pair of trials; this box was dark green with small musical notes). Like the 11.5-month-olds, however, these younger infants tended to look equally at the two L-box test displays after receiving three pairs of teaching trials involving *reverse* outcomes.

In all of the teaching experiments mentioned above, infants were shown contrastive observations during the teaching trials: one outcome occurred when a condition was met, and a different outcome occurred when that same condition was not met. In a new experiment with

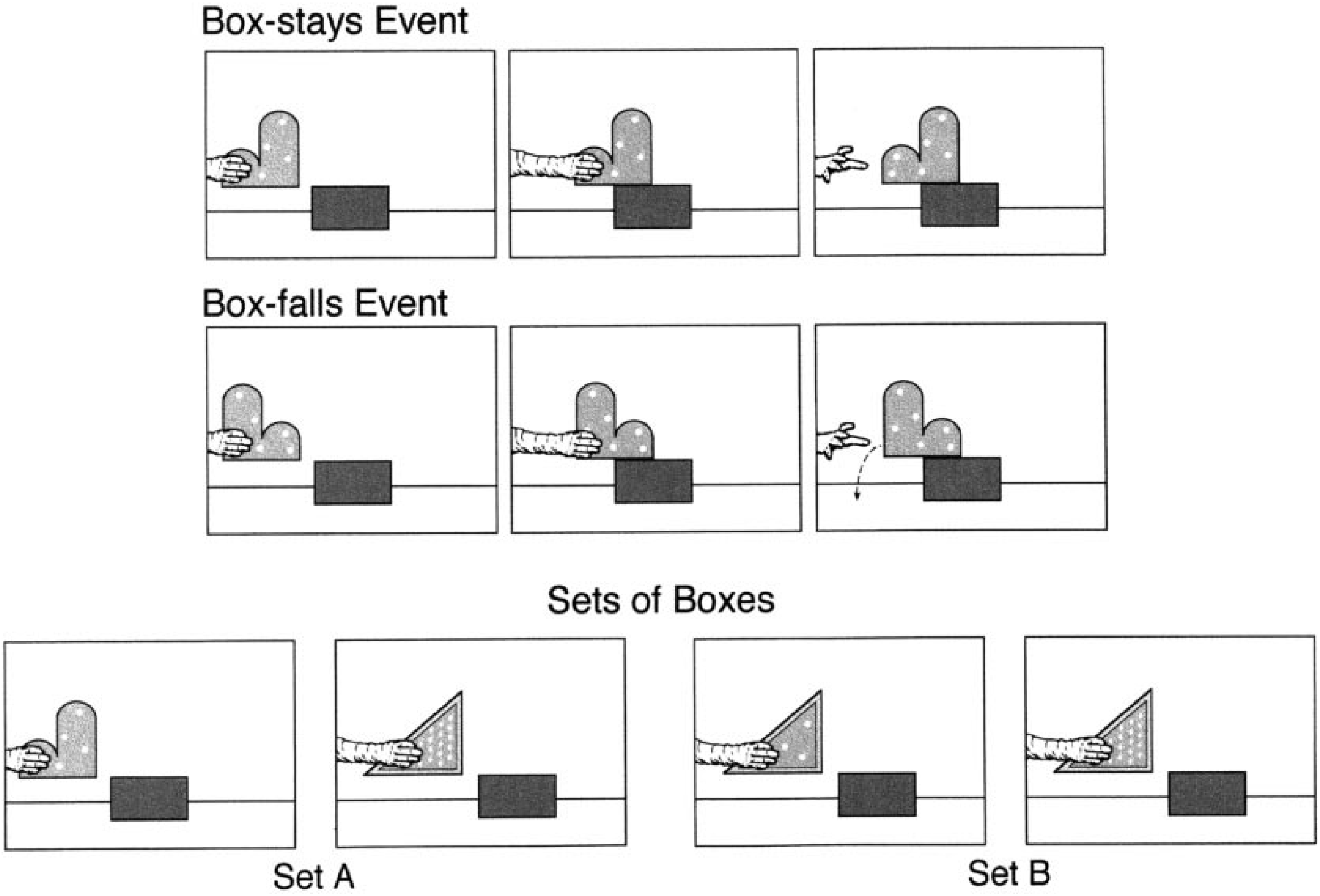


Figure 10 *Schematic drawing of the teaching events shown in the teaching condition (Baillargeon* et al.*, 1999). One group of infants saw the boxes in Set A, and a second group of infants the boxes in Set B.*

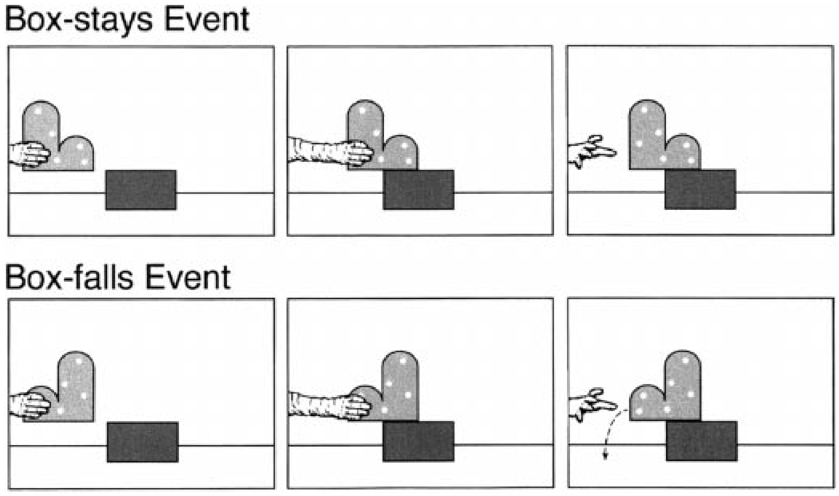


Figure 11 *Schematic drawing of the teaching events shown in the reverse condition (Baillargeon* et al.*, 1999).*

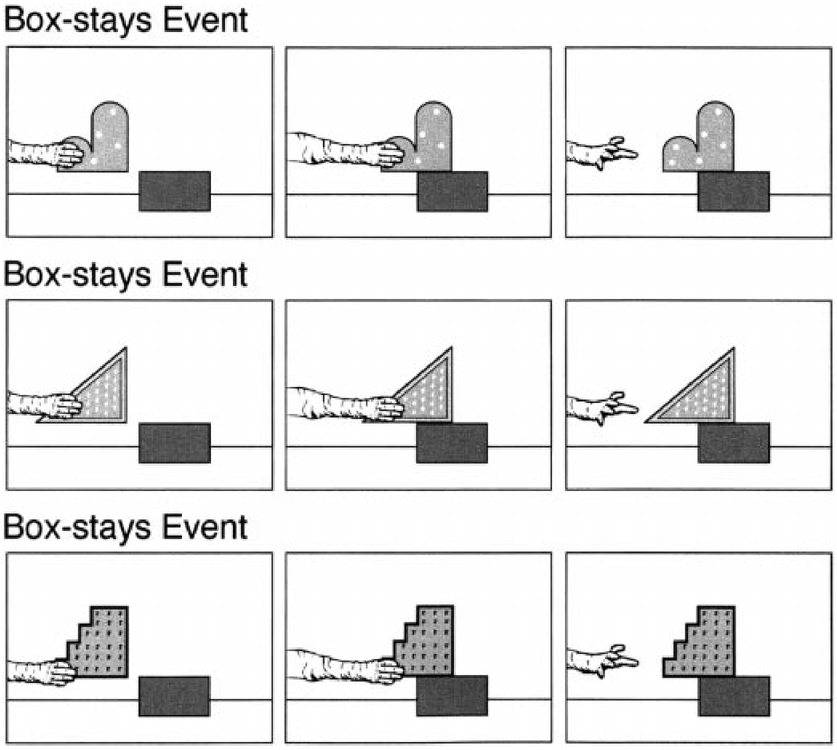


Figure 12 *Schematic drawing of the teaching events shown in the no-contrast condition (Baillargeon* et al.*, 1999).*

11-month-olds (see Figure 12), the infants are *not* shown contrastive outcomes during teaching. Rather, the infants see only correct, box-stays events during the six teaching trials (the three box-stays events from our successful teaching experiment are repeated twice). The data collected to date indicate that infants show no evidence of learning in test after seeing only box-stays events during the teaching trials.

The results presented in this section suggest that many factors contribute to infants' identification of a variable: infants apparently require teaching observations that involve contrastive condition–outcome relations, that show similar relations for two or more distinct objects, and that are consistent with infants' prior knowledge. I have presented these experiments at some length for two reasons: because I wanted to give a sense of how we are exploring infants' acquisition of physical knowledge, and because I believe that the outcomes of these and future teaching experiments (on support as well as occlusion, containment and other events) will have important implications for issues of innateness. Consider, in particular, the case of continuity: if infants must see contrastive observations to learn initial concepts and variables, then how could they ever learn, for example, that moving objects continue to exist and pursue continuous paths when behind occluders? Infants will never encounter unambiguous evidence that when one condition is met, objects exist and move continuously, and when that same condition is not met, objects do not exist and move continuously. In our world, such evidence does not exist, because continuity always applies.[7]

If it is the case that (a) infants acquire their knowledge about event categories through exposure to contrastive evidence and (b) an expectation that objects exist and move continuously when behind occluders cannot be learned through a contrastive-evidence mechanism, then how can we explain the fact that 2.5-month-old infants already possess such an expectation (e.g. Spelke *et al.*, 1992; Wilcox *et al.*, 1996; Aguiar & Baillargeon, in press)? On the one hand, it could be suggested that a

---

[7] Unambiguous evidence that continuity does not hold might be of the following form: (a) a stationary object occupying a specific location is seen to exist, to not exist, and then to exist anew, or (b) a moving object is seen to disappear at one point along its path and to reappear at a later point, without having travelled the distance between them. Seeing an object disappear at one edge of an occluder and reappear at the other edge would not fulfill condition (b) because infants would have no information as to whether the object existed and moved continuously behind the occluder; infants must have direct evidence that the object does not exist or travel continuously for the evidence against continuity to be unambiguous.

different learning mechanism operates for a short period after birth that is capable of supporting the acquisition of such an expectation. On the other hand, we could conclude, following Spelke (1994; Spelke *et al.*, 1992, 1995b), that such an expectation reflects infants' innate belief in continuity.

If it turns out (as I think is likely) that infants do possess an innate notion of continuity, let me emphasize again that this notion cannot be tantamount to a full-fledged understanding of continuity. As we saw in the preceding section, infants initially fail to detect many continuity violations in occlusion, containment, and no doubt other events. This suggests that continuity provides infants with no more than a scaffold – albeit a very important scaffold – to guide their knowledge acquisition. Because of their notion of continuity, infants will assume from the start that an object continues to exist when hidden behind an occluder or in a container. However, infants will need to learn, one variable at a time, how to interpret and predict additional facets of these events.

Third challenge

A third challenge that has been directed at reports that young infants represent hidden objects is that these reports can all be explained more parsimoniously in terms of perceptual biases in infants' encoding and processing of events, or in terms of transient expectations formed during habituation trials and later extended to test trials (e.g. Thelen & Smith, 1994; Bogartz, Shinskey & Speaker, 1997; Haith & Benson, 1997; Mueller & Overton, 1998). Each of these claims is considered in turn.

Perceptual-bias accounts

Can prior findings that young infants represent hidden objects all be reinterpreted in terms of perceptual biases? I believe that the answer to this question is undeniably *yes*. As we will see in a moment, it is not at all difficult to generate perceptual-bias explanations for findings. But do these explanations offer a more parsimonious account of infants' responses to occlusion, containment and other physical events? I would argue that the perceptual-bias approach is in fact very far from parsimonious: a new bias must be invoked for virtually every new finding, and very similar findings must be attributed to entirely different biases.

To illustrate these points, let me begin with a recent example of a perceptual-bias explanation offered by Bogartz *et al.* (1997) for findings Marcia Graber and I obtained with 5.5-month-olds (Baillargeon & Graber, 1987) and Julie DeVos and I subsequently extended to 3.5-month-olds (Baillargeon & DeVos, 1991). On alternate familiarization trials (see Figure 13), the infants saw a tall or a short rabbit moving back and forth behind a wide screen. Next, a window was created in the screen's upper half, and the infants again saw the short and tall rabbits move back and forth behind the screen; neither rabbit appeared in the window, although the tall rabbit was taller than the bottom of the window. The infants tended to look equally at the tall- and short-rabbit familiarization events, but looked reliably longer at the tall- than at the short-rabbit test event. We took these results to mean that the infants (a) believed that each rabbit continued to exist after it disappeared from view; (b) realized that each rabbit could not disappear at one edge of the screen and reappear at the other edge without travelling the distance behind the screen; (c) recognized that the height of each rabbit relative to that of the window determined whether the rabbit would become visible when passing behind the screen; and hence (d) expected the tall rabbit to appear in the window and were surprised when it failed to do so.

The interpretation proposed by Bogartz *et al.* (1997) was very different. They suggested that as the infants watched the tall or short rabbit during the familiarization trials, they tended to focus on the rabbit's face and,

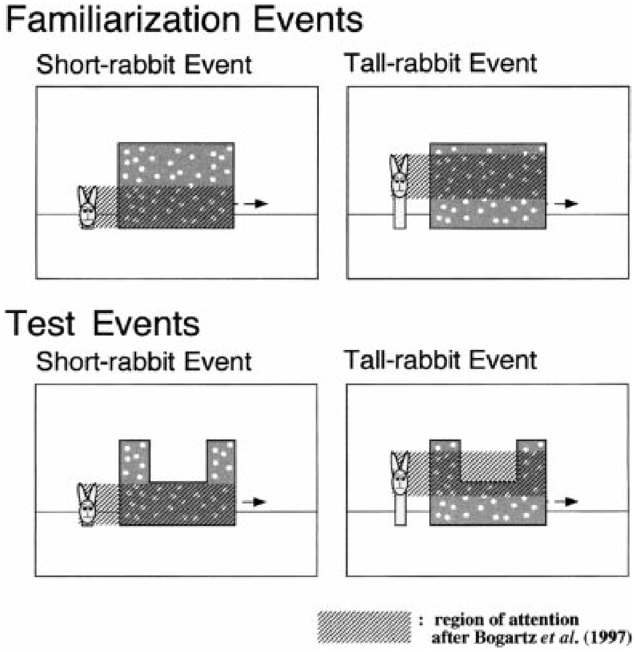


Figure 13 *Schematic drawing of the familiarization and test events used by Baillargeon and Graber (1987); region of attention adapted from Bogartz* et al. *(1997).*

as they scanned horizontally back and forth, attended only to the portion of the screen that lay at the same height as the face (see Figure 13). During the test trials, the infants continued to respond in the same manner. This led them to notice, in the tall-rabbit test event, that a window had been created in the upper portion of the screen; in the short-rabbit test event, however, the infants did not detect the window's presence, because the portion of the screen that they attended to lay below the window. The infants' differential test responses thus stemmed from the fact that they detected the introduction of the window in the tall- but not the short-rabbit test event.

This account can be elaborated to explain the results Andréa Aguiar, Julie DeVos and I have obtained with 3- and 2.5-month-old infants (Baillargeon & DeVos, 1991; Aguiar & Baillargeon, 1999, in press). Although 3-month-olds fail to detect the violation shown in the rabbit task, as well as the more extreme violation depicted in the bottom row of Figure 5, they do succeed in detecting the violation shown in the middle row of Figure 5. To explain these results within a perceptual-bias approach, one could assume that 3-month-old infants track the feet or lowest portion of objects, rather than their faces, and hence can detect the introduction of low but not high windows. Next, consider our results with 2.5-month-old infants. Infants this age fail to detect the violations shown in the middle and bottom rows of Figure 5, but they do succeed in detecting the violation shown in the top row (see also Figure 4 for another version of this same violation). To account for these results, one could propose that infants this age do not track either the top or bottom portions of objects; instead, infants focus on screens and show prolonged looking whenever they detect a change from one to two screens.

In our rabbit experiment, Marcia Graber and I found that 5.5-month-old infants tended to look equally at the tall- and short-rabbit test events if they were shown two tall and two short rabbits standing motionless on either side of the screen (see Figure 14) in two pretest trials at the start of the experiment (Baillargeon & Graber, 1987). Julie DeVos and I later extended this result to 3.5-month-old infants (Baillargeon & DeVos, 1991). Our interpretation for these results was that the infants were able to use the 'hint' they were given to make sense of the tall-rabbit test event: they realized that two tall rabbits were involved in the event, one travelling to the left and one to the right of the screen window. To explain these results, Bogartz *et al.* (1997) suggested that the two pretest trials led the infants to focus only on the leftmost and rightmost edges of the screen, so that they failed to detect the introduction of the window in the test events. This explanation cannot be extended to the control data Andréa Aguiar and I obtained with 3- and 2.5-month-old infants (Aguiar & Baillargeon, 1999, in press), because our procedure was somewhat different: recall that each habituation and test trial began with two mice standing visible behind the screen(s), which lay flat on the apparatus floor (see Figure 14). In this situation, one could not claim that the proximity of the mice to the screens' leftmost and rightmost edges led the infants to attend only to these edges. However, an alternative perceptual-bias interpretation might be that the two-mice pretrials led the infants to focus entirely on the mice; during the events, the infants simply ignored the screen(s) and compared the mice that emerged on either side.

Let us now turn to the results, described in the first section, that Susan Hespos and I obtained with 4.5-month-old infants (Hespos & Baillargeon, 1999a). We take the positive results of the occluder and container-as-occluder conditions to be similar to those of the

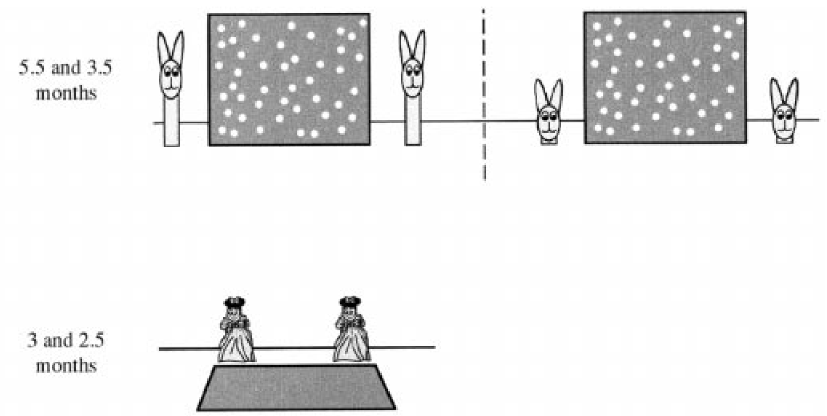


Figure 14 *Schematic drawing of the control conditions used by Baillargeon and Graber (1987) and Baillargeon and DeVos (1991) with 5.5- and 3.5-month-olds, and by Aguiar and Baillargeon (1999, in press) with 3- and 2.5-month-olds.*

rabbit task (Baillargeon & Graber, 1987; Baillargeon & DeVos, 1991), and as such to provide further evidence that infants aged 3.5–5.5 months are able to reason about the variable 'height' in occlusion events. The account proposed by Bogartz *et al.* (1997) for the rabbit task could not be easily extended to these new data, because the infants did not track objects with faces back and forth but rather saw faceless objects being lowered behind occluders. Nevertheless, it is still possible to generate a perceptual-bias explanation for these findings. One could propose, for example, that when infants see an object held above and behind an occluder, they tend to compare their relative heights and are biased to attend especially to mismatches involving tall objects and short occluders, though not the reverse. To explain the negative results of the container condition, one could perhaps suggest that this bias does not hold when objects are held above and over, as opposed to above and behind, other objects.

The exercise we have just performed could easily be repeated with other series of experiments. As I mentioned earlier, I believe that *all* visual-attention experiments that have revealed physical reasoning abilities in young infants could be reinterpreted within a perceptual-bias approach. As long as infants are shown perceptually distinct test events, or identical test events preceded by perceptually distinct pretrials, differences in infants' looking times at the events can always be attributed to perceptual biases. All it requires, as we just saw, is some degree of ingenuity and a willingness to generate biases as needed. Therefore, the question before us as researchers is not whether prior findings of early cognitive competencies can be explained in terms of perceptual biases, but rather how much progress can be achieved by pursuing such an approach. It is not at all clear that this approach is bringing us much closer to attaining a parsimonious and theoretically coherent account of infants' responses to physical events.

Transient-expectation accounts

As I mentioned earlier, reports that young infants represent hidden objects have also been criticized on the grounds that the experiments often included habituation trials, raising the possibility that infants' responses during the test trials simply reflected transient expectations acquired during the habituation trials (e.g. Thelen & Smith, 1994; Bogartz *et al.*, 1997; Haith & Benson, 1997; Mueller & Overton, 1998).

Transient-expectation accounts differ from perceptual-bias accounts in two key respects. First, transient-expectation accounts are parsimonious in the sense that the same explanation is invoked to account for superficially diverse findings. Second, there is of course a great deal of theoretical and empirical justification for transient-expectation accounts: young infants do develop specific expectations from observing the same repeated events (e.g. Haith, 1993; Kotovsky & Baillargeon, 1998).

In light of these arguments, it is important to ask the following question. Is there any evidence that prior results with young infants were in fact due to transient expectations formed during the habituation trials and subsequently extended to the test trials? I know of no such evidence. At the same time, however, I do know of evidence that calls into question specific transient-expectation accounts that have been offered for prior results (see also Aguiar & Baillargeon, 1998).

To illustrate what I mean, I will begin with the transient-expectations account offered by Thelen and Smith (1994) for results I obtained with 6.5- and 8-month-olds (Baillargeon, 1986) and Julie DeVos and I later extended to 4-month-olds (Baillargeon & DeVos, 1991). The infants sat in front of a small screen; to the left of the screen was an inclined ramp. The infants were habituated to the following event (see Figure 15): first, the screen was raised (to reveal that there was no object behind it) and then lowered; next, a toy car rolled down the ramp, passed behind the screen, and finally exited the apparatus to the right. Following habituation, the infants saw two test events identical to the habituation event except that an object such as a large box now stood behind the screen; this box was revealed when the screen was raised. In one event (off-track event), the box was placed *behind* the car's tracks; in the other event (on-track event), the box stood on *top* of the car's tracks, blocking its path. The 8- and 6.5-month-old infants, and the 4-month-old female infants, looked reliably longer at the on- than at the off-track event, suggesting that they (a) believed that the box continued to exist, in its same location, after the screen was lowered; (b) believed that the car continued to exist, and pursued its trajectory, when behind the screen; (c) realized that the car could not roll through the space occupied by the box; and hence (d) were surprised to see the car roll past the screen when the box lay in its path.

The account offered by Thelen and Smith (1994) for these results was very different. I will greatly simplify here but will try to remain faithful to the spirit of their account. What they proposed is that during habituation infants form both a 'what' description, which focuses on what objects are present, and a 'where' description, which focuses on where events are occurring over time. The 'where' description is the one that is crucial here and I will focus on it (see Figure 16). During habituation, infants

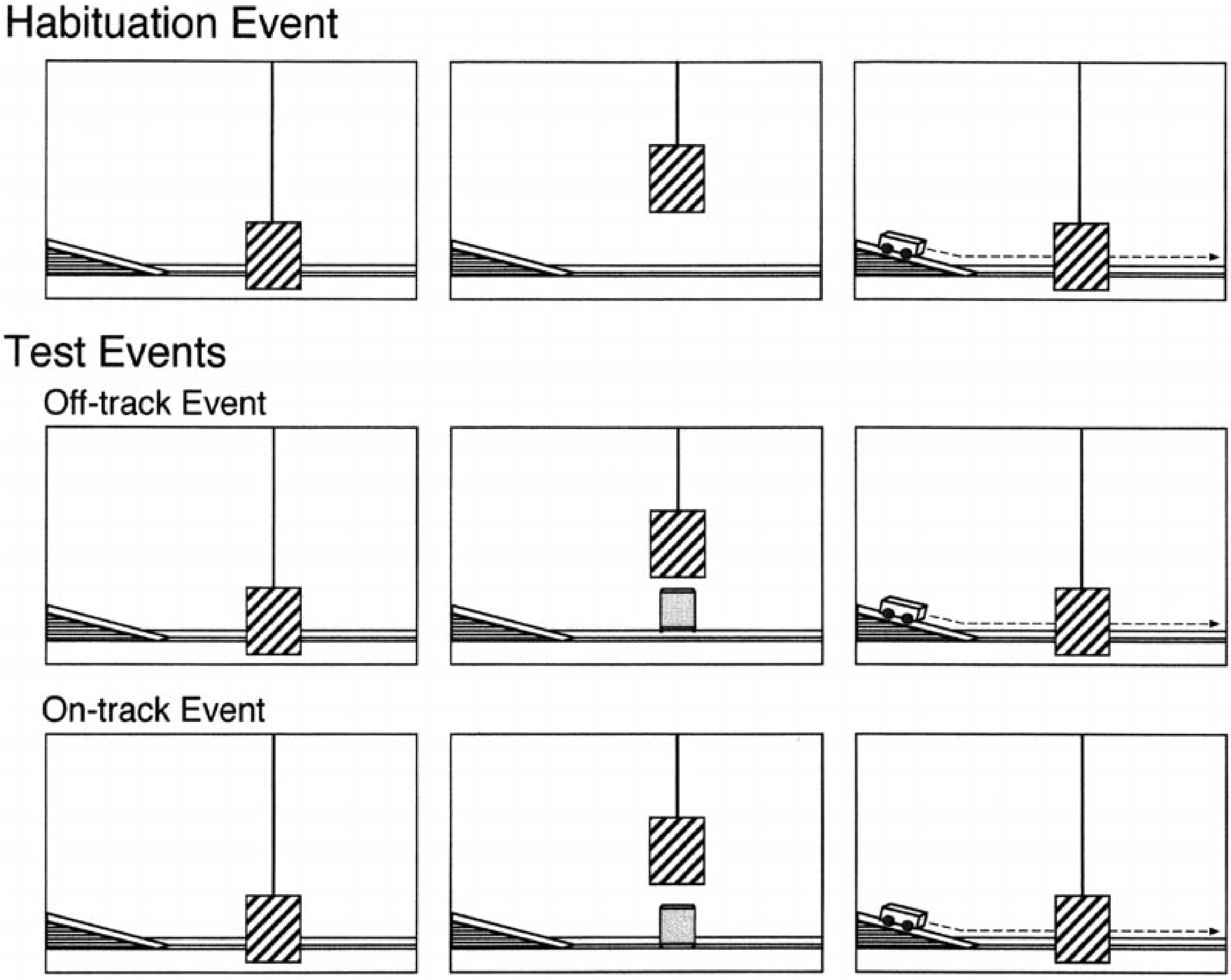


Figure 15 *Schematic drawing of the habituation and test events used by Baillargeon (1986).*

gradually develop a 'where' description – an attracting trajectory – with roughly the following locations: screen (when it is raised and lowered), ramp (when the car rolls down the ramp), left track (when the car rolls there), screen (when the car rolls behind the screen), and finally right track (when the car rolls past the screen). During the off-track event, when the box is behind the track, there is a brief deviation from this description because a new location is introduced corresponding to the position of the box behind the track; after the screen is lowered, however, all returns to normal. During the on-track event, however, a problem arises because the location of the box is closer to that of the screen. This causes infants in a sense to jump ahead in the 'where' description to the next screen location, resulting in a serious perturbation of the expected trajectory.

One difficulty with this account is that it cannot explain the data obtained in a second experiment (Baillargeon, 1986; Baillargeon & DeVos, 1991) that was identical to the first except that, in the off-track event, the box was placed in *front* of rather than behind the tracks. The box was thus even closer to the screen location in this condition, and yet there was no perturbation of the infants' 'where' description.

Let me now discuss a transient-expectation account that could be offered for some of the findings I presented earlier (Aguiar & Baillargeon, in press). Recall that 2.5-month-old infants looked reliably longer at the two-screens than at the high-window event shown in Figure 2. It might be suggested – this interpretation has been proposed for similar results by Thelen and Smith (1994), Bogartz *et al.* (1997) and others – that the infants formed a superficial expectation during the habituation trials that the mouse would reappear at the next vertical screen edge in its path. This expectation caused the infants to be surprised by the two-screens test

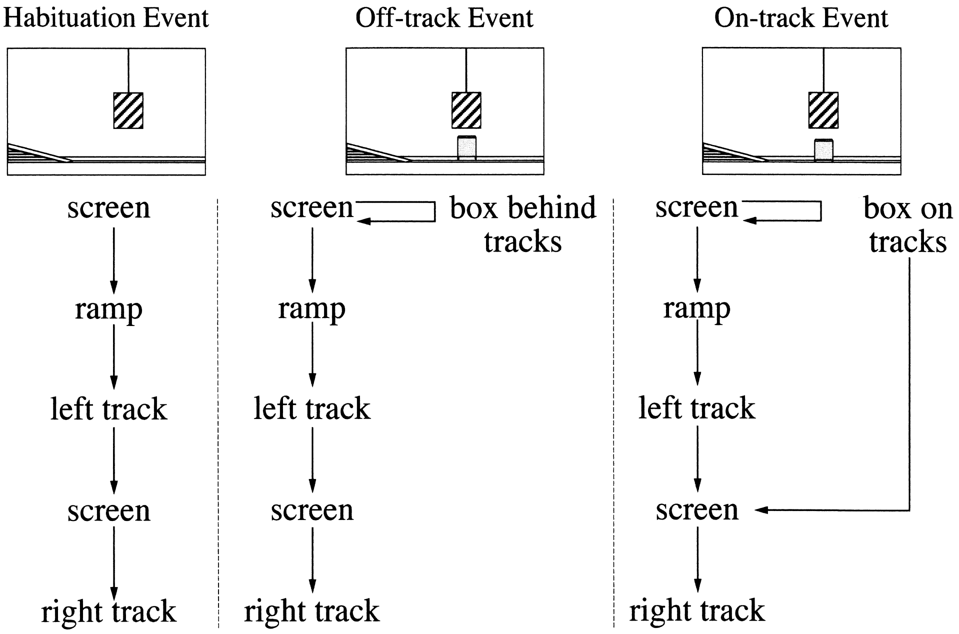


Figure 16 *Schematic drawing of the 'where' description hypothesized by Thelen and Smith (1994) for the experiment of Baillargeon (1986).*

event, which violated this expectation, but not the high-window test event, which confirmed it.

The transient expectation just proposed is unlikely to be correct, however: recall that the infants did not show prolonged looking when the two screens were connected at the top to form a single occluder, or when the two screens were lowered at the start of each trial to reveal two mice (Aguiar & Baillargeon, in press). Such results are inconsistent with the hypothesis that the infants simply formed an expectation during the habituation trials that the mouse would consistently reappear at the next screen edge in its path.

Before leaving this section, I would like to make two further points. The first concerns findings that infants succeed at representing hidden objects when tested *with* but not *without* habituation trials (e.g. Wakeley & Rivera, 1997). Such findings are sometimes taken to provide conclusive evidence that the habituation trials engendered a superficial expectation which in turn caused infants' positive responses during the test trials (e.g. Haith & Benson, 1997; Wakeley & Rivera, 1997). The difficulty with this approach is that it ignores the possibility that infants failed when tested without habituation trials simply because they were presented with complex or unfamiliar events and needed some opportunity to orient to the events in order to respond to them appropriately (for a similar argument, see Thelen & Smith, 1994, pp. 224–225). Many cognitive tasks with children and adults include some orientation or training trials at the start of the experimental session, and researchers rarely make the assumption that subjects should be viewed as competent only if they succeed with or without training trials. Why should the case be different with infants, who cannot be given verbal instructions, and for whom many experimental situations must appear very foreign? Clearly, what needs to be examined, as was discussed above, is whether specific habituation events inadvertently lead infants to develop specific expectations which then provide the basis for their responses to the test events; such hypotheses, as we saw, can readily be tested through additional experimental or control conditions.

The second point I would like to make concerns future tests of young infants' responses to hidden objects. The best way to refute the transient-expectation approach would of course be to demonstrate that young infants can produce positive responses even when tested *without* habituation trials. There are already reports in the literature of 5.5- and 6.5-month-old infants reasoning successfully about hidden objects in tasks involving only one or two habituation trials (e.g. Baillargeon *et al.*, 1995, pp. 92–93; Baillargeon, Graber, DeVos & Black, 1990). In light of these results, it seems likely that a no-habituation task could be devised using simple and familiar events that would yield positive evidence with even younger infants. The fact that no-habituation tasks have been used successfully to explore young infants' expectations about other types of physical events (e.g.

Needham & Baillargeon, 1993) provides further support for this possibility.

Concluding remarks

I have made essentially three points. The first is that young infants' expectations about hidden objects in occlusion and containment events undergo considerable development, and that progress in each event category follows the same general developmental pattern that has been observed for other physical events. The second point is that by studying *how* infants acquire their physical knowledge we may be in a better position to determine whether the expectations that 2.5-month-old infants possess about hidden objects are learned or whether they reflect, as Spelke (1994; Spelke *et al.*, 1992, 1995b) has proposed, an innate belief in continuity. Finally, I have argued that perceptual-bias and transient-expectation accounts of prior reports that young infants represent hidden objects are neither parsimonious nor compelling. There is now a great deal of converging evidence, obtained in different laboratories and using different experimental situations, all pointing to the conclusion that young infants are able to represent hidden objects. It is doubtful at this point whether alternative interpretations that single out individual conditions or experiments can add significantly to our understanding of young infants' responses to physical events.

As I mentioned earlier, there are now several constructive efforts under way to formulate models of how infants' expectations about physical events develop. I believe that it is these attempts that will eventually provide the answer to the question of what knowledge structures infants bring to the task of learning about the physical world.

Acknowledgements

This research was supported by a grant from the National Institute of Child Health and Human Development (HD-21104). I would like to thank Cynthia Fisher and Kristine Onishi for their detailed and insightful comments on the manuscript, and Andréa Aguiar, Jerry DeJong and Susan Hespos for many helpful discussions.

References

Adolph, K.E. (1997). Learning in the development of infant locomotion. *Monographs of the Society for Research in Child Development*, **62** (3, Serial No. 251).

Aguiar, A., & Baillargeon, R. (1998). 8.5-month-old infants' reasoning about containment events. *Child Development*, **69**, 636–653.

Aguiar, A., & Baillargeon, R. (1999). Can young infants generate explanations for impossible events? Manuscript under revision.

Aguiar, A., & Baillargeon, R. (in press). 2.5-month-old infants' reasoning about when objects should and should not be occluded. *Cognitive Psychology*.

Arterberry, M.E. (1997). Perception of object properties over time. In C. Rovee-Collier & L.P. Lipsitt (Eds), *Advances in infancy research* (Vol. **11**, pp. 219–268). Greenwich, CT: Ablex.

Aslin, R.N. (1981). Development of smooth pursuit in human infants. In D.F. Fisher, R.A. Monty & J.W. Senders (Eds), *Eye movements: Cognition and visual perception* (pp. 31–51). Hillsdale, NJ: Erlbaum.

Bahrick, L.E. (1988). Intermodal learning in infancy: learning on the basis of two kinds of invariant relations in audible and visible events. *Child Development*, **59**, 197–209.

Baillargeon, R. (1986). Representing the existence and the location of hidden objects: object permanence in 6- and 8-month-old infants. *Cognition*, **23**, 21–41.

Baillargeon, R. (1993). The object concept revisited: new directions in the investigation of infants' physical knowledge. In C.E. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 265–315). Hillsdale, NJ: Erlbaum.

Baillargeon, R. (1994). How do infants learn about the physical world? *Current Directions in Psychological Science*, **3**, 133–140.

Baillargeon, R. (1995). A model of physical reasoning in infancy. In C. Rovee-Collier & L.P. Lipsitt (Eds), *Advances in infancy research* (Vol. **9**, pp. 305–371). Norwood, NJ: Ablex.

Baillargeon, R. (1998). Infants' understanding of the physical world. In M. Sabourin, F. Craik & M. Robert (Eds), *Advances in psychological science* (Vol. **2**, pp. 503–529). Hove, UK: Psychology Press.

Baillargeon, R., & DeVos, J. (1991). Object permanence in 3.5- and 4.5-month-old infants: further evidence. *Child Development*, **62**, 1227–1246.

Baillargeon, R., & Graber, M. (1987). Where's the rabbit? 5.5-month-old infants' representation of the height of a hidden object. *Cognitive Development*, **2**, 375–392.

Baillargeon, R., Graber, M., DeVos, J., & Black, J. (1990). Why do young infants fail to search for hidden objects? *Cognition*, **36**, 225–284.

Baillargeon, R., Needham, A., & DeVos, J. (1992). The development of young infants' intuitions about support. *Early Development and Parenting*, **1**, 69–78.

Baillargeon, R., Kotovsky, L., & Needham, A. (1995). The acquisition of physical knowledge in infancy. In D. Sperber, D. Premack & A.J. Premack (Eds), *Causal cognition: A multidisciplinary debate* (pp. 79–116). Oxford: Clarendon Press.

Baillargeon, R., DeJong, G., & Sheehan, J. (1999). Teaching infants physical concepts. Manuscript in preparation.

Banks, M.S. (1983). Infant visual perception. In P. Mussen (Series Ed.) & M.M. Haith & J.J. Campos (Eds), *Handbook of child psychology* (Vol. **2**, pp. 435–571). New York: Wiley.

Bogartz, R.S., Shinskey, J.L., & Speaker, C.J. (1997). Interpreting infant looking: the event set X event set design. *Developmental Psychology*, **33**, 408–422.

Fischer, K.W., & Bidell, T. (1991). Constraining nativist inferences about cognitive capacities. In S. Carey & R. Gelman (Eds), *The epigenesis of mind: Essays on biology and cognition* (pp. 199–235). Hillsdale, NJ: Erlbaum.

Haith, M.M. (1993). Future-oriented processes in infancy: the case of visual expectations. In C.E. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 235–264). Hillsdale, NJ: Erlbaum.

Haith, M.M., & Benson, J.B. (1997). Infant cognition. In W. Damon (Series Ed.) & D. Kuhn & R. Siegler (Eds), *Handbook of child psychology* (Vol. **2**, pp. 199–254). New York: Wiley.

Hespos, S.J., & Baillargeon, R. (1999a). Infants' reasoning about occlusion and containment events: evidence of a surprising discrepancy. Manuscript submitted for publication.

Hespos, S.J., & Baillargeon, R. (1999b). Reasoning about containment events in 5.5- to 7.5-month-old infants. Manuscript under review.

Hespos, S.J., & Baillargeon, R. (1999c). Reasoning about containment events in very young infants. Manuscript submitted for publication.

Karmiloff-Smith, A. (1992). *Beyond modularity: A developmental perspective on cognitive science*. Cambridge, MA: MIT Press.

Kotovsky, L., & Baillargeon, R. (1994). Calibration-based reasoning about collision events in 11-month-old infants. *Cognition*, **51**, 107–129.

Kotovsky, L., & Baillargeon, R. (1998). The development of calibration-based reasoning about collision events in young infants. *Cognition*, **67**, 311–351.

Mandler, J.M. (1992). How to build a baby: II. Conceptual primitives. *Psychological Review*, **99**, 587–604.

Mareschal, D., Plunkett, K., & Harris, P. (1999). A computational and neuropsychological account of object-oriented behaviours in infancy. Manuscript submitted for publication.

Meltzoff, A.N., & Moore, M.K. (1998). Object representation, identity, and the paradox of early permanence: steps toward a new framework. *Infant Behavior and Development*, **21**, 201–235.

Mueller, U., & Overton, W.F. (1998). How to grow a baby: a reevaluation of image-schema and Piagetian action approaches to representation. *Human Development*, **41**, 71–111.

Munakata, Y. (1998). Infant perseveration and implications for object permanence theories: a PDP model of the AB task. *Developmental Science*, **1**, 161–184.

Munakata, Y., McClelland, J.L., Johnson, M.H., & Siegler, R. (1997). Rethinking infant knowledge: toward an adaptive process account of successes and failures in object permanence tasks. *Psychological Review*, **104**, 686–713.

Needham, A. (1998). Infants' use of featural information in the segregation of stationary objects. *Infant Behavior and Development*, **21**, 47–75.

Needham, A., & Baillargeon, R. (1993). Intuitions about support in 4.5-month-old infants. *Cognition*, **47**, 121–148.

Oakes, L.M., & Cohen, L.B. (1995). Infant causal perception. In C. Rovee-Collier & L.P. Lipsitt (Eds), *Advances in infancy research* (Vol. **9**, pp. 1–54). Norwood, NJ: Ablex.

Rochat, P. (1992). Self-sitting and reaching in 5- to 8-month-old infants: the impact of posture and its development on early eye–hand coordination. *Journal of Motor Behavior*, **24**, 210–220.

Sitskoorn, S.M., & Smitsman, A.W. (1995). Infants' perception of dynamic relations between objects: passing through or support? *Developmental Psychology*, **31**, 437–447.

Slater, A. (1995). Visual perception and memory at birth. In C. Rovee-Collier & L.P. Lipsitt (Eds), *Advances in infancy research* (Vol. **9**, pp. 107–162). Norwood, NJ: Ablex.

Spelke, E.S. (1994). Initial knowledge: six suggestions. *Cognition*, **50**, 431–445.

Spelke, E.S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of knowledge. *Psychological Review*, **99**, 605–632.

Spelke, E.S., Katz, G., Purcell, S.E., Ehrlich, S.M., & Breinlinger, K. (1994). Early knowledge of object motion: continuity and inertia. *Cognition*, **51**, 131–176.

Spelke, E.S., Kestenbaum, R., Simons, D.J., & Wein, D. (1995a). Spatiotemporal continuity, smoothness of motion and object identity in infancy. *British Journal of Developmental Psychology*, **13**, 1–30.

Spelke, E.S., Phillips, A., & Woodward, A.L. (1995b). Infants' knowledge of object motion and human action. In D. Sperber, D. Premack & A.J. Premack (Eds), *Causal cognition: A multidisciplinary debate* (pp. 44–78). Oxford: Clarendon Press.

Thelen, E., & Smith, L.B. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press.

Wakeley, A., & Rivera, S.M. (1997, April). Replication of Baillargeon's 'drawbridge' effect: Is habituation necessary? Paper presented at the biennial meeting of the Society for Research in Child Development, Washington, DC.

Wilcox, T., & Baillargeon, R. (1998a). Object individuation in infancy: the use of featural information in reasoning about occlusion events. *Cognitive Psychology*, **17**, 97–155.

Wilcox, T., & Baillargeon, R. (1998b). Object individuation in young infants: further evidence with an event-monitoring task. *Developmental Science*, **1**, 127–142.

Wilcox, T., Nadel, L., & Rosser, R. (1996). Location memory in healthy preterm and fullterm infants. *Infant Behavior and Development*, **19**, 309–323.

Xu, F., & Carey, S. (1996). Infants' metaphysics: the case of numerical identity. *Cognitive Psychology*, **30**, 111–153.

Received: 29 June 1998
Accepted: 16 December 1998