



## Discussion

# Infants' use of featural and experiential information in segregating and individuating objects: a reply to Xu, Carey and Welch (2000)

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## 1. Introduction

Researchers have long been interested in identifying the various factors that affect adults' organization of displays. One such factor, adults' knowledge about objects, was discussed long ago by James (1890). Many investigators have since incorporated this factor into their accounts of how adults interpret visual stimuli (e.g. Biederman, 1987; Gregory, 1980; Hummel & Biederman, 1992; Humphries & Bruce, 1989; Kellman & Spelke, 1983; Marr, 1982; Shepard, 1983; Spelke, 1982, 1988). Following these researchers, lead, we have suggested that adults draw on at least three different kinds of object knowledge when parsing displays: featural (or configural), physical, and experiential knowledge (Needham, Baillargeon & Kaufman, 1997). In what follows, we briefly describe these three kinds of knowledge, focusing on their use in the segregation of partly occluded and adjacent displays. In a partly occluded display, two collections of surfaces lie behind and protrude from either side of a nearer object or occluder (e.g. Fig. 1A); in an adjacent display, two collections of surfaces form a spatially contiguous unit (e.g. Fig. 1B). In each case, the viewer's task is to determine whether the two collections of surfaces belong to the same object or to two distinct objects.

Featural knowledge refers to adults' expectations about how objects typically appear. Adults recognize that objects are generally regular in shape, pattern, color, and texture. As a result, adults tend to group surfaces that present the same featural properties into the same units, and surfaces that present different featural properties into separate units. Thus, using our featural knowledge to segregate the

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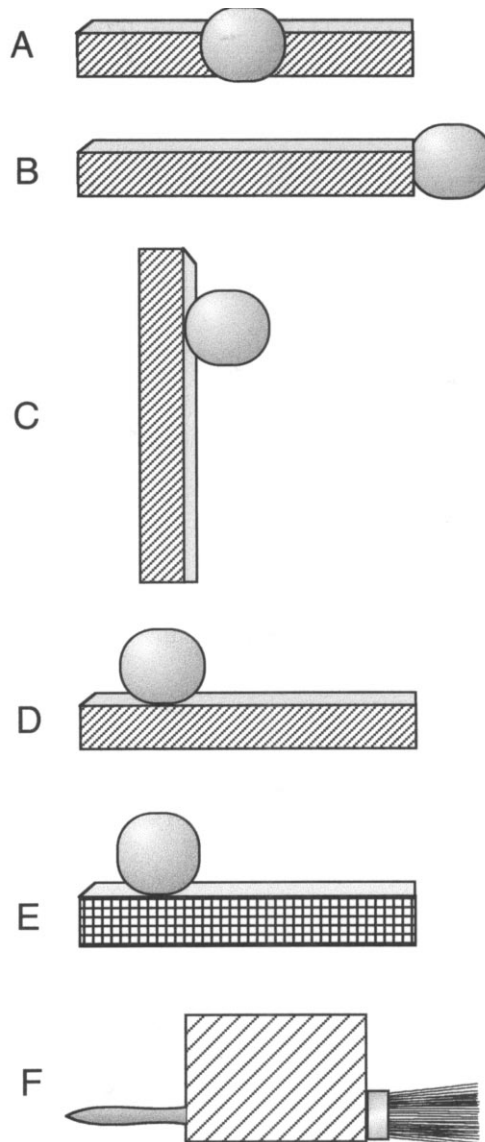


Fig. 1. See text for explanation.

partly occluded display in Fig. 1A would lead us to group the portions of the box visible to the left and right of the flattened sphere into a single object, because of the marked similarities in their features. The same knowledge applied to the adjacent display in Fig. 1B would lead us to view the box and sphere as distinct objects, because of the marked differences in their features.

Physical knowledge corresponds to adults' beliefs about the lawful ways in which objects can move and interact, such as the beliefs that objects cannot remain stable without support and cannot move through space occupied by other objects. Adults not only bring to bear their physical knowledge when organizing displays, but, in cases of conflict, typically allow interpretations suggested by this knowledge to override interpretations suggested by their featural knowledge. In Fig. 1C, for example, we perceive the sphere and box as a single unit, despite the featural differences between them, because we realize that the sphere could not retain its position without being attached to the box.

Experiential knowledge refers to adults' knowledge of what specific objects, or categories of objects, exist in the world. This knowledge involves representations of particular objects (e.g. our coffee mug, sunglasses, or slippers) as well as more abstract representations of object categories (e.g. ducks, cars, or brooms). As with their physical knowledge, adults usually allow interpretations suggested by their experiential knowledge to supersede interpretations suggested by their featural knowledge. To illustrate, after encountering the display in Fig. 1C, we might group the featurally distinct sphere and box in Fig. 1D into one object, because Fig. 1D would appear to us as the same display as Fig. 1C, now in a novel orientation. A prior exposure to Fig. 1C might also lead us to view the display in Fig. 1E as a single unit, because we would regard Fig. 1C and Fig. 1E as potential members of the same object category. Finally, we would be inclined to group the featurally distinct surfaces to the left and right of the screen in Fig. 1E into a single object, because this object resembles a familiar tool, namely, a paintbrush.

Over the past 15 years, there has been a great deal of research on when and how infants come to use the three kinds of object knowledge described above to segregate displays (for recent reviews, see Johnson, 1997; Needham & Modi, 1999a; Needham et al., 1997; Spelke & Van de Walle, 1993). In a recent series of experiments, Xu et al. (1999) examined infants' ability to use experiential knowledge, and more particularly knowledge of familiar object categories or 'kinds', to parse adjacent displays. Based on their results, Xu et al. (1999) concluded that it is not until infants are about 12.5 months of age that they succeed at using kind information to determine objects' boundaries. We believe that there are several reasons to question this conclusion. Before detailing these reasons, we first summarize prior findings on object segregation in infancy. In this summary, we focus on research conducted with displays such as those used by Xu et al. (1999), namely, static displays composed of two or more distinct objects. For ease of description, we refer to these displays as static dissimilar displays.

## **2. Prior findings on object segregation in infancy**

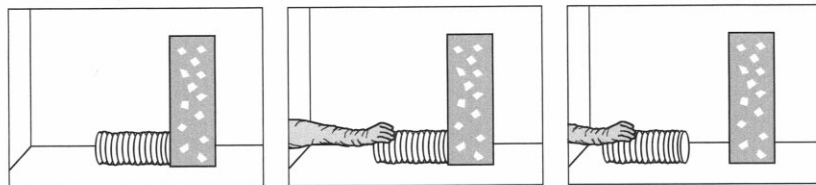
### *2.1. Use of featural knowledge*

Are young infants able to organize at least some dissimilar adjacent and partly

occluded displays in accordance with their featural properties? Recent experiments conducted with infants aged 4–9.5 months of age suggest that the answer to this question is positive (e.g. Craton, Poirier & Heagney, 1998; Needham, 1998, 1999b; Needham & Baillargeon, 1997; Needham & Kaufman, 1997; Needham et al., 1997). For example, in one experiment (Needham, 1998), 4.5- and 6.5-month-old infants first received a familiarization trial in which they saw an adjacent display composed of a zigzag-edged yellow cylinder and a tall blue box decorated with small white squares (see Fig. 2). The familiarization trial gave the infants the opportunity to inspect the display and decide on its composition. Next, the infants received test trials in which a gloved hand grasped the cylinder and pulled it a short distance to the left. For half of the infants (move-together condition), the box moved with the cylinder; for the other infants (move-apart condition), the box remained stationary. The infants in the move-together condition looked reliably longer than did those in the move-apart condition. These results suggested that the infants (a) were led by the featural differences between the cylinder and box to view them as distinct objects and (b) expected the cylinder to move alone and were surprised that it did not. These conclusions were supported by the results of a control experiment in which infants did not receive a familiarization trial and therefore had little opportunity to form an interpretation of the display; these control infants tended to look equally at the move-together and move-apart test events.

Positive results have been obtained with other dissimilar adjacent displays (e.g. Needham, 1999b; Needham & Baillargeon, 1997; Needham & Kaufman, 1997), as well as with dissimilar partly occluded displays (e.g. Craton et al., 1998; Needham, 1998; Needham et al., 1997). Despite these positive results, it is clear that young infants' ability to use featural knowledge to segregate displays is limited, in at least

### Move-apart Event



### Move-together Event

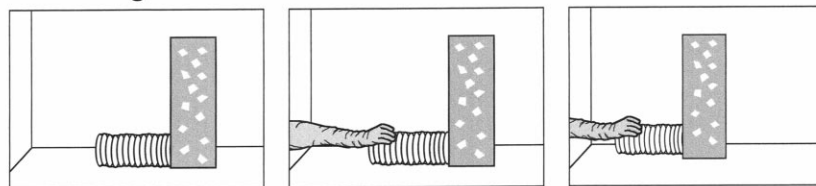


Fig. 2. Move-apart and move-together test events featuring the cylinder-and-box display in Needham (1998).

two ways. First, the more complex the display, the less likely young infants are to succeed at parsing it (e.g. Needham, 1998; Schmidt, Spelke & LaMorte, 1986; Spelke, 1991; Spelke, Breinlinger, Jacobson & Phillips, 1993). In order to successfully segregate a display, infants must first encode and compare the spatial and featural properties of the surfaces in the display; it is plausible that complex displays overwhelm young infants' ability to encode and compare surfaces, resulting in ambiguous interpretations. Second, young infants can use shape but not pattern and color information to organize displays; the earliest age at which infants have been shown to use pattern and color information for this purpose is 7 months (e.g. Craton et al., 1998; Needham, 1999b).

## 2.2. *Use of physical knowledge*

As adults, we conceive of objects as bounded entities and view collections of adjacent surfaces that are separated by empty space as distinct objects. There is consistent evidence that, from a very early age, if not from birth, infants also see collections of surfaces in separate spatial locations as distinct objects (e.g. Aguiar & Baillargeon, 1999b; Baillargeon & DeVos, 1991; Kestenbaum, Termine & Spelke, 1987; Slater, Morison, Somers, Mattock, Brown & Taylor, 1990; Spelke, 1982).

Do infants bring to bear other facets of their physical knowledge when organizing static dissimilar displays? To find out, we carried out experiments with 8-month-old infants (Needham & Baillargeon, 1997). One experiment examined whether infants would apply their knowledge of support when parsing a dissimilar adjacent display. This experiment built on the finding that infants aged 5.5 months and older expect an object to be stable when released on but not against another object (for reviews, see Baillargeon, 1995; Baillargeon, Kotovsky & Needham, 1995). The infants in one condition (cylinder-down condition) were presented with a somewhat more complex version<sup>1</sup> of Needham's cylinder-and-box display (Needham, 1998) (see Fig. 3A). The infants in another condition (cylinder-up condition) saw a similar display except that the cylinder was now suspended above the apparatus floor, with the box as its only visible means of support (see Fig. 3B). As in Needham (1998), the infants in each condition saw either a move-together or a move-apart test event.

One noteworthy aspect of the design of this experiment was that the use of featural and physical knowledge in the cylinder-up condition led to conflicting interpretations. On the one hand, the featural differences between the cylinder and box suggested that they were two distinct objects. On the other hand, the support relation

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<sup>1</sup> In this more complex version of the cylinder-and-box display, the two ends of the cylinder were curved forward, so that the cylinder's zigzag edge was less regular (it was more compressed in the cylinder's midsection). In addition, one corner, rather than one side wall, of the box faced the infants. The right end of the cylinder rested against the box's left rear wall. In an attempt to make clear to the infants that the cylinder and box were adjacent, a small portion of the cylinder's right end protruded from the box's left corner.

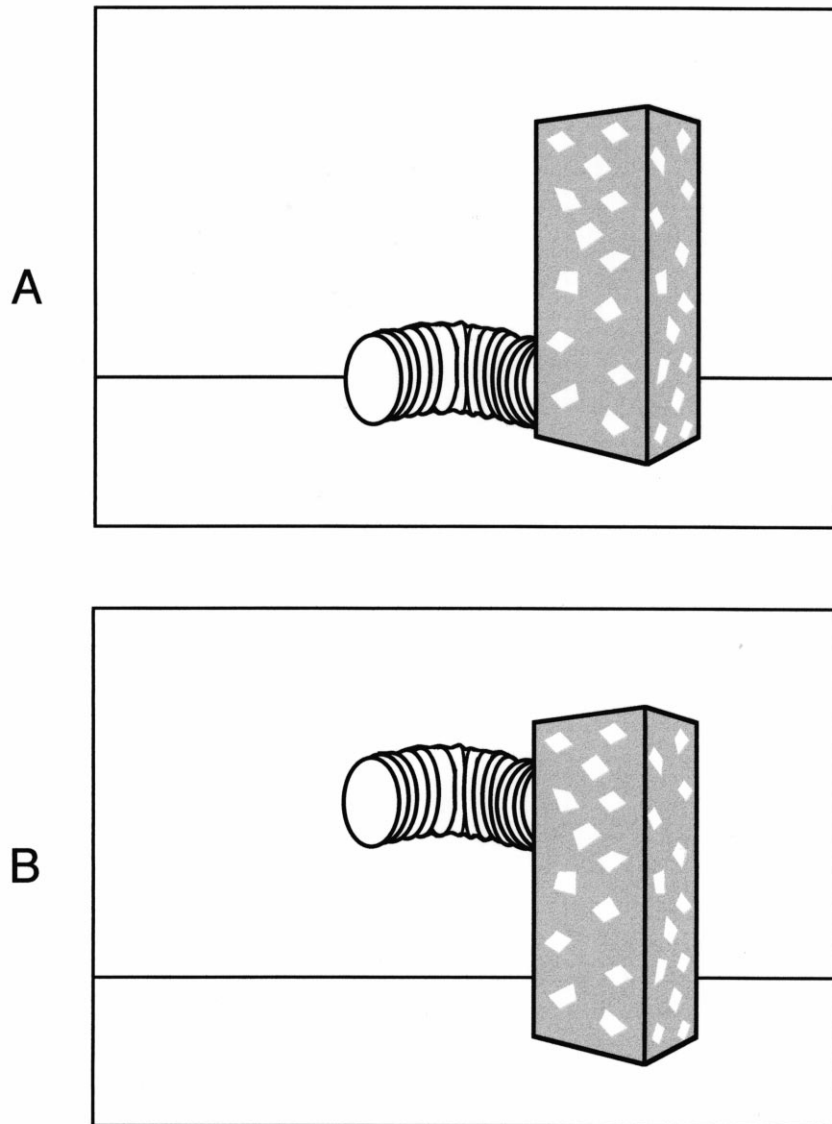


Fig. 3. Cylinder-down (A) and cylinder-up (B) displays in Needham and Baillargeon (1997).

between the cylinder and box suggested that they formed a single object. This design thus made it possible to determine what kind of knowledge – featural or physical – the infants relied upon to interpret the display.

The infants in the cylinder-down condition looked reliably longer at the move-together than at the move-apart test event, whereas those in the cylinder-up condi-

tion showed the reverse looking pattern. These results suggested that (a) the infants in the cylinder-down condition were led by the featural differences between the cylinder and box to view them as two distinct objects and (b) the infants in the cylinder-up condition perceived the cylinder and box as a single object, despite the featural differences between them, because they realized that the cylinder could not remain stable without the box's support. Together, these results indicated that, by 8 months of age, infants bring to bear both their featural and their physical knowledge when segregating adjacent displays. Furthermore, when a conflict exists between the interpretations suggested by these two kinds of knowledge, infants, like adults, choose the interpretation consistent with their physical knowledge.

### 2.3. Use of experiential knowledge

Several experiments have explored infants' ability to use experiential knowledge to segregate dissimilar adjacent displays (Needham, in press; Needham & Baillargeon, 1998; Needham & Lockhead, 1999; Needham & Modi, 1999b). A first series of experiments examined 4.5-month-old infants' ability to use a prior exposure to one of the objects in an adjacent display to correctly parse the display (Needham & Baillargeon, 1998). These experiments built on long-standing evidence that young infants can recognize objects studied for brief periods on both immediate and delayed memory tests (e.g. Fagan, 1971, 1973). The infants were tested with the more complex cylinder-and-box display (see Fig. 3A) used by Needham and Baillargeon (1997). A preliminary experiment revealed that, unlike 8-month-old infants (Needham & Baillargeon, 1997), 4.5-month-old infants were unable to form an interpretation of the display based on an analysis of its featural properties; these younger infants tended to look equally at the move-together and move-apart test events<sup>2</sup>. However, following a 5 s exposure to the box alone, or a 15 s exposure to the cylinder alone, infants succeeded in parsing the display; they now looked reliably longer at the move-together than at the move-apart event. Additional results indicated that infants also correctly parsed the display if they were exposed to the box or cylinder alone for 2 min in their own homes 24 h (though not 72 h) prior to seeing the display in the laboratory (Needham & Baillargeon, 1998; Needham & Modi, 1999b).

In another series of experiments (Needham, in press), small changes were introduced in the color and pattern of the box infants were exposed to prior to the test (e.g. the small squares on the surface of the box were yellow or red rather than white). Under these conditions, infants' parsing of the cylinder-and-box display was no longer facilitated; they tended to look equally at the move-together and

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<sup>2</sup> Why did the 4.5-month-old infants succeed with the simpler but not the more complex version of this display? In additional experiments, we found that the infants' responses to these two displays were the same whether the boundary between the two objects was visible or hidden by a narrow screen. These results suggest that it was not the connection between the objects that was the critical difference between these two displays, but rather the three-dimensional shapes of the objects from the infants' perspective.

move-apart test events.<sup>3</sup> However, infants did succeed in parsing the display when exposed simultaneously to three (though not two) of the modified boxes (Needham & Lockhead, 1999). Presumably, infants were then able to form a ‘box category’ which they could use to interpret the display, with the test box being perceived as yet another exemplar of this box category. These results are consistent with recent findings that infants aged 3 months and older are remarkably adept at forming perceptual categories (e.g. Quinn & Eimas, 1996; Quinn, Eimas & Rosenkrantz, 1993; Younger & Gotlieb, 1988).

Together, the results of these experiments suggest that, by 4.5 months of age, infants bring to bear their experiential knowledge when segregating adjacent displays. When faced with an adjacent display that they are unable to parse based on featural information alone, infants may nevertheless succeed at parsing the display if they are first exposed to (a) one of the objects in the display or (b) three or more objects that suggest a perceptual category to which one of the objects in the display can also be assigned.

#### *2.4. Use of experiential knowledge: further evidence*

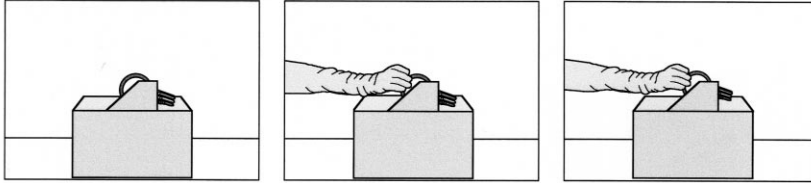
If infants are able to make use of novel perceptual categories formed ‘on the fly’ to parse displays, it seems reasonable that they would also be able to use more familiar and established object categories. To explore this possibility, Needham (1999a) examined 5.5- and 7.5-month-old infants’ responses to a dissimilar partly occluded display involving a large, colorful key-ring whose center was hidden by a narrow screen; the ring was visible to the left of the screen and the keys to the right (see Fig. 4). There were two main reasons for selecting a key-ring display. First, infants get a lot of experience looking at and playing with key-rings (their parents’ as well as their own key-ring rattles), so that it was likely to be a familiar object category. Second, because keys and rings are perceptually distinct, use of featural and experiential knowledge would lead to different interpretations, making it possible to determine which kind of knowledge infants relied on to interpret the display. The experiment’s design was thus similar to that of Needham and Baillargeon

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<sup>3</sup> These findings are striking when considered in conjunction with infants’ failures to organize displays in accordance with their featural properties (e.g. Needham, 1998; Needham & Baillargeon, 1998; Schmidt et al., 1986; Spelke, 1991; Spelke et al., 1993). If infants can recognize that the tall blue box with small white squares before them is not the same as the tall blue box with small yellow squares they saw a moment ago (Needham, in press), why can’t they also realize that the tall blue box with small white squares before them is very different from the curved yellow cylinder next to it, and as such is likely to be a separate object (Needham & Baillargeon, 1998)? If infants are capable of exquisite featural analysis in one context (object recognition), why not in another context as well (segregation)? The obvious answer is that object recognition and segregation involve two different perceptual mechanisms (and very likely brain circuitries). Recognition appears to rely on a featural analysis process that is largely automatic and effortless, with multiple featural properties being considered at once (e.g. shape, pattern, and color information). In contrast, the featural analysis process in segregation seems to be effortful and easily overwhelmed, with featural properties being identified one by one as useful predictors of object boundaries (e.g. Needham, 1998, 1999b).



### Move-together Event



### Move-apart Event

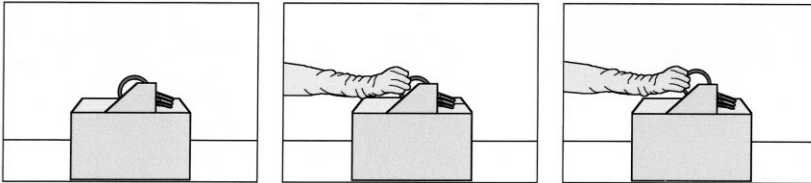


Fig. 4. Move-together and move-apart events featuring the key-ring display in Needham (1999a).

(1997) except that it pitted infants' use of featural and experiential knowledge against each other, rather than their use of featural and physical knowledge.

During the test trials, a gloved hand took hold of the ring and moved it a short distance away from the infant (the movement was in depth so that the portion of the key-ring that lay behind the screen remained hidden). For half of the infants in each age group, the ring and keys moved as a whole (move-together event); for the other infants, the ring moved alone (move-apart event).

The 5.5-month-old infants looked reliably longer at the move-together than at the move-apart test event, whereas the 7.5-month-old infants showed the reverse looking pattern. These and control results suggested that the younger infants interpreted the display in accordance with its featural properties and viewed the keys and ring as separate units. In contrast, the 7.5-month-old infants brought to bear their experiential knowledge, and more specifically their knowledge of key-rings, when interpreting the display; they perceived the keys and ring as a single unit, despite the featural differences between them.

These results suggest that, by 7.5 months of age, infants bring to bear their knowledge of familiar object categories when segregating displays (for other positive results, see Schwartz, 1982; Vishton, Stulac & Calhoun, 1998). Furthermore, when conflicts arise between the interpretations suggested by their experiential and featural knowledge, infants, like adults, prefer the experiential interpretation.

### 3. The findings of Xu et al. (1999)

Xu et al. (1999) sought to determine whether 10-month-old infants could use kind information – defined as information about “antecedently represented categories in

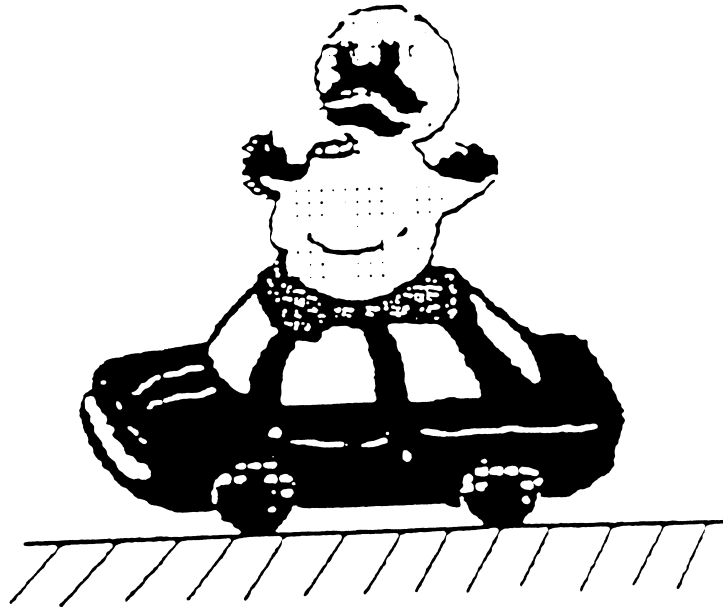


Fig. 5. Duck-car display in Experiments 1 and 2 of Xu et al. (1999).

long-term memory'' (p. 140) – to segregate a dissimilar adjacent display. The display used in Experiment 1 consisted of a yellow duck resting on top of a green car (see Fig. 5). The infants in one condition (static condition) were habituated to an event in which a hand reached for and stopped about 2 cm short of the duck. Following habituation, the infants saw two test events on alternate trials. In both events, the hand reached for and grasped the duck and lifted it vertically. In one event, the car moved with the duck (move-together event); in the other event, the car remained on the apparatus floor (move-apart event). The infants tended to look equally at the move-together and move-apart events. The same negative finding was obtained in another condition (static/handling condition) in which the infants were given the duck and car one at a time prior to testing and were allowed to play with each toy for about 30 s. Finally, negative results were also obtained in another experiment conducted with a display composed of a cup resting on a shoe (Experiment 3, static condition). Positive results were obtained at 10 months with the duck-and-car and cup-and-shoe displays only when the infants were habituated to a different event in which the hand reached for and grasped the top object (e.g. the duck) and moved it laterally relative to the bottom object (e.g. the car) (Experiments 1 and 3, movement conditions). In these conditions, the infants looked reliably longer at the move-together than at the move-apart test event, suggesting that they had achieved an unambiguous interpretation of the display as composed of two objects.

To find out at what age infants could successfully parse the duck-and-car display into two objects without the benefit of motion information, Xu et al. (1999) tested

12.5-month-old infants using a similar procedure (infants received only six habituation trials; Experiment 2). Unlike the 10-month-old infants, these older infants looked reliably longer at the move-together than at the move-apart test event, suggesting that they did perceive the duck and car as distinct objects and were surprised when they moved as a single unit.

Xu et al. (1999) took their results to mean that 12.5- but not 10-month-old infants are able to use kind information to interpret displays. Consistent with their earlier results and conclusions (Xu & Carey, 1996), Xu et al. (1999) proposed that 10-month-old infants cannot use kind information to parse displays because they do not yet possess “kind representations, representations of functionally relevant, inductively rich, namable categories” (p. 162). According to the authors, kind representations are not available until the end of the first year, when word learning begins to occur.

#### **4. A discussion of the findings of Xu et al. (1999)**

We believe that there are several reasons to question the results and conclusions of Xu et al. (1999). In what follows, we discuss the positive results obtained with the 12.5-month-old infants in the static condition of Experiment 2, the negative results obtained with the 10-month-old infants in the static/handling condition of Experiment 1, and finally the negative results obtained with the 10-month-old infants in the static conditions of Experiments 1 and 3.

##### *4.1. Positive findings with the 12.5-month-old infants in the static condition of Experiment 2*

One difficulty with the design used by Xu et al. (1999) is that it is not possible with such a design to determine what was the basis of the responses of the 12.5-month-old infants in the static condition of Experiment 2. The infants could have looked reliably longer at the move-together than at the move-apart test event because they (a) detected the featural differences between the duck and car and/or (b) brought to bear their knowledge of toy ducks and toy cars as familiar object categories to interpret the display.

Because any display will contain featural information, special steps must be taken to ascertain whether this or other information is being used by infants when interpreting a display. Researchers in the field of object segregation have taken two main approaches to circumvent this problem. One approach has been to show that infants are unable to parse a display based on featural information alone, but succeed in parsing the same display when given additional physical or experiential information (e.g. Kellman & Spelke, 1983; Needham & Baillargeon, 1998; Needham & Lockhead, 1999; von Hofsten & Spelke, 1985). Another approach has been to show that featural information alone leads to one interpretation of a display, and physical or experiential information to a different interpretation (e.g. Needham, 1999a; Needham & Baillargeon, 1997). Because Xu et al. (1999) used neither of these approaches, it is not possible to determine whether the 12.5-month-old infants in

the static condition of Experiment 2 were basing their responses on their featural or their experiential knowledge.

Xu and her colleagues might object that their results are less ambiguous than we suggest because their duck-and-car display cannot be parsed based on featural information alone. According to these authors, “gestalt principles do not clearly specify the boundaries of the objects – cues such as violation of good continuation and good form are only weakly provided in such complex stimuli. While color changes between the duck and the car, it also changes between the car and the wheels, or the body of the car and its windows” (Xu et al., 1999, p. 142). We are not persuaded by these arguments, for two reasons. First, the experiment examined only whether the infants viewed the duck as a single object; they could succeed at the task whether or not they also perceived the car as a single object. Second, our subjective impression of the duck is that its various parts (rounded yellow head and body and orange eyes, bill, and feet) were much more similar to each other than to the car parts (angular, metallic green frame and blue and yellow wheels). Hence, contrary to Xu et al. (1999), we would assume that the similarity in shape, color, and texture among the duck parts was in fact sufficient to enable the infants to view it as a single object. This sort of subjective debate makes clear why it is preferable for researchers not to simply assert that the featural information in a display is ambiguous, but to provide an experimental test of this assertion.

#### *4.2. Negative findings with the 10-month-olds in the static/handling condition of Experiment 1*

Xu et al. (1999) found that the 10-month-old infants in the static/handling condition of Experiment 1 did not look reliably longer at the move-together than at the move-apart test event even after playing with the duck or car alone for 30 s. These negative results are inconsistent with those of Needham (in press), Needham and Baillargeon (1998), and Needham and Modi (1999b). Recall, in particular, that after being exposed to the box alone for 5 s or to the cylinder alone for 15 s, 4.5-month-old infants succeeded in parsing the more complex cylinder-and-box display; infants also succeeded when exposed to the box or cylinder for 2 min in their homes on the day prior to testing (see Section 2.3). Why, then, did the 10-month-old infants in the static/handling condition not take advantage of their experiential knowledge of the duck and car to parse the duck-and-car display into two separate objects?

Xu et al. (1999) proposed that the duck and car were complex objects, and that a 30 s exposure was too brief to enable the infants to encode each object adequately; as a result, they failed to recognize either object when shown the duck-and-car display. We do not find this explanation compelling. It does not seem plausible that 10-month-old infants exposed to the duck or car for 30 s would fail to recognize them on subsequent trials. The literature on the development of visual memory certainly suggests that infants should have no difficulty recognizing either object (e.g. Bahrick & Pickens, 1995; Courage & Howe, 1999; Fagan, 1971, 1973).

We suspect that the infants in the static/handling condition did not show a reliable preference for the move-together over the move-apart test event because some

aspects of the events tended to draw their attention away from the composition of the display. Recall that the hand reached for and stopped short of the duck in the habituation trials, but reached for and grasped the duck in all of the test trials. It may be that this change in the hand's action or goal (Woodward, 1998) was so salient to the infants that they focused on it and ignored the secondary issue of whether the car should move with the duck when lifted. On this view, the positive results obtained with the 12.5-month-old infants in the static condition of Experiment 2 would reflect these older infants' ability to attend both to the change in the hand's action and to its consequences for the car. Furthermore, the positive results obtained with the 10-month-old infants in the movement conditions of Experiments 1 and 3 would be due to the fact that the hand reached for and grasped the duck or cup during both the habituation and test trials. The infants were therefore more likely to process the appropriate aspects of the events and hence to detect the violation in the move-together test event.

Support for the interpretation just proposed comes from a comparison of the looking times of the 10-month-old infants in the static and movement conditions of Experiments 1 and 3 (the looking times of the infants in the static and static/handling conditions of Experiment 1 were not reported separately). If the infants in the static conditions were focusing primarily on the change in the hand's action between habituation and test, we might expect them to look equally, and equally high, at the move-together and move-apart test events. As Table 1 shows, this was indeed the case. In both Experiments 1 and 3, the mean looking times of the static infants at the move-together and move-apart events were more similar to the movement infants' mean looking times at the move-together as opposed to move-apart event. These data thus support the notion that the static infants regarded both the move-together and move-apart events as novel.

A simple test of the interpretation advanced here would be to test infants in a static/handling condition in which the action of the hand during the habituation event is changed from an incomplete to a complete reach; the hand would reach for and grasp the duck, but not lift it. With the hand's action during the habituation event brought more closely in line with that performed in the test events, infants

Table 1  
Mean looking times (in seconds) of the infants in Xu et al. (1999) Experiments 1 and 3

	Test event	
	Move-together	Move-apart
Experiment 1		
Static	8.5	7.3
Movement	7.6	6.1
Experiment 3		
Static	5.7	5.9
Movement	4.7	2.8

should be free to focus on the composition of the display and to apply their prior experiences with the duck and car to its interpretation.

#### *4.3. Negative findings with the 10-month-old infants in the static conditions of Experiments 1 and 3*

Xu et al. (1999) found that the 10-month-old infants in the static conditions of Experiments 1 and 3 tended to look equally at the move-together and move-apart events, suggesting that they had an ambiguous interpretation of the duck-and-car (Experiment 1) and cup-and-shoe (Experiment 3) displays. At least three interpretations could be offered for these negative results. One possibility, mentioned in the previous section, is that the infants were too distracted by the change in the hand's action to focus on the issue of whether the car should move with the duck. A second possibility is that the display was too complex for the infants to parse. Although infants aged 4–9.5 months have been found to succeed at parsing static dissimilar displays (e.g. Craton et al., 1998; Needham, 1998, 1999b; Needham & Baillargeon, 1997; Needham & Kaufman, 1997; Needham et al., 1997), negative results have been obtained as well (e.g. Needham, 1998; Schmidt et al., 1986; Spelke et al., 1993). These discrepant results have been construed as a complexity effect. In order to interpret a display, infants must first encode and compare the spatial and featural properties of the relevant surfaces; with more complex displays, infants' information processing resources are unable to complete this featural analysis in a timely fashion, resulting in an ambiguous interpretation. Thus, one possibility is that the duck-and-car display and cup-and-shoe displays used by Xu et al. (1999) were simply too complex for the infants to process.

A third possibility has to do with a subtle difference between the experiments of Xu et al. (1999) and those of our experiments that have been successful in demonstrating infants' use of featural information in organizing adjacent displays (e.g. Needham, 1998, 1999b; Needham & Baillargeon, 1997). Whereas Xu et al. (1999) used two objects stacked one on top of the other (see also Spelke et al., 1993), we have consistently used two objects placed side by side (for ease of description, we will refer to the former type of adjacent display as a stacked display, and to the latter type as a side display). It could be that stacked displays are more difficult for infants to learn to organize than are side displays. When two objects are placed side by side, pulling on either object will bring about a gap between them. It makes sense that under these conditions infants would learn relatively rapidly that abrupt discontinuities in shape, pattern, color, and texture signal the presence of distinct objects. With stacked displays, however, the situation is more variable. Different outcomes occur when the top object is lifted (i.e. just the top object moves) and when the bottom object is lifted (i.e. both objects move). Consider a pitcher and glasses on a tray, a teacup on a saucer, or a doll in a toy car. In all of these cases, infants see top objects moving with their supporting objects. It would not be surprising if these common motions made learning how to segregate stacked displays more difficult for infants. After all, common motion is from an early age

a powerful and salient cue for object unity (e.g. Johnson, 1997; Kellman, 1993; Kellman & Spelke, 1983; Slater et al., 1990).

An experiment with 8-month-old infants is currently under way in Needham's laboratory to test the notion that stacked displays are more difficult for infants to parse than are side displays. The infants are shown the Needham (1998) simple cylinder-and-box display turned on its side, so that the box lies flat on the apparatus floor with the cylinder extending vertically from it. As in previous experiments, following a familiarization trial, infants receive test trials in which they see either a move-together or a move-apart event. In these events, the hand grasps and lifts the cylinder; the box either moves with the cylinder or remains stationary. The data collected so far suggest that, like the 10-month-old infants in the static conditions of Experiments 1 and 3 in Xu et al. (1999), the 8-month-old infants in the present experiment tend to look equally at the move-together and move-apart events. These data contrast sharply with those obtained with 4.5- and 6.5-month-old infants when the cylinder and box stood side by side (Needham, 1998). Such a contrast gives weight to the hypothesis that infants learn to use featural information to segregate first side and only later stacked displays. From this perspective, the positive findings obtained by Xu et al. (1999) with the 12.5-month-old infants in the static condition of Experiment 2 would indicate that stacked displays begin to be successfully parsed at about the end of the first year.<sup>4</sup>

## 5. Findings of Xu and Carey (1996)

Xu et al. (1999) pointed out that their results are strikingly consistent with those obtained by Xu and Carey (1996) using a different procedure. The experiments of Xu and Carey examined 10- and 12-month-old infants' responses to occlusion events involving two distinct objects (for ease of description, we will refer to

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<sup>4</sup> Two additional differences between the experiments of Xu et al. (1999) and our own (e.g. Needham, 1998, 1999b; Needham & Baillargeon, 1997) may be worth discussing. First, readers may have noted that, whereas Xu et al. used a within-subject design (each infant saw a move-together and a move-apart event on alternate trials), we used a between-subjects design (each infant saw either a move-together or a move-apart event on each trial). Our selection was based on a concern that, in a within-subject design, infants' responses in later trials might be contaminated by previous trials. We reasoned that seeing the same display move as though it were composed of, say, two objects in the first trial, one object in the second trial, two objects again in the third trial, and so on, might be puzzling for infants and as such might introduce complexities in the interpretation of their responses. Second, whereas Xu et al. gave their 10-month-old infants six to 14 habituation trials before the test trials, we gave our 4- to 8-month-old infants at most three familiarization trials. Our reasoning was simply that giving infants fewer familiarization trials (when more were not necessary) made it more likely that they would still be interested and engaged during the test trials. Since Xu et al. obtained positive results with the 12-month-old infants in the static condition of Experiment 2, the procedural differences noted here may have had limited impact. Nonetheless, it may be worth pointing out that the 12-month-old infants showed their clearest preference for the move-together event on the first test pair, a result consistent with the points made above (the infants' mean looking times at the move-together and move-apart events on the three test pairs were 14.3 and 10.0, 9.7 and 8.5, and 8.0 and 6.1, respectively).

these events as dissimilar occlusion events). The infants first received four introductory trials in which they saw one or two objects (e.g. bunny; bunny and basket; truck; truck and camel). Next, the infants received four test trials. At the start of each trial, one object (e.g. a ball) moved from behind the left edge of a wide screen to the left wall of the apparatus and then returned behind the screen; a different object (e.g. a bottle) then moved from behind the right edge of the screen to the right apparatus wall and then returned behind the screen. The process was repeated until the infants had observed multiple emergences of each object. At that point, the screen was removed to reveal either one object (e.g. a ball) or two distinct objects (e.g. a ball and a bottle); the infants saw the one-object display in one trial, the two-object display in another trial, and the entire sequence was repeated with two new objects (e.g. a cup and a book).

The 12-month-old infants looked reliably longer at the two- than at the one-object display during the introductory trials, but tended to look equally at the two displays during the test trials. These test results suggested that (a) the infants inferred that two objects were present behind the screen, (b) the infants were surprised when the screen was removed to reveal the one-object test display, and (c) the infants' surprise at the one-object test display, combined with their intrinsic preference for the two-object test display (a preference suggested by the introductory data), resulted in equal looking times at the two test displays (for additional positive data with 12-month-old infants tested with similar procedures, see Leslie, Xu, Tremoulet & Scholl, 1998; Wilcox & Baillargeon, 1998a).

In contrast to the 12-month-old infants, the 10-month-old infants looked reliably longer at the two- than at the one-object display during both the introductory and the test trials. Xu and Carey (1996) took these results to suggest that (a) the infants were not able to infer how many objects were involved in the trial, (b) the infants found neither the one- nor the two-object test display surprising, and (c) the infants' test responses reflected only their intrinsic preference for the two-object test display. The same negative result was obtained in additional experiments conducted with a similar procedure (Xu & Carey, 1996; see also Wilcox & Baillargeon, 1998a).

According to Xu and her colleagues, the results of Xu and Carey (1996) and Xu et al. (1999) provide converging evidence that the ability to form kinds, or "functional, namable" (p. 162) object categories such as ducks, cars, balls, and bottles, emerges between 10 and 12 months of age. Because infants younger than 12 months still lack kinds, they cannot use this type of object knowledge to identify the object boundaries in dissimilar adjacent displays, or to individuate the objects in dissimilar occlusion events. Earlier we presented our reasons for questioning the results and conclusions of Xu et al. (1999). In the next section, we discuss our reservations concerning the conclusions of Xu and Carey (1996).

## **6. A discussion of the findings of Xu and Carey (1996)**

Several of the issues raised earlier concerning the results of Xu et al. (1999) also



apply to the results of Xu and Carey (1996). First, the positive results obtained with the 12-month-old infants again are ambiguous; the data are insufficient to determine whether the infants were basing their responses on featural information (e.g. noticing that the ball and bottle differed in shape) or experiential information (e.g. recognizing that the ball and bottle were instances of familiar object categories). Second, the negative results obtained with the 10-month-old infants again are inconsistent with the evidence reviewed in preceding sections that infants aged 4–9.5 months can use featural and experiential information to organize at least some dissimilar adjacent and partly occluded displays (e.g. Craton et al., 1998; Needham, 1998, 1999a,c; Needham & Baillargeon, 1997; Needham & Kaufman, 1997; Needham & Lockhead, 1999; Needham & Modi, 1999a,b; Needham et al., 1997; Schwartz, 1982; Vishton et al., 1998). How should this discrepancy be explained?

It might be suggested that the objects used by Xu and Carey (1996) were sufficiently complex that they overwhelmed the 10-month-old infants' memory and information processing abilities; the task of encoding and comparing the featural properties of the ball and bottle or cup and book was simply too difficult for the infants to complete, so that they were not able to determine how many objects were present behind the screen. Such an interpretation is consistent with the evidence, discussed in earlier sections, that infants are more likely to successfully parse simple as opposed to complex dissimilar displays (e.g. Needham, 1998; Needham et al., 1997; Schmidt et al., 1986; Spelke et al., 1993). This explanation does not seem likely, however, for two reasons. First, the objects used by Xu and Carey were actually rather simple, and certainly not appreciably more complex than the box and cylinder used by Needham and Baillargeon (1997) or the ring and keys used by Needham (1999a). Second, Wilcox and Baillargeon (1998a) conducted an experiment similar to that of Xu and Carey and found similar results – they obtained positive results with 11.5-month-old infants and negative results with 9.5-month-old infants – using two very simple objects, a ball and a box.

How else, then, should we explain the discrepancy between the negative results obtained by Xu and Carey (1996) and the positive results of Needham and her colleagues (Needham, 1998, 1999a,b; Needham & Baillargeon, 1997; Needham & Kaufman, 1997; Needham & Lockhead, 1999; Needham et al., 1997)? Wilcox and Baillargeon (1998a) proposed that this discrepancy reflects the use of two different types of tasks, event-mapping and event-monitoring tasks, to assess infants' featural and experiential knowledge. The distinction between these two types of tasks is based in part on recent evidence that infants 'sort' physical events into distinct categories (e.g. occlusion, containment, support, and collision events), and reason and learn separately about each category (e.g. Aguiar & Baillargeon, 1999a; Hespos & Baillargeon, 1999b). In an event-mapping task, infants see events from two different event categories and judge whether the two events are consistent (in light of their physical, experiential, or other knowledge). In an event-monitoring task, in contrast, infants see an event from one event category and judge whether the successive portions of the event are consistent.

According to Wilcox and Baillargeon (1998a), event-mapping tasks are more likely than event-monitoring tasks to challenge infants' memory and information processing abilities. To see why, consider the processing steps involved in each type of task. To succeed at an event-monitoring task, infants must set up a representation for the event before them and monitor objects' displacements and interactions within the event to assess whether they are consistent. Success in an event-mapping task requires a larger number of steps. First, infants must set up a representation for the first event and monitor its progress. Second, when the second event begins, infants must set up a representation for the new event and again monitor its progress. Finally, third, infants must attempt to link or map their two event representations, to determine whether they are consistent. This mapping process requires infants to (a) retrieve their representation of the first event and (b) compare it to their representation of the second event. Wilcox and Baillargeon have suggested that this retrieval and comparison process easily taxes infants' memory and information processing abilities, resulting in their failure to detect inconsistencies between the first and second events.

The task designed by Xu and Carey (1996) was an event-mapping task; each test trial involved first an occlusion and then (for lack of a better term) a no-occlusion event. The infants saw two objects emerge successively from behind a screen, and then the screen was removed to reveal a one- or a two-object test display. According to Wilcox and Baillargeon (1998a), success at the task required the infants to retrieve their representation of the occlusion event, compare it to the one- or two-object test display before them, and judge whether the two were consistent. The negative responses of the 10-month-old infants suggest that they were unable to complete this mapping process. It should be emphasized that from this perspective the infants very likely realized, based on their featural and/or experiential knowledge, that the occlusion event involved two distinct objects; the infants' primary difficulty was in mapping this knowledge onto the one- and two-object test displays.

Unlike Xu and Carey (1996), Needham and her colleagues (Needham, 1998, 1999a,c; Needham & Baillargeon, 1997; Needham & Kaufman, 1997; Needham & Lockhead, 1999; Needham et al., 1997) used event-monitoring tasks in their experiments. Recall, for example, that the 5.5- and 7.5-month-old infants tested by Needham (1999a) saw, in each test trial, an occlusion event in which a hand grasped and moved a large ring visible to the left of a narrow screen; keys visible to the right of the screen either moved with the ring or remained stationary. The infants were thus presented with an event from a single event category, since the screen was never removed; all they had to do was to judge whether the event unfolded in a manner consistent with their featural and/or experiential knowledge (i.e. should the keys move with the ring or not?).

The approach of Wilcox and Baillargeon (1998a) makes a number of testable predictions about the conditions under which infants should give evidence that they can use featural or experiential knowledge to individuate objects in dissimilar occlusion events. Three of these predictions are described in the next sections, along with some of the experiments that were conducted to test them.

### 6.1. Testing object individuation using event-monitoring tasks

One straightforward prediction from the approach of Wilcox and Baillargeon (1998a) is that positive evidence of infants' use of featural information when interpreting dissimilar occlusion events might be obtained in experiments conducted with event-monitoring as opposed to event-mapping tasks. To examine this prediction, Wilcox and Baillargeon (1998a) tested 7.5- and 9.5-month-old infants using a novel task. The infants first received familiarization trials in which a ball moved behind the left edge of a very wide screen that occluded the center and right portions of the apparatus; after a long pause, the ball reappeared at the screen's left edge and returned to its starting position. Following the familiarization trials, the very wide screen was replaced with a narrower test screen that occluded only the center portion of the apparatus. As before, the ball moved behind the left edge of the screen; after a pause, a box emerged at the screen's right edge and moved to the right. The entire sequence was then repeated in reverse. For half of the infants (wide-screen condition), the test screen was sufficiently wide to occlude the ball and box simultaneously; for the other infants (narrow-screen condition), the test screen was too narrow to occlude the two objects at once (see Fig. 6).

The task used in this experiment was an event-monitoring task because in each test trial the infants saw only one event, an occlusion event; success at the task required simply that the infants monitor the event and judge whether it unfolded in a manner consistent with their featural and physical knowledge.

The infants in the narrow-screen condition looked reliably longer during the test trials than did those in the wide-screen condition, suggesting that they (a) were led by the featural differences between the ball and box to view them as distinct objects, (b) realized that the ball and box could both be occluded by the wide but not the narrow screen, and hence (c) were surprised in the narrow-screen condition when this judgment was contradicted. These conclusions were supported by the results of a control experiment in which a smaller ball and box were used that could both fit behind the narrow screen (see Fig. 6). No reliable difference was found in this experiment between the looking times of the infants in the narrow- and wide-screen conditions.

In subsequent experiments, Wilcox extended her initial results to infants aged 4.5 months (Wilcox, 1999; Wilcox & Baillargeon, 1998b). She also observed a clear developmental sequence in the type of featural information infants can use to individuate objects in dissimilar occlusion events; she found that whereas 4.5-month-olds can use only shape or size information, 7.5-month-olds can also use pattern and 11.5-month-olds color information (Wilcox, 1999).

Wilcox's results (Wilcox, 1999; Wilcox & Baillargeon, 1998a,b) are thus consistent with those of Needham (Needham, 1998, 1999b; Needham & Baillargeon, 1997; Needham & Kaufman, 1997; Needham et al., 1997) in showing that (a) when tested with event-monitoring tasks, infants as young as 4.5 months of age give evidence that they can use featural information to determine what objects are present and (b) infants initially base their responses on shape or size and only later on pattern and color information.

### 6.2. Facilitating the mapping process in event-mapping tasks

According to Wilcox and Baillargeon (1998a,b), infants' main difficulty with event-mapping tasks is in retrieving their representation of the first event and comparing it to that of the second event. This analysis suggests that simplifying

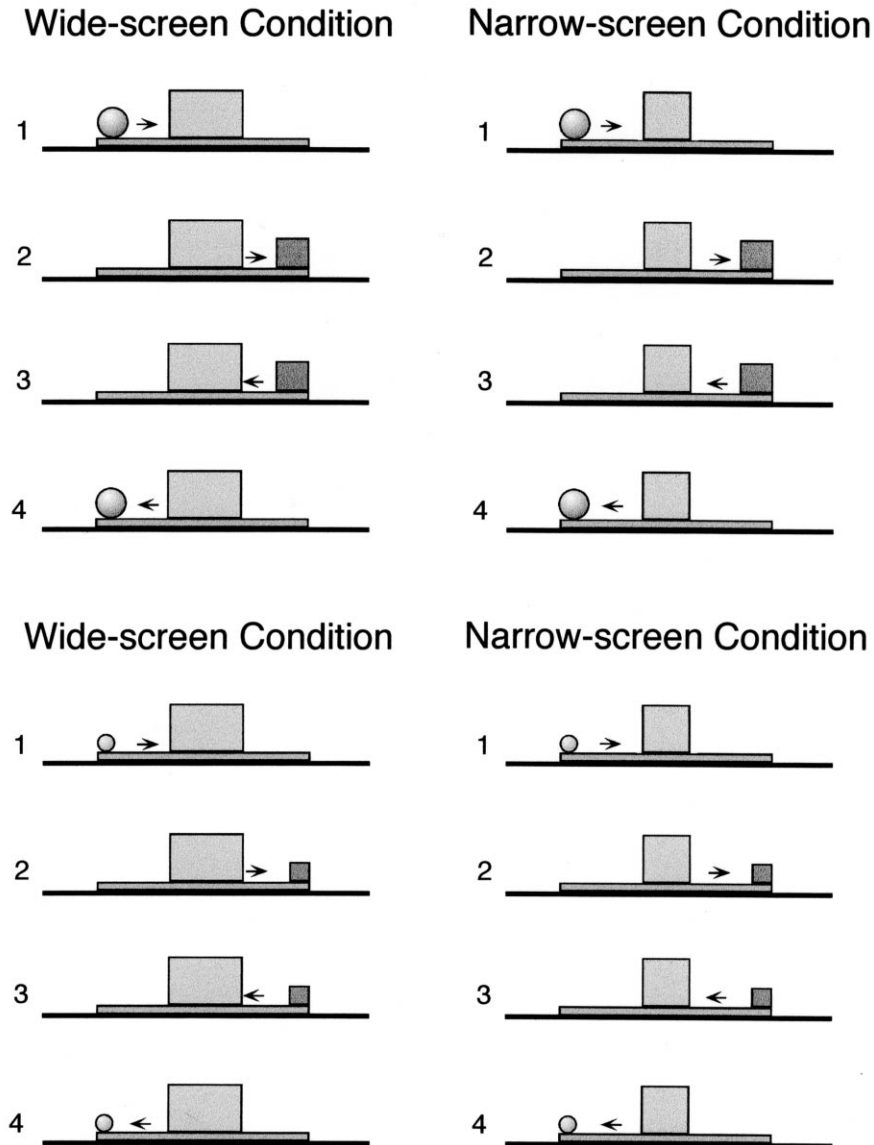


Fig. 6. Wide-screen and narrow-screen events in Wilcox and Baillargeon (1998a).

the first event should facilitate the retrieval and comparison process and thus result in an improved performance.<sup>5</sup> To test this prediction, Wilcox and Baillargeon (1998a) designed an event-mapping task in which 9-month-old infants again saw an occlusion and a no-occlusion event; however, the trajectories of the objects in the occlusion event were greatly simplified. The infants were assigned to a box–ball or a ball–ball condition and received one test trial (see Fig. 7). At the start of the trial in the box–ball condition, a gloved hand grasped a box to the left of a wide screen; the hand moved the box behind the left edge of the screen and, after a pause, moved a ball from behind the right edge of the screen. The screen was then lowered (no-occlusion event) to reveal an empty area; only the ball was visible to the right of the screen. In the ball–ball condition, a second, identical ball was substituted for the box in the occlusion event.

The infants in the box–ball condition looked reliably longer than did those in the ball–ball condition. These results suggested that the infants were able to (a) retrieve a representation of the occlusion event, (b) map this representation onto the no-occlusion event, and (c) determine that the occlusion and no-occlusion events in the ball–ball condition were consistent, but that those in the box–ball condition were not, as the box seemed to have disappeared. These conclusions were supported by a control condition similar to the box–ball condition, with one exception: when the screen was lowered, a second screen was revealed that was sufficiently tall to hide the box. The looking times of these control infants were similar to those of the ball–ball infants, suggesting that the control infants did indeed assume that the box was hidden by the second screen.

These results – which Wilcox and Schweinle (1999) have recently extended to 5.5-month-old infants – indicate that young infants can succeed at an event-mapping task involving an occlusion and a no-occlusion event, as long as the occlusion event is made very simple and brief so that the task of retrieving the occlusion event and comparing it to the no-occlusion event does not overwhelm infants' memory and information processing resources. In additional experiments, Wilcox and Baillargeon (1998a) showed infants occlusion events involving slightly longer object trajectories; the results were consistently negative. For example, in one experiment, 9-month-old infants saw an occlusion and a no-occlusion event identical to those in the box–ball condition described above, except that the box was hidden behind the screen at the start of the occlusion event; the hand first moved the box to the left of the screen, and then the event proceeded exactly as before. The addition of this single reversal in the box's trajectory was sufficient to confuse the infants; they no longer responded with prolonged looking when the screen was lowered to reveal an empty area. Only 11.5-month-old infants succeeded with occlusion events involving

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<sup>5</sup> The most obvious way to simplify a dissimilar occlusion event is, of course, to transform it into a similar occlusion event in which the same object appears on both sides of the occluder. Based on a reanalysis of data from Xu and Carey (1996), Wilcox and Baillargeon (1998a) argued that 10-month-old infants (a) believe that a similar occlusion event involves a single object and (b) map such an event onto a one- but not a two-object test display. Given the present focus on dissimilar occlusion events, we limit our discussion to simplifications of these events, which involve primarily changes in the objects' trajectories (Wilcox & Baillargeon, 1998a).

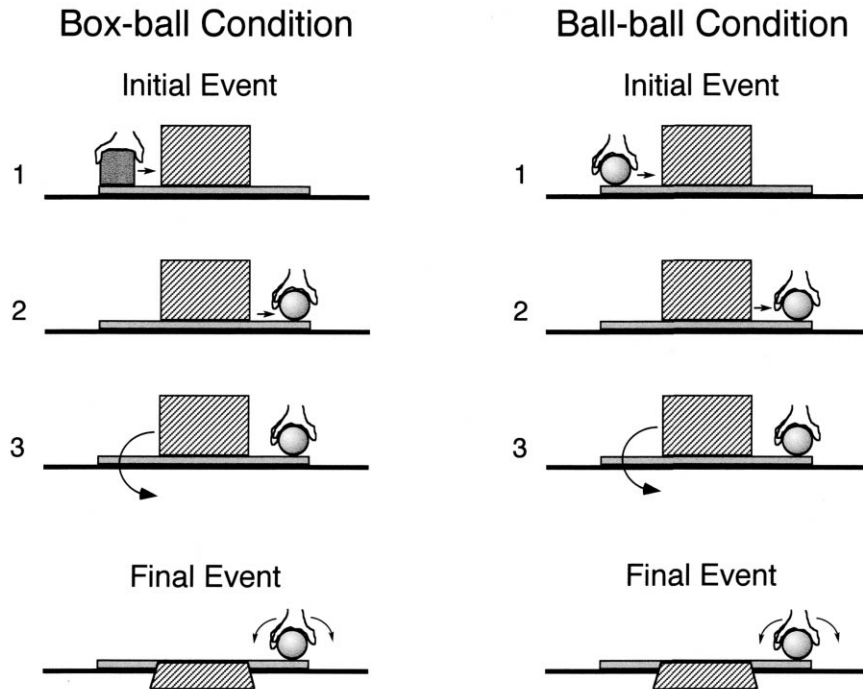


Fig. 7. Box-ball and ball-ball events in Wilcox and Baillargeon (1998a).

reversals, a result consistent with those of Xu and Carey (1996) (see also Leslie et al., 1998).<sup>6</sup>

Together, the experiments reviewed in this section provide strong evidence that event-mapping tasks such as those of Xu and Carey (1996), Leslie et al. (1998), and Wilcox and Baillargeon (1998a) are difficult for infants aged 10 months or less, not because they lack the featural knowledge to correctly interpret dissimilar occlusion events, but because they can only retrieve and compare information about very simple dissimilar occlusion events.

### 6.3. Facilitating the mapping process in event-mapping tasks: further results

Implicit in the preceding discussion is the assumption that, when infants retrieve an occlusion event to compare it to a no-occlusion event, they mentally scan the occlusion event to determine what were the objects involved in it. Two additional

<sup>6</sup> We do not mean to suggest that, by 11.5 or 12 months of age, infants' difficulties with event-mapping tasks are largely over. Leslie et al. (1998) found that 12-month-old infants who are shown two balls of different colors during the occlusion portion of an event-mapping task tend to look equally when shown no-occlusion displays involving two balls of the same or different colors. It seems that infants are able to map the information that two objects are present, but have difficulty mapping further information about the featural properties and especially the color of each object (see also Xu, Carey & Quint, 1997).

results of Xu and Carey (1996) suggest that infants are not limited to this approach but can solve event-mapping tasks through alternative strategies. The first result is that 10-month-old infants succeeded at the task if they saw the two objects to be used in the occlusion event side by side prior to the event. One interpretation of this result is that, rather than retrieving and scanning the entire occlusion event, the infants simply accessed their representation of the two objects shown side by side. This representation was presumably easy to retrieve and compare to the one- and two-object test displays, allowing the infants to detect the violation in the one-object display. The second result is that 10-month-olds were more likely to succeed if they knew the labels (as indicated by parental report) of the objects used in the occlusion event. Again, one interpretation for this result is that, rather than retrieving and scanning the occlusion event, the infants simply accessed the list of labels they had encoded while watching the event (e.g. ‘ball’, ‘bottle’), and used these labels to interpret the one- and two-object test displays.

What we are suggesting is that 10-month-old infants have more than one strategy at their disposal for mapping objects across two events (Wilcox & Baillargeon, 1998a). Whenever possible, infants retrieve what we might call summary representations of the objects in the first event: a mental picture of the objects standing side by side, a pair of labels, and so on. When such information is not available, however, infants have no choice but to fall back on the more laborious (and often unsuccessful) strategy of retrieving the entire first event and scanning its contents.

There are, of course, several alternative interpretations for the two results discussed here, and a great deal of research will be needed to explore them. For now, we simply want to raise the possibility that labeled kinds (that is, kinds for which infants either possess or are given labels; see Xu, 1997) may be important in an event-mapping task such as that of Xu and Carey (1996), not because they help infants individuate the objects in the occlusion event, but because they facilitate the mapping of the objects from the occlusion to the no-occlusion event. On this view, language would thus play a key role in helping infants and older children monitor multiple-event sequences and more generally view events not in independent episodes but in a rich, continuous stream.

#### *6.4. Testing individuation in event-mapping tasks involving different events*

Following Wilcox and Baillargeon (1998a), we have argued that infants have difficulty mapping objects across events from two distinct categories when they (a) have no summary representation of the objects involved in the first event and hence (b) must engage in the onerous process of retrieving the first event and scanning its contents. This analysis predicts that infants should respond similarly whether the two events involved are an occlusion and a no-occlusion event, as in Xu and Carey (1996), or some other pair of events. As long as infants are forced to retrieve and process the first event, the same difficulties should arise regardless of the specific pair of events used.

To examine this prediction, Hespos and Baillargeon (1999a) recently tested 6.5-month-old infants with an event-mapping task in which they saw first an occlusion

and then a containment event (occluder–container condition). Recent evidence suggests that infants view occlusion and containment events as belonging to distinct event categories, and reason and learn separately about these two categories (e.g. Aguiar & Baillargeon, 1999a; Hespos & Baillargeon, 1999b). The infants were assigned to a ball–box or a box–box condition (see Fig. 8). At the start of each test trial in the ball–box condition, a gloved hand lifted a Koosh ball above the right edge of a large screen, and then lowered it behind the screen. Next, the hand lifted a box above the left edge of the screen and again returned it behind the screen. This entire sequence was repeated three times. Next, the screen was lowered to the apparatus floor to reveal a rectangular container (the container differed from the screen in pattern and color, to help the infants notice the change). The hand lifted the box above the right and then the left edge of the container’s front wall; this sequence was repeated until the infant looked away and the trial ended. The infants in the box–box condition received similar test trials, except that the ball was replaced by a second, identical box.

The performance of the infants in the occluder–container condition was compared to that of a second group of infants (see Fig. 9) who saw similar ball–box and ball–ball events, with one exception: the container was replaced with a screen (occluder–occluder condition). When the large screen was lowered, a second, smaller screen was revealed that was identical in appearance to the front wall of the container in the occluder–container condition. In both the occluder–container and occluder–occluder conditions, observers monitored in each test trial how long the infant looked after the large screen was lowered.

The reasoning was that the infants in the occluder–container condition, who saw events from two distinct event categories, should perform just like the 10-month-old infants in the event-mapping task of Xu and Carey (1996) (see also Wilcox & Baillargeon, 1998a). Specifically, the infants in the ball–box condition should have difficulty retrieving their representation of the occlusion event and mapping it onto their representation of the containment event. As a result, the infants should

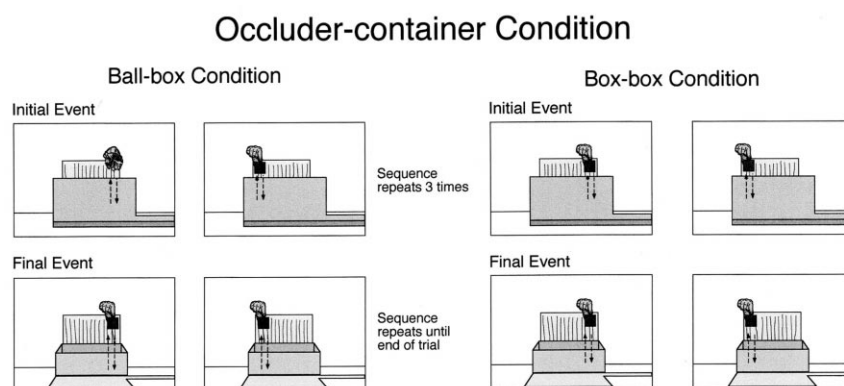


Fig. 8. Occluder–container events in Hespos and Baillargeon (1999a).



## Occluder-occluder Condition

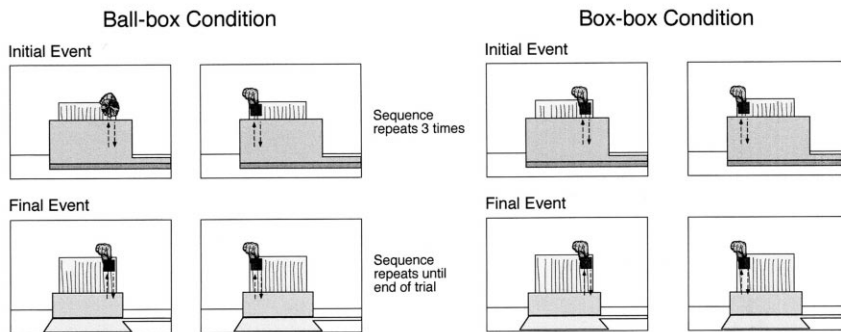


Fig. 9. Occluder-occluder events in Hespos and Baillargeon (1999a).

be unable to detect the change introduced in the containment event. That is, they should fail to notice that, whereas two distinct objects (the ball and box) were involved in the occlusion event, only one object (the box) was involved in the containment event. No difference should therefore be found between the looking times of the infants in the ball-box and box-box conditions after the large screen was lowered. In contrast, the infants in the occluder-occluder condition, who saw an event from a single event category, should perform like the infants of Wilcox and Baillargeon (1998a,b) who were given an event-monitoring task. They should monitor the occlusion event as it continued to unfold, first with the large and then with the small screen, and they should detect the change in the ball-box condition – the box appearing over the right edge of the occluder where the ball had previously appeared. The ball-box infants should thus look reliably longer than the ball-ball infants after the large screen was lowered.

The results confirmed these predictions. In the occluder-container condition, the ball-box and box-box infants tended to look equally during the test trials; in the occluder-occluder condition, however, the ball-box infants looked reliably longer than did the box-box infants.<sup>7</sup>

<sup>7</sup> One difference between the present paradigm and those of Xu and Carey (1996) and Wilcox and Baillargeon (1998a) may be worth mentioning. The infants in the occluder-container condition of Hespos and Baillargeon (1999a) were not presented, following the occlusion event, with an impossible containment event in which the ball had mysteriously disappeared from the apparatus. The infants could assume that the ball was still present, out of sight, inside the container. Therefore, what the experiment tested was not whether the infants detected that the ball had disappeared, but whether they recognized that the hand had altered the pattern of its actions and now lifted the box above both the right and left edges of the container. Such a change could, of course, have been too slight to induce prolonged looking in the infants. However, the fact that the infants in the occluder-occluder condition looked reliably longer at the ball-box than at the box-box event suggests that the change in the hand's actions was, indeed, attention-getting for the infants (for further evidence of young infants' prolonged looking at changes in a hand's action see Woodward, 1998).

The results of the occluder–container condition thus confirmed the negative results of Xu and Carey (1996) and Wilcox and Baillargeon (1998a), and also provided evidence that young infants have difficulty mapping objects across different event categories, whether these are occlusion and no-occlusion or occlusion and containment.

Further support for the conclusions of Hespos and Baillargeon (1999a) came from an additional experiment in which infants saw events similar to those in the occluder–container condition, except that the trajectory of the objects was simplified. Instead of one object (ball or box) being lifted and lowered at the right edge of the screen and another object (box) being lifted and lowered at the left edge of the screen, both objects underwent exactly the same trajectory (see Fig. 10). The hand lifted the first object above the right edge of the screen, moved it to the left above the screen (in plain view of the infants), and then lowered it behind the left edge of the screen; the hand then repeated the same actions with the second object. As in the first experiment, the entire sequence was repeated three times, and then the screen was lowered to reveal the container. During the containment event, the hand continued to perform the same actions as before, lifting the box above the right edge of the container, moving it to the left, lowering it behind the left edge of the container, and so on.

The infants in the ball–box condition looked reliably longer than did those in the box–box condition after the large screen was lowered in each test trial. These data suggest that the infants in the ball–box condition succeeded at mapping the occlusion onto the containment event when the object’s trajectory was simplified. These results are consistent with those of Wilcox’s simplified-trajectory experiments (Wilcox & Baillargeon, 1998a; Wilcox & Schweinle, 1999). Further research is needed to establish precisely how infants encode trajectory information, and what makes certain information easier or more complex to encode than other. For example, in the simplified-trajectory experiment of Hespos and Baillargeon (1999a), two changes occurred simultaneously: (a) the two objects in the occlusion event under-

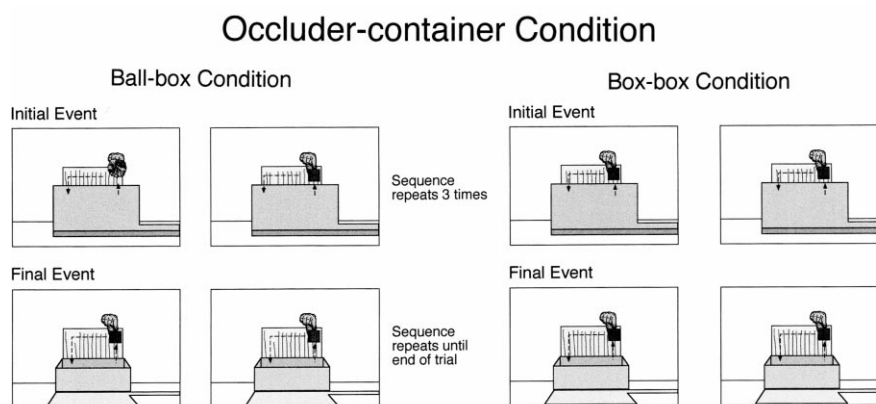


Fig. 10. Occluder–container events using a simplified trajectory in Hespos and Baillargeon (1999a).

went the same trajectory; and (b) neither object reversed its trajectory in plain view of the infants. A way to test which of these two changes was more crucial would be to have the ball and box in the occlusion event both be lifted and lowered above the center of the screen. Negative results would suggest that reversals are particularly difficult for infants to encode. Positive results, in contrast, would suggest that infants can handle occlusion events in which the two objects have either (a) distinct but very simple, no-reversal trajectories (Wilcox & Baillargeon, 1998a; Wilcox & Schweinle, 1999) or (b) a single but more complex trajectory involving reversals.

Irrespective of how these issues are eventually settled, the results of Hespos and Baillargeon (1999a) are important for two reasons. First, they indicate that infants' difficulties with event-mapping tasks are not limited to tasks involving occlusion and no-occlusion events, but also arise with other pairs of events such as occlusion and containment events. This finding provides strong support for the notion that it is in their attempt to link events from different event categories – to keep track of the world as multiple events unfold – that infants often falter. Second, the present results provide further evidence that infants aged less than 10 months can succeed at linking events from different categories as long as the amount of information – and especially trajectory information – involved does not overwhelm their memory and information processing resources.

## **7. Concluding remarks**

The research reviewed in this article can be summarized as follows. First, infants can use featural, physical, and experiential knowledge to segregate the objects in static dissimilar adjacent and partly occluded displays. Second, infants are less likely to succeed at parsing such displays when (a) the objects are sufficiently complex that the amount of information to be encoded and compared overwhelms infants' processing abilities or (b) the objects are placed in a stacked-adjacent display; stacked-adjacent displays apparently are understood later in development than are side-adjacent or partly occluded displays. Third, infants can also use featural knowledge to individuate the objects in dissimilar occlusion events (no conclusive evidence is available to date on infants' use of other types of knowledge, including kind knowledge, in interpreting dissimilar occlusion events). Fourth, infants are more likely to reveal their ability to individuate the objects in dissimilar occlusion events when tested with event-monitoring as opposed to event-mapping tasks. Fifth, infants experience similar difficulties whether they are tested with event-mapping tasks involving occlusion and no-occlusion or occlusion and containment events. Finally, infants are more likely to succeed at an event-mapping task when (a) they have access to a summary representation of the two objects in the first event (e.g. a mental picture of the two objects standing side by side, a mental list of the objects' labels) or (b) the two objects' trajectories are kept relatively simple so that there is less information to retrieve and compare.

The approach and results presented here differ radically from those of Xu and her colleagues (Xu & Carey, 1996; Xu et al., 1999). Unlike these authors, we believe

that infants are able to use featural and experiential information for segregation and individuation purposes long before the end of the first year. By the same token, we also disagree with the claim that the formation of object categories or kinds typically awaits early word learning. Nevertheless, we do acknowledge that language may play a key role in facilitating infants' performance in event-mapping tasks, by providing infants with summary labels that make considerably easier the mapping of objects across distinct events.

As we hope is clear from the present article, we believe that the fields of object segregation and individuation are entering a new and very exciting era. New questions are being asked – about the nature and contents of infants' representations, and the mechanisms that drive them – at a level of detail that would have been hard to imagine as little as 5 or 10 years ago. The next 10 years should yield fundamental insights into the process of mental representation in infancy, and the early links between representation and language.

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