Published in final edited form as:
Cognition. 2004 January ; 90(3): 265–302.

Priming infants to attend to color and pattern information in an individuation task

Teresa Wilcox[a,*] and **Catherine Chapa**[b]

[a]Department of Psychology, Texas A&M University, 4235 TAMU, College Station, TX 77843, USA

[b]Palo Alto College, San Antonio, TX, USA

Abstract

Wilcox (*Cognition 72* (1999) 125) reported that infants are more sensitive to form than surface features when individuating objects in occlusion events: it is not until 7.5 months that infants spontaneously use pattern information, and 11.5 months that they spontaneously use color information, as the basis for object individuation. The present research assessed the extent to which infants' sensitivity to surface features could be increased under more supportive conditions. More specifically, we examined whether younger infants could be primed to draw on color and pattern features in an individuation task if they were first shown the functional value of attending to color and pattern information (i.e. the color or the pattern of an object predicted the function it would engage in). Five experiments were conducted with infants 4.5 to 9.5 months of age. The main findings were that 9.5- and 7.5-month-olds could be primed to use color information, and 5.5- and 4.5-month-olds could be primed to attend to pattern information, after viewing the function events. The results are discussed in terms of the kinds of experiences that can lead to increased sensitivity to surface features and the mechanisms that support feature priming in young infants.

Keywords

Infant cognition; Object identity; Object individuation

1. Introduction

Perhaps one of our most important cognitive abilities is the ability to represent the world in terms of numerically distinct objects. It is not surprising, then, that infant researchers have shown considerable interest in the origins and development of this ability. Some investigators have been concerned with specifying the innate constraints on infants' ability to group surfaces into objects (e.g. Kellman & Spelke, 1983; Spelke, 1985; Spelke, Kestenbaum, Simons, & Wein, 1995). Other investigators have focused on how infants represent, in short-term memory, the objects that they individuate (e.g. Leslie, Xu, Tremoulet, & Scholl, 1998; Tremoulet, Leslie, & Hall, 2001; Wilcox & Schweinle, 2002). Still others have focused on developmental changes in the type of information infants can use to establish the presence of distinct objects (e.g. Aguiar & Baillargeon, 2002; Needham, 1999; Needham & Baillargeon, 1997, 1998; Needham, Baillargeon, & Kaufman, 1997; Wilcox, 1999; Wilcox & Baillargeon, 1998a,b; Wilcox & Schweinle, 2002, 2003; Xu & Carey, 1996; Xu, Carey, & Welch, 1999). The present research falls into this last category.

*Corresponding author. Tel.: +1-979-845-0618; fax: +1-979-845-4727. tgw@psyc.tamu.edu (T. Wilcox).

1.1. Object individuation in infancy

There is evidence that even very young infants use simple forms of spatiotemporal information to determine the number of objects present in an event (e.g. Kestenbaum, Termine, & Spelke, 1987; Slater, Johnson, Kellman, & Spelke, 1994; Slater et al., 1990; Spelke, 1985). For example, infants typically view adjacent, bounded surfaces that move together as a single object. Furthermore, infants perceive non-contiguous surfaces as distinct objects. Using spatiotemporal information, infants would be able to correctly individuate the objects in many different situations. To illustrate, consider an event in which a ball and a box sit separated by a spatial gap on an otherwise empty surface. Infants would view the ball as one object and the box as another, separate object.

However, infants are often faced with events in which spatiotemporal information alone is not sufficient to establish what objects are present. There are at least two types of situations that present difficulties. One type of situation arises when object boundaries are ambiguous, either because surfaces share a boundary or because the boundaries are occluded. To return to our example, what if a screen were placed in front of the ball and the box, in such a way that only a portion of each protruded on either side of the screen? Infants could not see whether the ball and box were connected (one object) or not connected (two objects) behind the screen. The problem of parsing visible surfaces into distinct units is typically referred to as *object segregation*.

Another type of situation that presents difficulties is when surfaces are viewed successively. To again return to our example, what if the ball moved behind one edge of the box and then appeared at the other edge? Because infants could not see whether the ball traced a single, continuous path behind the box they could not judge, based on spatiotemporal information alone, whether the ball that disappeared and the ball that reappeared were one and the same ball. The problem of determining whether an object currently in view is the same object, or a different object, than seen previously is referred to as *object individuation*.

The focus of the present research is infants' interpretation of events in which surfaces are viewed successively as they move back and forth behind an occluder. When spatiotemporal information does not clearly specify how many objects are involved in an occlusion event, infants must draw on other sources of information to individuate objects. One type of information that adults use is featural information. When the objects seen to each side of the occluder share the same features, adults typically conclude that they are the same object. In contrast, when the objects to each side of the occluder are different in appearance, adults generally conclude that they are two separate and distinct objects.

Over the last several years there has been some debate about whether infants, like adults, can use featural information to individuate objects in occlusion events. Although some of the initial findings were conflicting (Wilcox & Baillargeon, 1998a,b; Xu & Carey, 1996), many of the discrepancies observed can be explained by task variables (Wilcox & Baillargeon, 1998a; Wilcox & Chapa, 2002; Wilcox & Schweinle, 2002; for a review of the evidence see Wilcox, Schweinle, & Chapa, 2003). Currently, there seems to be agreement that, at least under some conditions, infants can use featural information to individuation objects.

1.2. Investigating infants' use of featural information: the narrow-screen task

One task that has been used quite effectively to investigate object individuation in infants is the narrow-screen task (Wilcox & Baillargeon, 1998a,b). In the narrow-screen task, infants' ability to individuate objects is assessed by examining infants' response to events in which a screen is either too narrow, or sufficiently wide, to hide two objects simultaneously. To illustrate, in one experiment 4.5- and 7.5-month-olds were assigned to either a ball–box or a ball–ball condition (Wilcox & Baillargeon, 1998b). The infants in the *ball–box* condition saw a test event in which a green ball moved behind the left edge of a screen; after a brief pause, a red box appeared at the right edge. The box then returned behind the screen and the ball emerged and returned to its starting position. This event sequence repeated until the end of the trial. For half the infants, the screen was too narrow to hide the ball and box simultaneously (narrow-screen event); for the other infants, the screen was sufficiently wide to hide both objects at the same time (wide-screen event). The infants in the *ball–ball* condition saw a test event similar to those in the ball–box condition, except that the green ball was seen to both sides of the narrow or wide screen.

The 4.5- and 7.5-month-olds in the ball–box condition looked reliably longer at the test event when it involved the narrow as opposed to the wide screen. In contrast, the infants in the ball–ball condition looked about equally at the narrow- and wide-screen test events, and their looking times were similar to those of the infants in the ball–box wide-screen condition. These and control results suggested that the infants in the ball–box condition (a) were led by the featural differences between the ball and the box to view them as distinct objects, (b) recognized that the ball and box could be occluded simultaneously by the wide but not the narrow screen, and (c) responded with prolonged looking when this expectation was violated. Furthermore, the infants in the ball–ball condition (a) viewed the identical balls seen to each side of the screen as one and the same ball and (b) recognized that the ball could fit behind either the wide or the narrow screen. The positive results obtained in the ball–box narrow-screen condition have been replicated, using variations of the narrow-screen procedure, in a number of experiments with infants aged 4.5–11.5 months (Wilcox, 1999; Wilcox & Baillargeon, 1998a,b). In addition, these results are consistent with those obtained with infants aged 5.5–9.5 months when other types of individuation tasks are used (Hespos, 2000; Leslie & Glanville, 2001; Wilcox & Baillargeon, 1998a; Wilcox & Chapa, 2002; Wilcox & Schweinle, 2002).

1.3. Infants' differential sensitivity to form and surface features

In the narrow-screen experiments of Wilcox and Baillargeon (1998a,b), the ball and the box varied on several featural dimensions, including shape, pattern, and color. The infants could have been using any one, or all, of these features as the basis for individuating the objects. Object features can be grouped into two general categories: those features that specify three-dimensional form, such as shape, size, or rigidity, and those features that constitute surface properties, such as pattern, color, or texture (e.g. De Yoe & Van Essen, 1988).[1] From an early age infants demonstrate sensitivity to form features when interpreting physical events. For example, 3-month-olds expect a toy mouse of sufficient height to appear in the window of an occluder (Aguiar & Baillargeon, 2002), 3.5-month-olds detect when an object is too wide to fit behind an occluder (Baillargeon & Brueckner, 2000), and 4-month-olds recognize that the circumference of a ball determines whether it will fit through an opening (Spelke, Breinlinger, Macomber, & Jacobson, 1992). In contrast, it is unclear when, and under what conditions, infants attend to surface features. Given the limited value of attending to surface features – whether an object is dotted or striped does not predict whether it will pass through an opening, appear in a window, or fit behind an occluder – one might expect infants to be less sensitive to surface features when interpreting physical events.

Wilcox (1999) systematically investigated infants' sensitivity to two form features –shape and size – and two surface features – pattern and color – when individuating objects in occlusion events. The narrow-screen task of Wilcox and Baillargeon (1998a,b) was used

[1]Some form features (e.g. height and width) might also be thought of spatiotemporal properties, because they can impact the computation of where an object is located in space. For the present purposes, however, we will refer to them as featural rather than spatiotemporal properties.

with one important modification: the objects seen to each side of the screen varied on only one dimension at a time. The results revealed that when the objects seen to each side of the occluder differed in shape (i.e. a box was seen to the left of the screen and a ball to the right) or size (i.e. a large ball was seen to the left of the screen and a small ball to the right), 4.5-month-olds perceived the event as involving two distinct objects, that could both fit behind the wide but not the narrow screen. In contrast, when the objects seen to each side of the screen differed in their pattern (i.e. dotted versus striped ball) or their color (i.e. green versus red ball), infants were less likely to succeed. It was not until 7.5 months that infants used the pattern difference, and 11.5 months that they used the color difference, to individuate the objects.[2] These results are consistent with recent findings in the object segregation literature; young infants show greater sensitivity to form than surface features when parsing adjacent and partly occluded displays (Craton, Poirier, & Heagney, 1998; Needham, 1999).

By 4.5 months infants have relatively good pattern and color vision: they detect, categorize, and demonstrate memory for pattern and color features (Banks & Salapatek, 1981, 1983; Banks & Shannon, 1993; Bornstein, Kessen, & Weiskopf, 1976; Brown, 1990; Catherwood, Crassini, & Freiberg, 1989; Fantz, 1961; Hayne, Rovee-Collier, & Perris, 1987; Quinn, 1987; Quinn & Eimas, 1996; Salapatek, 1975; Teller & Bornstein, 1987). So why did the young infants tested by Wilcox (1999) fail to draw on pattern and color information to individuate the objects in the narrow-screen task?

One possibility is that these findings reflect biases in the type of information that infants attend to when viewing occlusion events (Wilcox, 1999). There is evidence that infants group physical events into distinct categories (e.g. occlusion, containment, support) and then interpret events in terms of what is known about selected categories (Baillargeon, 1998; Baillargeon, Kotovsky, & Needham, 1995; Baillargeon & Wang, 2002). Within event categories infants first form an initial, all-or-none concept and then, with experience, gradually identify variables that are important to interpreting the event. In this way, initial concepts are elaborated and refined, resulting in more accurate predictions over time.

Using this conceptual framework, infants' initial concept that objects should be out of view when behind other objects and visible otherwise (Aguiar & Baillargeon, 1999) is refined as infants identify variables important to their interpretation of occlusion events (Aguiar & Baillargeon, 2002; Baillargeon & Brueckner, 2000; Baillargeon & Graber, 1987; Hespos & Baillargeon, 2001). Early during the first year infants identify form features as important occlusion variables, leading them to routinely draw on shape and size information to track the identity of objects as they move in and out of view. In contrast, infants are slow to identify surface features as relevant to the interpretation of occlusion events and, hence, do not fully appreciate the value of attending to pattern and color information until the end of the first year of life. Thus, even though infants can discriminate between colors (e.g. green and red) and patterns (e.g. dots and stripes), they fail to consider this information as relevant to their interpretation of occlusion events.[3]

[2]One might be concerned that the results obtained by Wilcox (1999) reflect the perceptual characteristics of the stimuli chosen, rather than differential processing of form and surface information by the object representation system. For example, perhaps it was easier for the infants to discriminate between the two shapes (box and ball) and sizes (large and small) shown than between the two colors (green and red) and patterns (dotted and striped) selected. Although we do not know whether the perceived shape and size differences were in fact greater than the perceived pattern and color differences, a perceptual saliency explanation is unlikely, for two reasons. First, the conditions in Wilcox (1999) were designed to optimize infants' attention to color and pattern information. The pattern and color differences fell well within the range of discriminability, lighting conditions were optimal, and infants were given ample time to view the objects. The infants should have had no difficulty telling the difference between the dotted and striped balls and the green and red balls. (Additional results from a color discrimination task support this conclusion.) Second, even if some differences were easier to discriminate than others, this would not necessarily translate into better performance on the individuation task. Of course, under more restrictive conditions, for example, if infants were given less time to view the objects, the objects were out of view for longer intervals behind the screen, or the test trials were shorter, it is possible that perceptual differences might become an issue.

What this analysis leaves open to debate is whether infants who have not yet identified surface features as relevant – who do not typically include surface features in their event representations – could be led to do so in a more supportive context. Perhaps, if pattern and color information were made more salient, infants would draw on pattern and color differences to individuate objects in the narrow-screen task. The present experiments tested this hypothesis.

1.4. The present research

The research reviewed above indicates that object individuation is a complex cognitive process that is supported in some situations but not others. If infants' sensitivity to surface features in the narrow-screen task could be altered, it would suggest that the developmental hierarchy observed by Wilcox (1999) is not fixed, but instead influenced by infants' experiences. What kinds of experiences might make surface features more salient to infants? How might infants be primed to attend to surface features? The approach taken in the present experiments was to present to infants, prior to the test trials, events designed to make clear the value of attending to color or pattern information. More specifically, infants were shown events in which the color (Experiments 1–3) or the pattern (Experiments 4 and 5) of an object predicted the function that it would engage in. Infants were then presented with the different-color or different-pattern test events from Wilcox (1999). If infants' sensitivity to color and pattern information can be altered by viewing events that highlight the functional value of attending to color and pattern information, then the infants in the present experiments should evidence improved performance on the individuation task. In contrast, if pairing color and pattern with object function does not prime infants to attend to color and pattern information, then the infants should not evidence improved performance on the narrow-screen task.

2. Experiment 1

Experiment 1 examined whether 9.5-month-olds, who do not spontaneously attend to color features in an individuation task, would use color information to individuate objects if first shown events in which the color of an object was associated with a distinct function. We chose to pair color with function for two reasons. First, research conducted with infants 8–18 months of age indicates that infants are sensitive to the functional properties of objects. Infants manipulate objects based on the functions that they afford (Freeman, Lloyd, & Sinha, 1980; Pieraut-Le Bonniec, 1985; Traeuble & Pauen, 2000), generalize functional properties to objects similar in appearance or that share important characteristics (Baldwin, Markman, & Melartin, 1993; Booth & Waxman, 2002), attend to novel ways objects can be used and later imitate those actions (Meltzoff, 1988a,b), and interpret physical events based on objects' functional properties (Kolstad & Baillargeon, 1993). Second, sensitivity to object function is seen throughout the life-span; it is observed in children and adults in a number of different contexts, from language acquisition to category formation (e.g. Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Kemler Nelson, Russell, Duke, & Jones, 2000; Nelson, 1973, 1974; Pick, 1997; Richards, Goldfarb, Richards, & Hassen, 1989). Together, these findings led us to conclude that function is probably one of the most salient properties of an object and that even young infants would include information about object function in their event representations.

The infants saw two pairs of pretest events: each pair consisted of a pound event and a pour event (Fig. 1). In the first pair, infants saw a green can with a handle pound a wooden peg;

[3]It is also possible that the present results reflect a more general bias to attend to form over surface features when interpreting physical events. In most physical situations, form features are more important than surface features for predicting event outcomes.

they then saw a red can with a handle scoop and pour salt. The two cans were identical in appearance except for their color. In the second pair of pretest events, infants saw the same events except that the green and red cans were replaced with green and red cups (Fig. 2): the green cup pounded and the red cup poured. Following the pretest events, infants saw the green ball–red ball test event from Wilcox (1999), with either the narrow or the wide screen (Fig. 3).

If showing infants the functional value of attending to color information in the pretest events heightens their sensitivity to color information in the test events, then infants should view the green and the red ball as two separate and distinct objects. Hence, the infants should look reliably longer at the narrow- than at the wide-screen test event. In contrast, if seeing the pound–pour events does not facilitate infants' use of color information in the test events, then the infants should fail to individuate the balls on the basis of the color difference. Hence, the infants should look about equally at the narrow- and wide-screen test events.

We have assumed here that infants would need to see at least two exemplar pairs in the pretest events in order to generalize to the test event (e.g. Baillargeon, 1998). If infants were to see only one exemplar pair (i.e. the green and red can), they would treat it as a unique situation (i.e. the green can pounds and the red can pours) and fail to extract the general rule that color features can be used to predict the function of an object (i.e. green containers pound and red containers pour). To test this assumption, infants in a one-exemplar condition saw the same pretest and test events as the infants in the two-exemplar condition, with one difference: the first pair of objects (i.e. the green and red cans) were seen on both pairs of pretest trials. Hence, the infants in the one-exemplar condition saw the same number of pretest trials as the infants in the two-exemplar condition, but with only one object pair.

2.1. Method

2.1.1. Participants—Participants were 32 healthy full-term infants, 16 male and 16 female (*M* = 9 months, 12 days; range = 9 months, 0 days to 9 months, 28 days). Five additional infants were tested but eliminated because they failed to complete two valid test trials: one because of fussiness, two because of sleepiness, and two because of procedural problems. Eight infants were randomly assigned to each of four groups (with the constraint that an equal number of males and females were tested in each condition) formed by crossing number of exemplars (two or one) and test event (narrow- or wide-screen): two-exemplars narrow-screen (*M* = 9 months, 10 days); two-exemplars wide-screen (*M* = 9 months, 14 days); one-exemplar narrow-screen (*M* = 9 months, 14 days); one-exemplar wide-screen (*M* = 9 months, 10 days).

In this and all subsequent experiments, the infants' names were obtained from birth announcements in the local newspaper. Parents were contacted by letters and follow-up phone calls. Parents were offered reimbursement for their travel expenses but were not compensated for their participation.

2.1.2. Apparatus—The apparatus consisted of a wooden cubicle 213 cm high, 105 cm wide, and 43.5 cm deep. The infant sat facing an opening 51 cm high and 93 cm wide in the front wall of the apparatus. The floor of the apparatus was covered with cream-colored contact paper, the side walls were painted cream, and the back wall was covered with patterned contact paper. A platform 1.5 cm high, 60 cm wide, and 19 cm deep and covered with patterned contact paper lay 4.5 cm from the back wall and centered between the left and right walls; a 6 cm wide piece of light blue flannel lay length-wise down the center of the platform. An opening, 25.5 cm high and 20 cm wide, was centered in the right wall of the apparatus 9 cm above the apparatus floor. During the pretest events, the opening was covered with cream-color cloth fringe and the experimenter manipulated the containers through the opening. During the familiarization and test trials the opening was concealed with a hinged door.

Two pairs of objects were used in the pretest events. Each pair consisted of two objects that were identical in appearance except for their color: one was painted green and the other red. The objects used in the first pair of events were tin cans 11 cm high and 8.5 cm in diameter and open at the top. A straight wooden handle 7.5 cm long and 0.75 cm in diameter protruded from the side of the cans 1.5 cm from the rim. The objects used in the second pair of events were plastic measuring cups 9 cm high and 8.5 cm in diameter (at the top) with a closed handle on the side. The boxes used in the pound and pour events were similar in construction: they were 8 cm high, 19.5 cm wide, 15.75 cm deep, open on one side (top or bottom), and covered with green and white marbled contact paper. The box used in the pound event was placed with the open side down and had a black wooden peg 5.5 cm high and 0.75 cm in diameter protruding upwards at the center. The box used in the pour event was placed with the opening side up and was filled with salt (it did not have a peg). During the pretest events the box sat directly in front of the platform with its right edge 20 cm from the right wall of the apparatus.

The balls used in the familiarization and test events were 10.25 cm in diameter and made of Styrofoam: one was painted green and the other red. Each ball was attached to a clear Plexiglas base 0.3 cm high, 10 cm wide, and 6.5 cm deep. Each base had a handle 16 cm long that protruded through an opening 3.25 cm high between the back wall and floor of the apparatus; the opening was masked by cream-colored fringe. By moving the Plexiglas handle, an experimenter could move the balls left and right along the platform (because the balls remained attached to the base, they did not roll). The experimenter’s hand holding the Plexiglas handle was concealed from the infants’ view by the ball, the back wall, and the fringe covering the slit; as an added precaution, the hand also wore a white glove that blended with the fringe.

The screen used in the familiarization trials was 41 cm high and 30 cm wide; it was made of yellow cardboard and covered with clear contact paper. The narrow test screen was 41 cm high and 17 cm wide and the wide test screen was 33 cm high and 30 cm wide. Thus, the familiarization screen differed from the narrow test screen in width and the wide test screen in height. Both test screens were made of blue cardboard, were decorated with small gold and silver stars, and were covered with clear contact paper. The screens were mounted on a wooden stand that was centered in front of the platform.

Embedded in the center of the platform was a metal bi-level composed of an upper and a lower shelf 16 cm apart; each shelf was 12.7 cm wide and 13 cm deep. The bi-level was designed so that both objects could be behind the screen simultaneously, one on the top shelf and the other on the bottom shelf. When at rest, the upper shelf was level with the top of the platform and the lower shelf lay underneath the apparatus floor. The bi-level could be lifted by means of a handle 19 cm long that protruded through an opening 19.5 cm high and 7 cm wide in the back wall of the apparatus; when the bi-level was lifted, its lower shelf became level with the platform. The bi-level remained hidden behind the screen in its raised position.

A muslin-covered shade was lowered in front of the opening in the front wall of the apparatus at the end of each trial. Two muslin-covered wooden frames, each 213 cm high and 68 cm wide, stood at an angle on either side of the apparatus. These frames isolated the infants from the experimental room. In addition to the room lighting, four 20-watt fluorescent bulbs were affixed to the inside walls of the apparatus (one on each wall).

2.1.3. Events—Each experimental session included pretest, familiarization, and test events. One experimenter produced all of the events. The experimenter wore a white glove on her right hand and followed a precise script, using a metronome that ticked softly once per second. The numbers in parentheses indicate the time taken to produce the actions described.

2.1.3.1. Two-exemplars narrow-screen condition: Each infant saw two pairs of *pretest events*. Each pair consisted of a pound event and a pour event. At the start of the first pound event, the experimenter held the green can by its handle, with the opening facing upwards, approximately 17.5 cm above the box with the wooden peg. The experimenter lowered the can to pound the peg two times (2 s), raised the can to the starting position and paused (2 s), lowered the can to pound the peg two times (2 s), and raised the can to the starting position and paused (2 s). The 8 s event sequence was repeated continuously until the end of the trial. In the first pour event, the experimenter held the red can by its handle, with the opening facing upwards, approximately 17.5 cm above the box with the salt. The experimenter lowered and tilted the can forward to scoop the salt from the box (2 s), raised the can and tilted the can forward to the starting position and paused (2 s), tilted the can forward to pour out the salt (2 s), and then returned the can to its starting position (2 s). The 8 s event sequence was repeated continuously until the end of the trial. The second pair of pretest events was identical to the first, except that the green and red cans were replaced with the green and red measuring cups.

Following the pretest events, the infants saw a *familiarization event*. At the start of each familiarization trial, the green ball sat with its center 6 cm from the left end of the platform. The familiarization screen stood upright and centered in front of the platform, and the red ball sat on the lower shelf of the bi-level.

Each familiarization trial began with a brief pretrial during which the observers monitored the infant's looking at the green ball until the computer signaled that the infant had looked for 1 cumulative second. After a 1 s pause, the green ball moved to the right until it reached the upper shelf of the bi-level behind the screen (2 s), and the handle of the ball's base aligned with the handle of the bi-level. Next, the bi-level was lifted until its lower shelf was level with the platform (1 s); the red ball then emerged from behind the screen and moved to the right until its center was 6 cm from the right end of the platform (2 s). After a 1 s pause, the red ball returned to the bi-level (2 s) which was lowered (1 s) until its upper shelf was once again even with the platform; the green ball then returned to its starting position at the left end of the platform (2 s). The balls moved at a rate of 12 cm/s. The 12 s event sequence just described was repeated continuously until the trial ended.

Next, the infants saw a *test event*. The test event was identical to the familiarization event except that the familiarization screen was replaced with the narrow test screen.

2.1.3.2. Two-exemplars wide-screen condition: The pretest, familiarization, and test events were identical to those in the two-exemplars narrow-screen condition with one exception: in the test event the narrow screen was replaced with the wide screen.

2.1.3.3. One-exemplar narrow- and wide-screen conditions: The pretest, familiarization, and test events were identical to those in the two-exemplars narrow- and wide-screen conditions except that the green and red cans were seen on both pairs of pretest events.

2.1.4. Procedure—Each infant sat on a parent's lap centered in front of the apparatus, approximately 78 cm from the objects on the platform. Parents were asked not to interact with their infant while the experiment was in progress and to close their eyes during the familiarization and test trials.

The infants participated in a three-phase procedure that consisted of a pretest, a familiarization, and a test phase. During the *pretest* phase, the infants saw the four pretest events appropriate for their condition on four successive trials. Each trial ended when the infant (a) looked away for 2 consecutive seconds after having looked at the event for at least 10 cumulative seconds or (b) looked for 30 cumulative seconds without looking away for 2 consecutive seconds. During the *familiarization* phase, the infants saw the familiarization event appropriate for their condition on six successive trials. Each trial ended when the infant (a) looked away for 2 consecutive seconds after having looked at the event for at least 12 cumulative seconds (beginning at the end of the pretrial) or (b) looked for 60 cumulative seconds without looking away for 2 consecutive seconds. During the *test* phase, the infants saw the test event appropriate for their condition on two successive trials. Each trial ended when the infant (a) looked away for 2 consecutive seconds after having looked at the event for at least 6 cumulative seconds (beginning at the end of the pretrial) or (b) looked for 60 cumulative seconds without looking away for 2 consecutive seconds. The number of familiarization and test trials each infant saw, as well as the trial termination criteria, were identical to those used with the 9.5-month-olds in the color experiments of Wilcox (1999). The pretest trial termination criteria were chosen to ensure that the infants had sufficient time to view each pound–pour event cycle at least one time, while at the same time keeping the trials short enough so that the infants would be able to complete the experimental session.

The infant's looking behavior was monitored by two observers who watched the infant through peepholes in the cloth-covered frames on either side of the apparatus. Each observer held a button connected to a computer and depressed the button when the infant attended to the events. The looking times recorded by the primary observer determined when a trial had ended (see above) and were used in the data analyses. Each trial was divided into 100 ms intervals, and the computer determined in each interval whether the two observers agreed on the direction of the infant's gaze. Inter-observer agreement was measured for 26 of the infants (for six of the infants, only one observer was present) and was calculated for each test trial on the basis of the number of intervals in which the computer registered agreement out of the total number of intervals in the trial. Agreement averaged 90% per test trial per infant.

Preliminary analyses were conducted for each of the experiments reported herein to explore whether males and females responded differently to the test events. These analyses failed to reveal reliable sex differences. Consequently, in this and the following experiments, the data were collapsed across sex. However, because of the small number of infants in each cell for each analysis, these results need to be interpreted with caution.

2.2. Results

2.2.1. Pretest trials—The infants' looking times during the four pretest trials were averaged and analyzed by means of an ANOVA with number of exemplars (two or one) and test event (narrow- or wide-screen) as between-subjects factors. The main effects of exemplars ($F(1, 28) = 2.27$, $P > 0.05$) and test event ($F(1, 28) < 1$), and the interaction between these two factors ($F(1, 28) < 1$), were not significant, indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (two-exemplars narrow-screen, $M = 23.8$, SD = 5.8; two-exemplars wide-screen, $M = 25.4$, SD = 4.3; one-exemplar narrow-screen, $M = 26.7$, SD = 3.5; one-exemplar wide-screen, $M = 26.9$, SD = 2.8).

NIH-PA Author Manuscript

NIH-PA Author Manuscript

2.2.2. Familiarization trials—The infants' looking times during the six familiarization trials were averaged and analyzed in the same manner as the pretest trials. The main effects of number of exemplars ($F(1, 28) = 3.40$, $P > 0.05$) and test event ($F(1, 28) = 1.62$, $P > 0.05$), and the interaction between these two factors ($F(1, 28) < 1$), were not significant, indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (two-exemplars narrow-screen, $M = 27.3$, SD = 4.6; two-exemplars wide-screen, $M = 30.2$, SD = 7.1; one-exemplar narrow-screen, $M = 31.7$, SD = 10.0; one-exemplar wide-screen, $M = 35.2$, SD = 5.8).

2.2.3. Test trials—The infants' looking times during the two test trials were averaged (Fig. 4) and analyzed in the same manner as the pretest trials. The main effects of number of exemplars ($F(1, 28) < 1$) and test event ($F(1, 28) = 1.40$, $P > 0.05$) were not significant. However, the interaction between number of exemplars and test event was significant ($F(1, 28) = 6.57$, $P < 0.025$). Planned contrasts indicated that the infants in the two-exemplars condition looked reliably longer at the narrow-screen ($M = 23.7$, SD = 12.3) than at the wide-screen ($M = 12.1$, SD = 4.3) test event ($F(1, 28) = 7.03$, $P < 0.025$). In contrast, the infants in the one-exemplar condition looked about equally at the narrow-screen ($M = 14.7$, SD = 6.7) and wide-screen ($M = 18.9$, SD = 9.6) test events ($F(1, 28) < 1$).

2.3. Discussion

The 9.5-month-olds in the two-exemplars condition looked reliably longer at the narrow- than at the wide-screen test event, as if the infants (a) perceived the green ball and the red ball as two distinct objects, (b) recognized that the narrow screen was too narrow to hide both balls simultaneously, and, hence, (c) found the narrow-screen event unexpected. In contrast, the 9.5-month-olds in the one-exemplar condition looked about equally at the narrow- and wide-screen test events, as if they had failed to individuate the balls on the basis of the color difference. The negative results obtained with the infants in the one-exemplar condition are consistent with those typically obtained with infants less than 11.5 months in color experiments (Chapa & Wilcox, 1999; Tremoulet et al., 2001; Wilcox, 1999).

These results suggest two conclusions. The *first* conclusion is that the infants in the two-exemplars condition recognized, when viewing the pound–pour events, that color was relevant to the situation before them: the color of the containers predicted the function in which they would engage. (Of course, color in and of itself did not predict the objects' functions, but rather the infants learned to associate color with function.) This experience, of pairing color with function in the pound–pour events, heightened infants' sensitivity to color information. Once infants were primed to attend to color differences, they successfully individuated the green and red balls in the different-color test event.

The *second* conclusion is that the infants formed a categorical representation of the pound–pour events that included color and function information, and it was this process that facilitated infants' use of color information in the test event. Remember that the infants needed to see two different color–function pairings – that is, two exemplar pairs – before they would generalize to the test event. Seeing only one color–function pairing was not sufficient to facilitate infants' use of color information in the narrow-screen task.[4] That infants organize objects and events into categories is a well documented finding (for reviews

[4]There is an alternative interpretation of these results that does not require the use of categorical event representations. Recall that the infants in the one-exemplar condition saw the cans on both sets of pretest trials; they never saw the cups. It is possible that the infants' success in the two-exemplar condition, and their failure in the one-exemplar condition, reflects infants' greater sensitivity to cups than cans. That is, if the one-exemplar condition had been conducted with the cups, rather than the cans, positive results would have been obtained. Although there is no reason to believe that infants would be more responsive to cups than cans, and we think it unlikely that this manipulation would have yielded a different pattern of results, we cannot rule out this possibility.

see Baillargeon, 1998; Madole & Oakes, 1999; Mandler, 1997; Quinn & Eimas, 1996). The present results are novel in that they suggest that categorical representations formed while viewing one event, that include information specific to that event, can influence infants' interpretation of a subsequent event, even when the second event is very different from the first. Infants' propensity to form categorical representations of physical events is a powerful tool. It allows infants to organize physical events as they unfold before them, aids in their interpretation of those events, and biases how they interpret future events.

What is left open to debate is whether the positive results obtained in Experiment 1 are specific to events involving object function or whether infants might be equally sensitive to other kinds of events. We made the case earlier that function is one of the most salient properties of objects and that infants would be particularly sensitive to events involving object function. However, it is possible that we have overstated the importance of object function or have defined function too narrowly. Our working definition of function is "the action an object affords and is specifically fitted for". This definition presupposes, at least to some extent, that function is related to an object's structural properties. For example, the can and the cup could be used effectively for pounding because each had a handle and a flat surface with which to make contact with the nail. Likewise, the can and the cup were specifically fitted for scooping and pouring because they were concave, with closed sides and bottoms. It is possible, however, that infants would find events in which the can and the cup performed distinct actions that they were not specifically fitted for (i.e. that were not functionally relevant) equally salient. Experiment 2 tested this possibility.

3. Experiment 2

To examine whether 9.5-month-olds would find events involving distinct actions as compelling as those involving distinct functions, infants were presented with pretest and test events identical to those seen by the infants in the two-exemplars condition of Experiment 1 with one exception: in the pretest events the green containers moved up and down in a pounding motion without ever coming in contact with the wooden peg, and the red containers made scooping and pouring motions without acquiring and releasing salt (i.e. the peg and the salt were still present in the display). Hence, the actions that the containers engaged in were similar to those of the objects in Experiment 1 but they were not functionally relevant. If infants form categorical representations of color–action pairings, just like they form categorical representations of color–function pairings, and this process enhances infants' sensitivity to color features, then the infants in Experiment 2 should use the color difference to individuate the green and the red ball in the test event. In contrast, if we were right in our assumption about the unique role that object function plays in early event representations, then the infants in Experiment 2 should fail to show increased sensitivity to color features in the test trials.

3.1. Method

3.1.1. Participants—Participants were 16 healthy full-term infants, eight male and eight female (M = 9 months, 11 days; range = 8 months, 26 days to 9 months, 27 days). Three additional infants were eliminated: one because of fussiness, one because the parent was labeling the balls, and one because the primary observer was unable to determine the direction of the infant's gaze. Eight infants were randomly assigned to each of the two motion groups: narrow-screen (M = 9 months, 13 days) or wide-screen (M = 9 months, 9 days).

3.1.2. Apparatus—The apparatus used in Experiment 2 was identical to that of Experiment 1.

3.1.3. Events

3.1.3.1. Narrow-screen condition: The pretest, familiarization, and test events were identical to those of the two-exemplars narrow-screen condition of Experiment 1 with one exception: the boxes with the peg and the salt were moved 21.5 cm leftward, so that they sat to the left of the area in which the events were performed. During the pretest events, the containers never came in contact with the nail (pound event) or the salt (pour event).

3.1.3.2. Wide-screen condition: The pretest, familiarization, and test events were identical to those in the narrow-screen condition except that the narrow test screen was replaced with the wide test screen.

3.1.4. Procedure—The procedure was identical to that of Experiment 1. Inter-observer agreement was measured for 15 of the infants and averaged 92%. To evaluate whether the infants responded differentially to the test events depending on whether the objects' motions in the pretest events were functionally relevant, the data from Experiment 2 were analyzed together with the data from the two-exemplars condition of Experiment 1.

3.2. Results

3.2.1. Pretest trials—The infants' looking times during the four pretest trials were averaged and analyzed by means of an ANOVA with pretest event (motion or function) and test event (narrow- or wide-screen) as the between-subjects factors. The main effects of pretest event and test event, and the interaction between these two factors, were not significant (all $F(1, 28)$ $S < 1$), indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (Experiment 2, narrow-screen condition, $M = 23.2$, SD = 5.2; wide-screen condition, $M = 22.5$, SD = 4.9).

3.2.2. Familiarization trials—The infants' looking times during the six familiarization trials were averaged and analyzed in the same manner as the pretest trials. The main effects of pretest event and test event, and the interaction between these two factors, were not significant (all $F(1, 28)$ $S < 1.25$) (Experiment 2, narrow-screen condition, $M = 26.4$, SD = 7.2; wide-screen condition, $M = 28.7$, SD = 7.0).

3.2.3. Test trials—The infants' looking times during the two test trials were averaged (Fig. 4) and analyzed in the same manner as the pretest trials. The main effects of pretest event ($F(1, 28) < 1$) and test event ($F(1, 28) = 3.9$, $P > 0.05$) were not significant. The interaction between pretest event and test event was significant ($F(1, 28) = 4.7$, $P < 0.05$). Planned comparisons indicated that the infants in the two-exemplars condition of Experiment 1 looked reliably longer at the narrow- than wide-screen test event ($F(1, 28) = 4.5$, $P < 0.05$). In contrast, the infants of Experiment 2 looked about equally at the two events ($F(1, 28) < 1$) (narrow-screen condition, $M = 15.3$, SD = 7.8; wide-screen condition, $M = 15.9$, SD = 4.5).

3.2.4. Additional results—When the pound–pour pretest events of Experiment 1 were altered so that the containers did not come in contact with the nail (pound event) and the salt (pour event), another aspect of the event was changed as well: the green and red containers no longer made distinct sounds. Perhaps the motion infants failed to individuate by color, not because infants are more sensitive to pretest events involving object functions than object motions, but because they found the "soundless" pretest events less interesting. To assess this possibility, another group of infants was tested using the procedure of Experiment 2 with the following modifications. In the pound motion event a metal ball was inserted into the container; each time the container made a 'pounding' motion, the ball hit the bottom of the container, simulating the noise the container made when it came in contact with the peg. In the pour motion event a small red Plexiglas box filled with tiny beads was attached to the bottom of the container; the noise made by the beads moving within the Plexiglas box during the ‘scooping’ and ‘pouring’ motion simulated that of the noise made by the sand in Experiment 1. Sixteen infants, eight male and eight female (*M* = 9 months, 14 days), were randomly assigned to one of two groups: narrow screen or wide screen.

The infants’ mean looking times were analyzed by means of a one-way ANOVA. The main effect of screen (narrow or wide) failed to reach significance in the pretest (narrow screen, *M* = 24.0, SD = 4.3; wide screen, *M* = 26.9, SD = 6.1), familiarization (narrow screen, *M* = 30.7, SD = 8.7; wide screen, *M* = 34.2, SD = 10.7), and test (narrow screen, *M* = 25.1, SD = 11.4; wide screen, *M* = 21.4, SD = 11.7) trial analyses (all $F(1, 14) < 1.2$). Although the infants’ looking times during the familiarization and test trials were elevated (the infants may have found the pretest events more intriguing because the objects produced sounds without an apparent cause), the infants did not respond differentially to the narrow- and wide-screen test events.

3.3. Discussion

The 9.5-month-olds in Experiment 2, who saw the green and red containers perform distinct motions, looked about equally at the narrow- and wide-screen test events. These results stand in contrast to the positive results obtained with the infants in the two-exemplars condition of Experiment 1, who saw the green and red containers perform distinct functions. One interpretation of these results, and the one alluded to earlier, is that infants are more sensitive to events that make clear the functional properties of objects than events that show objects engaged in arbitrary motions. According to this viewpoint, when watching physical events infants distinguish between different kinds of actions on objects, those that are functionally relevant and those that are not. In addition, they weigh these two kinds of actions differently, giving more weight to actions that are functionally relevant. Hence, in the present experiments seeing the green and red containers perform distinct *motions* was not sufficient to promote infants’ use of color information in the test events; the containers had to perform distinct *functions* in order for infants to attend to color information.

There are weaker interpretations of these results that could be offered, however, and many of these do not require the distinction between object motion and object function. For example, perhaps the infants simply found the function events more interesting or intriguing than the motion events, not because they involved object function, per se, but because they were more complex. Or, maybe the infants attempted to form simple associations between parts of the event (e.g. between the green container and the peg or the red container and the salt), and this was easier to do in the function events because the “parts” (e.g. the container and the peg/salt) were in closer proximity. Although alternative interpretations like these are possible, we prefer the stronger functional interpretation. Infants consistently and reliably demonstrate sensitivity to the functional properties of objects, across many different tasks and ages (e.g. Baldwin et al., 1993; Booth & Waxman, 2002; Freeman et al., 1980; Greco, Hayne, & Rovee-Collier, 1990; Kolstad & Baillargeon, 1993; Meltzoff, 1988a,b; Pieraut-Le Bonniec, 1985; Traeuble & Pauen, 2000), and this sensitivity influences how we perceive, think about, and talk about objects throughout the life-span (e.g. Kemler Nelson, Frankenfield et al., 2000; Kemler Nelson, Russell et al., 2000; Nelson, 1973, 1974; Pick, 1997; Richards et al., 1989). Given this evidence, it seems reasonable to propose that events involving object function would be more salient to infants than other kinds of events.

Nevertheless, for the present purposes, what is important is that we have demonstrated that infants can be primed, by viewing events in which color has predictive value, to attend to color information in an individuation task. Future research will be required to sort out why some kinds of events support feature priming and others do not, and to explore the nature of the associations that underlie feature priming in this task.

An important issue that has yet to be addressed is whether feature priming can be observed in younger infants and, if so, whether the conditions that support feature priming in younger infants differ from those that support feature priming in older infants. The next experiment is a step in this direction.

4. Experiment 3

Experiment 3 examined whether 7.5-month-olds, like 9.5-month-olds, could be led to use color differences to individuate objects in the narrow-screen task after viewing the pound–pour events. In a pilot experiment, 7.5-month-olds were tested in the two-exemplar condition of Experiment 1. Although the infants tended to look longer at the narrow-screen ($N = 8$, $M = 27.9$, SD = 12.9) than at the wide-screen ($N = 8$, $M = 22.3$, SD = 9.6) test event, these differences were not reliable ($F < 1$). We were concerned, however, that the 7.5-month-olds might have had difficulty because they needed to see more exemplar pairs in the pretest events. There is evidence that when forming categorical representations of objects or events, infants sometimes require more than two exemplars before they will generalize across instances (Baillargeon, 1998; Needham, 2001). Perhaps 7.5-month-olds would succeed if they were presented with more exemplar pairs in the pretest events.

To investigate this possibility, 7.5-month-olds were tested in one of two conditions: three-exemplars or two-exemplars. The infants in the *three-exemplars* condition saw the same pretest and test events as the infants in the two-exemplars condition of Experiment 1 with one exception: the infants were presented with three pairs of pretest events using three different object pairs. The third pair consisted of green and red squiggly-shaped cups (Fig. 2). To control for the possibility that 7.5-month-olds simply require more exposure to the pound–pour events, and not more exemplar pairs, another group of infants was tested in a *two-exemplars* condition. The infants in the two-exemplars condition saw the same pretest and test events as the infants in the three-exemplars condition with one exception: the second pair of pretest objects (i.e. the measuring cups) was seen on the second and third pair of pretest events (i.e. the squiggly cups were not used). Hence, these infants saw three pairs of pretest trials, but with only two object pairs.

If 7.5-month-olds can be led to use color to individuate objects, but need to see more than two color–function pairings before they will generalize across pairings, then the infants in the three-exemplars, but not the two-exemplars, condition should succeed. That is, the infants in the three-exemplars condition should look reliably longer at the narrow-than at the wide-screen test event. In contrast, if 7.5-month-olds do not recognize, even under more supportive conditions, that color can be used as the basis for individuating objects, then the infants in the two conditions should look about equally at the narrow- and wide-screen test events.

4.1. Method

4.1.1. Participants—Participants were 32 healthy full-term infants, 16 male and 16 female ($M = 7$ months, 16 days; range = 7 months, 0 days to 8 months, 13 days). One additional infant was eliminated because of procedural error. Eight infants were randomly assigned to each of four groups formed by crossing the number of exemplar pairs (three or two) and test events (narrow screen or wide screen): three-exemplars narrow-screen ($M = 7$ months, 16 days); three-exemplars wide-screen ($M = 7$ months, 14 days); two-exemplars narrow-screen ($M = 7$ months, 16 days); two-exemplars wide-screen ($M = 7$ months, 19 days).

4.1.2. Apparatus and stimuli—The apparatus and stimuli were identical to those in Experiment 1. In addition, a green and a red squiggly-shaped cup 13 cm high and 6.5 cm in diameter with a closed handle were used in the three-exemplars condition.

4.1.3. Events

4.1.3.1. Three-exemplars narrow- and wide-screen conditions: The pretest, familiarization, and test events were identical to those of the two-exemplars narrow- and wide-screen conditions of Experiment 1 except that the infants saw an additional pair of pretest events with the squiggly-shaped cups. The green squiggly cup pounded and the red squiggly cup poured.

4.1.3.2. Two-exemplars narrow- and wide-screen conditions: The pretest, familiarization, and test events were identical to those in the three-exemplars narrow- and wide-screen conditions with one exception. The second pair of containers was used in the second and third pair of pretest events (i.e. infants did not see the green and red squiggly cups).

4.1.4. Procedure—The procedure was identical to that of Experiment 1. Inter-observer agreement was measured for 23 of the infants and averaged 94%.

4.2. Results

4.2.1. Pretest trials—The infants' looking times during the six pretest trials were averaged and analyzed by means of an ANOVA with number of exemplar pairs (three or two) and test event (narrow-or wide-screen) as between-subjects factors. The main effects of number of exemplar pairs and test event were not significant ($F(1, 28)$ $S < 1$), and the interaction between these two factors was not significant ($F(1, 28) = 2.59$, $P > 0.05$), indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (three-exemplars narrow-screen, $M = 27.5$, SD = 3.0; three-exemplars wide-screen, $M = 25.3$, SD = 4.5; two-exemplars narrow-screen, $M = 26.3$, SD = 3.9; two-exemplars wide-screen, $M = 28.3$, SD = 3.2).

4.2.2. Familiarization trials—The infants' looking times during the six familiarization trials were averaged and analyzed in the same manner as the pretest trials. The main effects of number of exemplar pairs ($F(1, 28) = 1.90$, $P > 0.05$) and test event ($F(1, 28) < 1$) were not significant, nor was the interaction between these two factors ($F(1, 28) < 1$), indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (three-exemplars narrow-screen, $M = 38.1$, SD = 10.4; three-exemplars wide-screen, $M = 34.9$, SD = 10.9; two-exemplars narrow-screen, $M = 31.1$, SD = 8.4; two-exemplars wide-screen, $M = 32.3$, SD = 9.7).

4.2.3. Test trials—The infants' looking times during the two test trials were averaged (Fig. 5) and analyzed in the same manner as the pretest trials. The main effect of number of exemplar pairs was not significant ($F(1, 28) < 1$). The main effect of test event was significant ($F(1, 28) = 4.24$, $P < 0.05$), indicating that the infants looked reliably longer at the narrow-screen ($M = 27.8$, SD = 13.1) than wide-screen ($M = 18.9$, SD = 11.4) test event. The interaction between number of exemplar pairs and test event was not significant ($F(1, 28) = 1.37$, $P > 0.05$). Planned contrasts were conducted to determine if the infants in both the three- and two-exemplars condition looked reliably longer at the narrow-screen test event. The results revealed that the infants in the three-exemplars condition looked reliably longer at the narrow-screen ($M = 29.3$, SD = 10.3) than at the wide-screen ($M = 15.2$, SD = 3.8) test event ($F(1, 28) = 5.21$, $P < 0.05$). In contrast, in the two-exemplars condition the looking times of the narrow-screen ($M = 26.4$, SD = 16.1) and wide-screen ($M = 22.5$, SD = 15.2) infants did not differ reliably.

4.3. Discussion

The 7.5-month-olds in the three-exemplars condition looked reliably longer at the narrow- than at the wide-screen test event, as if the infants (a) perceived the green and the red ball as two distinct objects and (b) recognized that the narrow screen was too narrow to occlude both balls at the same time. A different pattern of results was obtained for the infants in the two-exemplars condition. The infants in the two-exemplar condition tended to look longer at the narrow- than at the wide-screen test event but the difference was not reliable, as if these infants had failed to clearly individuate the green and the red ball.

These results suggest that 7.5-month-olds, like 9.5-month-olds, are capable of using color features to individuate objects in occlusion events. Furthermore, 7.5-month-olds, like 9.5-month-olds, are more likely to reveal this ability when they are shown the functional value of attending to color information. Where the 7.5-month-olds *differed* from the 9.5-month-olds was in the number of exemplar pairs needed to promote infants' use of color features. The younger infants needed to see three color–function pairings, with three distinct object pairs, to show a significant benefit from viewing the pound–pour pretest events. These results are consistent with other reports that when infants are acquiring new physical knowledge, or when they are inexperienced at using the knowledge that they have, they require more exemplar pairs to build categorical representations (Baillargeon, 1998; Needham, Dueker, & Lockhead, 2003).

5. Experiment 4

The results of Experiments 1–3 demonstrate that infants younger than 11.5 months can use color information to reason about the identity of objects in occlusion events. These results led us to wonder whether this phenomenon is specific to color information – color is unique in that it can be accessed under some conditions but not others – or whether infants might be flexible in their use of pattern information as well. Recall that in Wilcox (1999), 7.5- but not 4.5-month-olds successfully used a pattern difference to individuate objects in the narrow-screen task. Perhaps infants younger than 7.5 months could be led to draw on pattern information if they were tested using the pound–pour procedure. In light of the color results obtained with the 7.5-month-olds, we further speculated that younger infants would need to see at least three exemplar pairs in the pretest events.

To test these hypotheses, we examined 5.5-month-olds' response to a different-pattern test event after first viewing pound–pour pretest events involving containers with different patterns. The infants were assigned to one of two conditions: three exemplars or two exemplars. The *three-exemplars* condition was identical to the three-exemplars condition of Experiment 3 with two exceptions: (1) the green and red pretest containers were replaced with dotted and striped containers (Fig. 6); and (2) the green and red test balls were replaced with dotted and striped balls (Fig. 7). The *two-exemplars* condition was identical to the three-exemplars condition except that in the pretest trials infants saw the second pair of containers twice (i.e. infants did not see the third pair of containers). If 5.5-month-olds can be led to use pattern features by viewing the pound–pour pretest events, but need to see at least three exemplar pairs in order to generalize across pairs, then the infants in the three-exemplars condition should look longer at the narrow- than at the wide-screen test event, whereas those infants in the two-exemplars condition should look about equally at the two events. In contrast, if 5.5-month-olds are unable to draw on pattern information to individuate objects, even in a more supportive context, then the infants in both the three- and the two-exemplars condition should look about equally at the narrow-and wide-screen test event.

5.1. Method

5.1.1. Participants—Participants were 32 healthy full-term infants, 16 male and 16 female (*M* = 5 months, 12 days; range = 5 months, 1 day to 5 months, 28 days). Twelve additional infants were eliminated: four because of fussiness, one because of sleepiness, one because of procedural problems, four because the primary observer was unable to determine the direction of the infant's gaze, and two because of exceptionally long looking times during the familiarization event (i.e. they looked for the maximum of 60 s on five or more of the familiarization trials). Eight infants were randomly assigned to each of four groups formed by crossing number of exemplar pairs (three or two) and test event (narrow- or wide-screen): three-exemplars narrow-screen (*M* = 5 months, 8 days); three-exemplars wide-screen (*M* = 5 months, 14 days); two-exemplars narrow-screen (*M* = 5 months, 16 days); two-exemplars wide-screen (*M* = 5 months, 11 days).

5.1.2. Apparatus and stimuli—The apparatus and stimuli were identical to those in Experiment 3 except that the green and red pretest and test objects were replaced with dotted and striped pretest and test objects, respectively. The dotted containers were painted green with yellow, red, and blue dots; the dots were 2 cm in diameter and placed approximately 2.5 cm apart. The striped containers were painted green with yellow, red, and blue stripes; the stripes were 1.3 cm in width and placed approximately 2 cm apart. The size and placement of the dots and the stripes on the balls were similar to those of the dots and the stripes on the containers. The dotted and striped balls were identical to those of Wilcox (1999).

5.1.3. Events

5.1.3.1. Three-exemplars narrow- and wide-screen conditions: The pretest, familiarization, and test events were identical to those of the three-exemplars narrow- and wide-screen conditions of Experiment 3 with the following exceptions: (1) the green and red cans, cups, and squiggly cups were replaced with the dotted and striped cans, cups, and squiggly cups, respectively; and (2) the green and red balls were replaced with the dotted and striped balls, respectively.

5.1.3.2. Two-exemplars narrow- and wide-screen conditions: The pretest, familiarization, and test events were identical to those in the three-exemplars narrow- and wide-screen conditions with one exception: the second pair of objects was used in the second and the third pair of pretest events.

5.1.4. Procedure—The procedure was identical to that of Experiment 3. Inter-observer agreement was measured for 25 of the infants and averaged 92%.

5.2. Results

5.2.1. Pretest trials—The infants' looking times during the six pretest trials were averaged and analyzed by means of an ANOVA with number of exemplar pairs (three or two) and test event (narrow-or wide-screen) as between-subjects factors. The main effects of number of exemplar pairs and test event were not significant ($F(1, 28)$ *S* < 1) and the interaction between these two factors was not significant ($F(1, 28) < 1.25$), indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (three-exemplars narrow-screen, *M* = 28.0, SD = 3.5; three-exemplars wide-screen, *M* = 27.9, SD = 4.0; two-exemplars narrow-screen, *M* = 27.7, SD = 1.8; two-exemplars wide-screen, *M* = 29.6, SD = 0.8).

5.2.2. Familiarization trials—The infants' looking times during the six familiarization trials were averaged and analyzed in the same manner as the pretest trials. The main effects of number of exemplar pairs and test event were not significant ($F(1, 28) < 1$), and the interaction between these two factors was not significant ($F(1, 28) < 1.25$), indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (three-exemplars narrow-screen, $M = 36.4$, SD = 11.4; three-exemplars wide-screen, $M = 29.0$, SD = 7.4; two-exemplars narrow-screen, $M = 32.5$, SD = 10.6; two-exemplars wide-screen, $M = 33.2$, SD = 14.6).

5.2.3. Test trials—The infants' looking times during the two test trials were averaged (Fig. 8) and analyzed in the same manner as the pretest trials. The main effect of number of exemplar pairs was not significant ($F(1, 28) < 1$). The main effect of test event ($F(1, 28) = 4.56$), and the interaction between exemplar pairs and test event ($F(1, 28) = 4.99$) were significant ($P < 0.05$). Planned contrasts indicated that the infants in the three-exemplars condition looked reliably longer at the narrow-screen ($M = 46.0$, SD = 15.3) than at the wide-screen ($M = 21.9$, SD = 14.5) test event ($F(1, 28) = 9.52$, $P < 0.01$), whereas those infants in the two-exemplars condition looked about equally at the two events (narrow-screen, $M = 31.8$, SD = 10.7; wide-screen, $M = 32.4$, SD = 20.5) ($F(1, 28) < 1$).

5.3. Discussion

The 5.5-month-olds in the three-exemplars condition looked reliably longer at the narrow- than at the wide-screen test event, as if viewing the pattern–function pairings in the pretest trials led them to attend to pattern information in the test trials. In contrast, the infants in the two-exemplars condition looked about equally at the two test events, as if seeing only two exemplar pairs was not sufficient to support their use of the pattern difference to individuate the objects in the test event.

These results build on the color findings from Experiments 1–3 in two ways. First, they suggest that infants can be induced to attend to pattern information, just like they can be induced to attend to color information, at an age younger than they attend to this information spontaneously. Second, these results provide converging evidence for the conclusion that younger infants need to see more exemplar pairs in order to form a categorical representation of the pound–pour events. Regardless of which featural properties infants are asked to process, color or pattern, infants younger than 9.5 months need to see three feature–function pairs before they will generalize across pairs.

The next experiment investigated whether 4.5-month-olds might also demonstrate sensitivity to pattern features after viewing the pound–pour events.

6. Experiment 5

In Experiment 5 we first tested 4.5-month-olds in the three-exemplars condition of Experiment 4. The pilot data did not look promising: the infants looked about equally at the narrow- and wide-screen test events. We were concerned, however, that the younger infants failed, not because they were unable to use the pattern difference to individuate the objects but because of information processing constraints. Perhaps as the pretest trials progressed the younger infants had difficulty keeping track of which container did what (i.e. was the previous container striped or dotted?). Without a clear representation of each container and the function it performed, the infants would be unable to form a categorical representation of the pound–pour events. One way to alleviate information processing demands associated with keeping track of objects across trials would be to present both containers (dotted and striped) together in each pretest event.

Hence, in Experiment 5 infants aged 4.5 months were tested in one of two conditions: successive or simultaneous presentation. The infants in the *successive-presentation* condition saw the same pretest and test events as the 5.5-month-olds in the three-exemplars condition of Experiment 4. The infants in the *simultaneous-presentation* condition saw similar pretest and test events except that the containers were seen together in the pretest events (Fig. 9). In the pound event, the striped container sat to the left of the display while the dotted container pounded the peg; in the pour event, the dotted container sat to the left of the display while the striped container poured salt. If infants find it easier to form a categorical representation of the event when the containers are viewed at the same time than when they are viewed one at a time, then the infants in the simultaneous-presentation condition should succeed at individuating the dotted and striped ball in the test event.

6.1. Method

6.1.1. Participants—Participants were 32 healthy full-term infants, 16 male and 16 female (*M* = 4 months, 11 days; range = 4 months, 0 days to 4 months, 29 days). Twelve additional infants were eliminated: six because of fussiness, four because of sleepiness, one because of procedural problems, and one because the primary observer was unable to determine the direction of the infant's gaze. Eight infants were randomly assigned to each of four groups formed by crossing type of presentation (successive or simultaneous) and test event (narrow- or wide-screen): successive-presentation narrow-screen (*M* = 4 months, 10 days); successive-presentation wide-screen (*M* = 4 months, 8 days); simultaneous-presentation narrow-screen (*M* = 4 months, 17 days); simultaneous-presentation wide-screen (*M* = 4 months, 9 days).

6.1.2. Apparatus and stimuli—The apparatus and stimuli were identical to those in Experiment 4.

6.1.3. Events

6.1.3.1. Successive-presentation narrow- and wide-screen conditions: The pretest, familiarization, and test events were identical to those of the three-exemplars narrow-and wide-screen conditions of Experiment 4.

6.1.3.2. Simultaneous-presentation narrow- and wide-screen conditions: The pretest, familiarization, and test events were identical to those of the successive-presentation narrow- and wide-screen conditions with one exception: in the pound event the striped container sat to the left of the display and in the pour event the dotted cup sat to the left of the display.

6.1.4. Procedure—The procedure was identical to that in Experiment 4. Inter-observer agreement was measured for 29 of the infants and averaged 90%.

6.2. Results

6.2.1. Pretest trials—The infants' looking times during the six pretest trials were averaged and analyzed by means of an ANOVA with type of presentation (successive or simultaneous) and test event (narrow- or wide-screen) as between-subjects factors. The main effects of type of presentation and test event were not significant ($F(1, 28) < 1$), and the interaction between these two factors was not significant ($F(1, 28)$ $S < 1.5$), indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (successive-presentation narrow-screen, *M* = 27.4, SD = 2.5; successive-presentation wide-screen, *M* = 28.0, SD = 2.2; simultaneous-presentation narrow-screen, *M* = 28.6, SD = 1.6; simultaneous-presentation wide-screen, *M* = 27.2, SD = 3.2).

NIH-PA Author Manuscript

NIH-PA Author Manuscript

6.2.2. Familiarization trials—The infants' looking times during the six familiarization trials were averaged and analyzed in the same manner as the pretest trials. The main effects of type of presentation ($F(1, 28) < 1.5$) and test event ($F(1, 28) < 1$) and the interaction between these two factors ($F(1, 28) < 1$) were not significant, indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (successive-presentation narrow-screen, $M = 32.4$, SD = 10.5; successive-presentation wide-screen, $M = 32.6$, SD = 8.1; simultaneous-presentation narrow-screen, $M = 38.8$, SD = 10.0; simultaneous-presentation wide-screen, $M = 35.4$, SD = 13.9).

6.2.3. Test trials—The infants' looking times during the two test trials were averaged (Fig. 10) and analyzed in the same manner as the pretest trials. The main effects of type of presentation ($F(1, 28) = 5.99$) and test event ($F(1, 28) = 6.11$) were significant ($P < 0.05$). The interaction between these two factors was also significant ($F(1, 28) = 7.12$, $P < 0.025$). Planned contrasts indicated that the infants in the simultaneous-presentation condition looked reliably longer at the narrow-screen ($M = 55.7$, SD = 5.3) than at the wide-screen ($M = 31.6$, SD = 17.6) test event ($F(1, 28) = 13.20$, $P < 0.01$), whereas those infants in the successive-presentation condition looked about equally at the two events (narrow-screen, $M = 31.7$, SD = 13.5; wide-screen, $M = 32.6$, SD = 13.6) ($F(1, 28) < 1$).

6.3. Discussion

The infants in the simultaneous-presentation condition looked reliably longer at the narrow- than at the wide-screen test event, suggesting that they were able to use the difference in pattern to individuate the dotted and striped balls. In contrast, the infants in the successive-presentation condition looked about equally at the narrow- and wide-screen test events, suggesting that they failed to use the pattern information to signal the presence of distinct objects. These results suggest that the infants in the simultaneous- but not the successive-presentation condition successfully formed a categorical representation of the pound–pour events, and that this process supported their use of pattern information in the test event.

Why did seeing the objects together in the pretest trials make such a difference in performance? One possible explanation focuses on the importance of comparison to the categorization process. Seeing the objects together gave the infants the opportunity to directly compare and contrast the two containers, and highlighted the fact that containers with different featural properties performed different functions. This experience led the infants to attend more closely to the categorical distinctions between the two containers. In support of this hypothesis, there is evidence that infants aged 3–18 months demonstrate enhanced performance on categorization tasks when they are allowed to directly compare items than when they are presented with items one at a time (Namy, Smith, & Gershkoff-Stowe, 1997; Needham, 2001; Needham et al., 2003; Oakes, 2001; Quinn, 1987). Gentner and Namy (1999) argued that the process of comparison facilitates the extraction of deeper and more abstract relations among category members.

An alternative explanation focuses on limitations in memory. In the successive-presentation condition, where only one container was seen at a time, the infants had to rely on their memory of the previously viewed container in order to identify a meaningful relation between them. If the infants had difficulty retrieving this information (i.e. what the container looked like or the function that it engaged in), they would be unable to establish a conceptual structure of the event. When allowed to view the dotted and striped containers together in the pretest events the infants did not need to recall what the other container in the pair looked like – it was right before them – and they demonstrated significantly improved performance.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Although the data do not distinguish between these two possibilities, we tend to favor the former for two reasons. First, there is evidence that age-related changes in memory cannot easily account for infants' propensity to form more sophisticated categories when they are allowed to directly compare exemplars (Oakes, 2001). Second, there is evidence that infants' memory for previously presented stimuli is quite robust, often lasting over several weeks (e.g. Rovee-Collier, 1995, 1997). Although the infants in our experiments had to compare and contrast multiple feature–function pairings, the memory demands associated with the pound–pour procedure seem to fall well within the bounds of infants' memory capabilities.

7. General discussion

Wilcox (1999) reported that infants are more sensitive to form than surface features when individuating objects in occlusion events: it is not until 7.5 months that infants spontaneously use pattern information, and 11.5 months that they spontaneously use color information, as the basis for object individuation. The present research investigated whether infants' sensitivity to surface features could be elevated by changes in supportive conditions. More specifically, we assessed whether younger infants could be primed to draw on color and pattern features in an individuation task if they were first shown the functional value of attending to color and pattern information. In the first three experiments, 9.5- and 7.5-month-olds were shown events in which the color of an object predicted its function: green containers pounded a peg and red containers poured salt. Infants' ability to individuate a green and red ball was then assessed using the narrow-screen task. Positive results were obtained with both age groups, although the 7.5-month-olds needed to see three different color–function pairings in order to benefit from the pound–pour events, whereas the 9.5-month-olds needed only to see two different color–function pairings. In the last two experiments, 5.5- and 4.5-month-olds were shown events in which the pattern of a container (i.e. dotted or striped) predicted whether it would pound or pour, followed by the narrow-screen task using a dotted ball and a striped ball. Positive results were once again obtained, although the 4.5-month-olds needed to directly compare the dotted and striped containers during the pound–pour events in order to demonstrate heightened sensitivity to pattern information in the test events.

These results indicate that infants' limited sensitivity to pattern and color features, observed by Wilcox (1999), can be altered by exposure to events that highlight the importance of attending to pattern and color information. These results are important for two reasons. First, they point to a flexibility in the type of information to which infants attend when tracking objects through occlusion. Although infants may not spontaneously attend to surface features in occlusion events, they can be led to do so under more supportive conditions. Second, they provide insight into the kinds of experiences that can alter the type of information to which infants attend. Not all experiences with pattern and color information prime infants to attend to pattern and color features in an individuation task. At the same time, these results raise questions about how feature priming works. How can viewing one set of events increase infants' sensitivity to color or pattern information in another, separate event? What mechanisms support feature priming? Are there other kinds of experiences that can lead to increased sensitivity to surface features? In the discussion that follows these questions are addressed.

7.1. Infants' sensitivity to surface features across events

One might wonder how viewing pound–pour events, in which containers of different patterns or colors perform different functions, could lead infants to use pattern or color differences to signal the presence of distinct objects. What were infants learning in the pound–pour events? How did this process influence their interpretation of the occlusion event? Remember that in the pound–pour events, the containers in each exemplar pair were

NIH-PA Author Manuscript

NIH-PA Author Manuscript

identical in appearance except for their pattern or color. The *only* way that infants could distinguish between the two containers, and the event that they would engage in, was to attend to their surface features. We suspect that the experience of using surface features as a marker of object function (e.g. green containers pound and red containers pour) primed infants to attend more closely to surface features. This resulted in increased sensitivity to color and pattern differences in the subsequent test events.

To be clear, we are not suggesting that viewing the pound–pour events led infants to erroneously conclude that the function of a container depended on its surface features (i.e. that the affordance of an object is somehow related to its pattern or color), but rather that infants learned that containers with different surface features could be used for different purposes (i.e. the pattern or color of an object predicted which function it would engage in). Once infants recognized, in this situation, that these surface features had predictive value, they were more likely to attend to these same surface features in another situation. What remains open to speculation is the long-term consequences of this experience. For example, it is possible that the effects of feature priming are relatively transient; infants are led to temporarily attend to surface features, but viewing the pound–pour events does not permanently change the way that infants use surface information to interpret occlusion situations. Alternatively, it is possible that the experience of linking surface features to function, of learning that color can be a useful source of information, significantly increases the probability that infants will draw on color information when interpreting future occlusion events, and perhaps even other physical events. If the latter is the case, it would implicate feature priming as an important mechanism for changing the way that infants' apprehend objects in the physical world.

7.2. Categorical event representations and feature priming

In the present research, infants demonstrated feature priming only when they were shown multiple exemplar pairs in the pretest events, pointing to the importance of categorical event representations to the priming process.[5] It is not entirely clear, however, how to conceptualize these categorical event representations. We have, for ease in presentation, discussed the priming results as if the pattern pound–pour events primed infants to attend to pattern information and the color pound–pour events primed infants to attend to color information. This interpretation implies that during the pretest trials the infants formed event categories that were relatively inclusive: that is, the infants extracted from the pound–pour events that different-colored (or different-patterned) objects engage in different functions. Infants then carried forward to the test trials an increased sensitivity to color (or pattern) information. There are, however, equally plausible alternative interpretations of the priming results. One possibility is that the infants formed event categories that were *less* inclusive. For example, the infants may have extracted from the pound–pour events that green containers pound and red containers pour. Their response to the test events, then, reflects an increased sensitivity to those specific features (i.e. green and red). Another possibility is that the infants formed event categories that were *more* inclusive, for example, objects with different surface features engage in different functions. According to this interpretation, the infants were primed to attend to surface features more generally (i.e. not just pattern or color).

[5]It is important to make a distinction between the categorical event representations discussed here and the kind of event categorization that Baillargeon and her colleagues have proposed (e.g. Baillargeon, 1998; Baillargeon et al., 1995; Baillargeon & Wang, 2002). The former includes local categories that are created "on the fly", that are used in select situations, and that are probably relatively transient. The latter refers to global categories (e.g. occlusion, containment, support) that are deeply embedded in infants' physical knowledge, are used continuously, and remain relatively stable over time.

Although the present data do not distinguish between these three interpretations, each interpretation makes clear predictions that would be relatively easy to test. For example, if priming of surface features is very specific, then infants should demonstrate sensitivity to the difference between the green and red balls in the test trials only when the containers seen in the pretest trials are green and red. In contrast, if feature priming is less specific but limited to a feature type (i.e. pattern primes pattern and color primes color), then infants should individuate the green and red balls in the test trials when the pretest containers are different colors (e.g. blue and yellow) but not when they are different patterns (e.g. dotted and striped). Finally, if infants form an abstract representation of the pound–pour events, and feature priming can be accomplished with abstract event representations, then any surface feature used in the pretest events should prime all surface features in the test events. We are currently testing these predictions and the preliminary results suggest that infants' categorical event representations are quite specific: 9-month-olds demonstrate increased sensitivity to color information in the test trials only when the containers seen in the pretest trials are of the same color. Future research will explore whether infants can form abstract categorical event representations under more supportive conditions, for example, if infants are allowed to directly compare the exemplars during the pound–pour events.

7.3. The kinds of experiences that support feature priming

Perhaps one of the most intriguing findings was that infants' sensitivity to color features was enhanced by viewing the pound–pour, but not the pound–pour motion, events. Why did one set of events support feature priming whereas the other set of events did not? Our answer to this question rests on the assumption that infants' increased sensitivity to surface features in the pound–pour experiments was accomplished by placing surface features in a context that, first, engaged infants' attention and, second, enabled infants to attach meaning to those features. Using this as a starting point, two possible interpretations were offered earlier. One interpretation focused on the perceptual saliency of event characteristics as an important factor. For example, perhaps the pound–pour events were perceived as more interesting or complex and, hence, were more likely to capture the infants' attention. Or, maybe the structure of the pound–pour events made it easier for infants to form associations between surface features and the actions the objects engaged in (e.g. the parts of the event, including the containers, the peg, and the salt, were closer in proximity). A second interpretation focused on object function as the important difference between the pound–pour and the motion events. According to this viewpoint, the pound–pour events engaged the infants' attention because the events revealed something about the functional properties of the objects involved. Identifying the functional relevance of objects, and learning to distinguish between objects based on their functional properties, is perhaps one of infants' most important tasks (e.g. Meltzoff & Moore, 1995, 1998).

There is a third interpretation, however, that should be considered. It is possible that any event in which objects move and interact in ways that provide useful and meaningful information about the objects (e.g. what they can be used for, what they are made of, their mechanical or causal properties), *and* that allow infants to discriminate between objects or categories of objects, will support feature priming. This interpretation proposes that infants are sensitive to a wide range of events that include, but are not limited to, events that specify the functions of objects. This interpretation also implies that forming associations between objects and seemingly arbitrary actions is a lesser used learning mechanism – infants are not impelled to attend to events that provide little useful information about an object. This is not to say that infants cannot form associations between objects and arbitrary actions, and that this type of learning might be useful in certain situations. It simply means that infants are not easily led to attend to arbitrary actions when attempting to sort out and make sense of physical events.

Regardless of the specific processes that are involved, the important point is that viewing events in which surface features predict how an object will be used, or the kind of event it will engage in, can lead infants to link surface features to objects. This experience, in turn, changes the way that infants perceive and interpret objects and events in other contexts. Given the importance of feature priming to infants' apprehension of their world, one might wonder whether there are other ways to prime infants to attend to information that they typically do not consider. Two groups of researchers are currently working on this problem. First, we have examined whether simultaneous visual and tactile exploration of objects, which tends to focus infants on surface properties, will facilitate infants' capacity to use surface features to individuate objects in a subsequent individuation task. Generally speaking, the results of these experiments have been positive, although this more subtle form of priming appears to work better with older infants (see Wilcox et al., 2003 for a description of this research). Second, Wang and Baillargeon have taken a slightly different approach (Baillargeon & Wang, 2002; Wang & Baillargeon, 2003). They have explored whether infants can be led to use knowledge that they already possess about one physical situation to extract new knowledge about another physical situation. For example, they have found that viewing height information in occlusion events can prime infants to attend to height information in uncovering events.

7.4. Exploring a tunnel effect interpretation of the narrow-screen results

Throughout this article, we have presented the narrow-screen task as a measure of object individuation in infancy. Recently, Xu and Carey (2000) have offered an alternative explanation for infants' prolonged looking to different-features narrow-screen events. The logic of their account rests on a perceptual phenomenon called the tunnel effect (e.g. Burke, 1952; Michotte, Thinès, & Crabbé, 1964/1991). Under select conditions, adults perceive a different-features event as involving a single object that changes its appearance. Xu and Carey suggested that the conditions of the narrow-screen event are the same as those that support the tunnel effect. On this view, infants evidence prolonged looking to narrow-screen different-features events because they (a) perceive the events as involving a single object and (b) find changes in the object's appearance, as it moves back and forth behind the screen, unexpected.

One way to address this question is to assess adults' interpretation of narrow-screen events. Following a procedure used by Xu, Carey, and Quint (2003), we showed adult participants ($N = 30$) a narrow-screen different-features (green ball–red box) event using a screen violation identical to that of the present experiments. To assess adults' initial impression of the event, we asked them to describe the event as accurately as possible. In response, 50% gave a literal description of the event (e.g. a ball goes behind the screen and a box comes out the other side), 23.3% gave an explanation for how the event was produced using two objects (e.g. the ball is replaced with the box), and 26.7% gave wording to the effect that the ball changed into a box (e.g. the ball turns into a box). These results suggest that the adults' initial perception of the event was not that of a single object that changed its appearance. To get more detail about how the adults perceived and understood the event, we asked two additional questions (Is there anything unusual about the event? How is the event produced?). In response to the two probe questions, 60% used wording to the effect that two objects were involved in the event, and of these 88% provided mechanisms for how the event was produced using these two objects (e.g. the ball slid into the box, the ball sat on top of the box, or the ball moved behind the box); 10% used wording to the effect that the ball changed into a box; 23.3% gave both kinds of responses (e.g. used wording to the effect that the ball changed into a box and also gave explanations for how the ball and box were exchanged behind the screen); and 6.7% gave literal descriptions of the event. These results suggest that the majority of the adults viewed the event as involving two distinct objects, and of those that used “object changed” terminology only a small proportion did so exclusively. Whether we look at adults’ initial responses, or their responses to probe questions, the results do not support a tunnel effect interpretation of the narrow-screen event (for additional reasons to doubt the tunnel effect interpretation see Wilcox et al., 2003; for an alternative viewpoint see Xu et al., 2003).

7.5. Concluding remarks

The present research is the first to report that infants can be primed, through select experiences with objects or categories of objects, to draw on information to which they do not typically attend when individuating objects in occlusion events. These results join other reports that infants’ apprehension of objects is a dynamic process, supported in some situations and not others (e.g. Johnson & Aslin, 1996; Johnson & Náñez, 1995; Needham, 1999; Needham & Baillargeon, 1998) and influenced by their experiences with objects (e.g. Needham, 2001; Needham & Baillargeon, 1998). The charge of future research will be to identify exactly how feature priming is accomplished, the long-term consequences of the priming experience, and the specific mechanisms that support feature priming. Clearly, feature priming is a phenomenon that demands attention and the outcome of future research will have important implications for how we conceptualize the development of object representation during infancy.

Acknowledgments

This research was supported by a grant from the National Institute of Child Health and Human Development (HD-36741) and the Advanced Research Program of the Texas Higher Education Coordinating Board (SBS-3656) to the first author. We would like to thank Renée Baillargeon, Terrence Barnhardt, and Vincent Brown for many helpful conversations about this work; Gevel Bruner, Carmen Nephew, Lisa Tuggy, Amy Schweinle, Amy Waldrip and Rebecca Woods, and the undergraduate assistants of the Infant Cognition Laboratory at The University of Texas at Arlington and at Texas A&M University for their help with data collection; and the parents who so graciously agreed to have their infants participate in the research.

References

Aguiar A, Baillargeon R. 2.5-month-old infants’ reasoning about when objects should and should not be occluded. Cognitive Psychology. 1999; 39:116–157. [PubMed: 10462457]

Aguiar A, Baillargeon R. Developments in young infants’ reasoning about occlusion events. Cognitive Psychology. 2002; 45:267–336. [PubMed: 12528903]

Baillargeon, R. Infants’ understanding of the physical world. In: Sabourin, M.; Craik, FIM.; Robert, M., editors. Cognitive and biological aspects. Vol. 1. London: Psychology Press; 1998. p. 503-529.Advances in psychological science

Baillargeon, R.; Brueckner, L. 3.5-month-old infants’ reasoning about the width of hidden objects. Paper presented at the biennial meeting of the International Society on Infant Studies; Brighton, UK. 2000 Jul.

Baillargeon R, Graber M. Where’s the rabbit? 5.5-month-old infants’ representation of the height of a hidden object. Cognitive Development. 1987; 2:375–392.

Baillargeon, R.; Kotovsky, L.; Needham, A. The acquisition of physical knowledge in infancy. In: Sperber, D.; Premack, D.; Premack, AJ., editors. Causal cognition: a multidisciplinary debate. Oxford: Clarendon Press; 1995. p. 79-116.

Baillargeon R, Wang S. Event categorization in infancy. Trends in Cognitive Science. 2002; 6:85–93.

Baldwin DA, Markman EM, Melartin RL. Infants’ ability to draw inferences about nonobvious object properties: evidence from exploratory play. Child Development. 1993; 64:711–728. [PubMed: 8339691]

Banks MS, Salapatek P. Infant pattern vision: a new approach based on the contrast sensitivity function. Journal of Experimental Child Psychology. 1981; 31:1–45. [PubMed: 7217886]

Banks, MS.; Salapatek, P. Infant visual perception. In: Haith, MM.; Campos, JJ., editors. Handbook of child psychology. New York: Wiley; 1983. p. 435-571.

Banks, MS.; Shannon, E. Spatial and chromatic visual efficiency in human neonates. In: Granrud, CE., editor. Visual perception and cognition in infancy. Hillsdale, NJ: Erlbaum; 1993. p. 1-46.

Booth AE, Waxman S. Object names and object functions serve as cues to categories for infants. Developmental Psychology. 2002; 38:948–957. [PubMed: 12428706]

Bornstein MH, Kessen W, Weiskopf S. Color vision and hue categorization in young human infants. Journal of Experimental Psychology: Human Perception and Performance. 1976; 2:115–129. [PubMed: 1262792]

Brown AM. Development of visual sensitivity to light and color vision in human infants: a critical review. Vision Research. 1990; 30:1159–1188. [PubMed: 2205977]

Burke L. On the tunnel effect. Quarterly Journal of Experimental Psychology. 1952; 4:121–138.

Catherwood D, Crassini B, Freiberg K. Infant response to stimuli of similar hue and dissimilar shape: tracing the origins of the categorization of objects by hue. Child Development. 1989; 60:752–762. [PubMed: 2737022]

Chapa, C.; Wilcox, T. Object experience and individuation: infants' use of color information. Paper presented at the biennial meeting of the Society for Research in Child Development; Albuquerque, NM. 1999 Apr.

Craton, L.; Poirier, C.; Heagney, C. Perceptual completion and object segregation in infancy. Paper presented at the International Conference on Infant Studies; Atlanta, GA. 1998 Apr.

De Yoe EA, Van Essen DC. Concurrent processing streams in monkey visual cortex. Trends in Neuroscience. 1988; 11:219–226.

Fantz RL. The origin of form perception. Scientific American. 1961; 204:66–72. [PubMed: 13698138]

Freeman NH, Lloyd S, Sinha CG. Infant search tasks reveal early concepts of containment and canonical usage of objects. Cognition. 1980; 8:243–262. [PubMed: 7398233]

Gentner D, Namy L. Comparison in the development of categories. Cognitive Development. 1999; 14:487–513.

Greco C, Hayne H, Rovee-Collier C. Roles of function, reminding, and variability in categorization by 3-month-old infants. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1990; 16:617–633.

Hayne H, Rovee-Collier C, Perris EE. Categorization and memory retrieval by three-month-old infants. Child Development. 1987; 58:750–767. [PubMed: 3608647]

Hespos, S. Tracking individual objects across occlusion and containment events in 6.5-month-old infants. Paper presented at the International Conference on Infant Studies; Brighton, UK. 2000 Jul.

Hespos SJ, Baillargeon R. Infants' knowledge about occlusion and containment events: a surprising discrepancy. Psychological Science. 2001; 12:140–147.

Johnson SP, Aslin RN. Perception of object unity in young infants: the roles of motion, depth, and orientation. Cognitive Development. 1996; 11:161–180.

Johnson SP, Náñez JE. Young infants' perception of object unity in two-dimensional displays. Infant Behavior and Development. 1995; 18:133–143.

Kellman PJ, Spelke ES. Perception of partly occluded objects in infancy. Cognitive Psychology. 1983; 15:483–524. [PubMed: 6641127]

Kemler Nelson DG, Frankenfield A, Morris C, Blair E. Young children's use of functional information to categorize artifacts: three factors that matter. Cognition. 2000; 77:133–168. [PubMed: 10986365]

Kemler Nelson DG, Russell R, Duke N, Jones K. Two-year-olds will name artifacts by their functions. Child Development. 2000; 71:1271–1288. [PubMed: 11108096]

Kestenbaum R, Termine N, Spelke ES. Perception of objects and object boundaries by 3-month-olds infants. British Journal of Developmental Psychology. 1987; 5:367–383.

Kolstad, V.; Baillargeon, R. Appearance- and knowledge-based responses to containers in infants. 1993. Unpublished manuscript

Leslie, AM.; Glanville, M. Is individuation by feature in young infants limited by attention or by working memory?. Paper presented at the biennial meeting of the Society for Research in Child Development; Minneapolis, MN. 2001 Apr.

Leslie AM, Xu F, Tremoulet P, Scholl B. Indexing and the object concept: developing 'what' and 'where' systems. Trends in Cognitive Sciences. 1998; 2:10–18. [PubMed: 21244957]

Madole KL, Oakes LM. Making sense of infant categorization: stable processes and changing representations. Developmental Review. 1999; 19:263–296.

Mandler, JM. Development of categorization: perceptual and conceptual categories. In: Bremner, G.; Slater, A.; Butterworth, G., editors. Infant development: recent advances. Hove: Erlbaum; 1997.

Meltzoff AN. Infant imitation after a 1-week delay: long-term memory for novel acts and multiple stimuli. Developmental Psychology. 1988a; 24:470–476.

Meltzoff AN. Infant imitation and memory: nine-month-olds in immediate and deferred tests. Child Development. 1988b; 59:217–225. [PubMed: 3342714]

Meltzoff, AN.; Moore, MK. Infants' understanding of people and things: from imitation to folk psychology. In: Bermudez, JL.; Marcel, A.; Eilan, N., editors. The body and the self. Cambridge, MA: MIT Press; 1995. p. 43-69.

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

Michotte, A.; Thinès, G.; Crabbé, G. Amodal completion of perceptual structures. In: Thines, G.; Costall, A.; Butterworth, G., editors. Michotte's experimental phenomenology of perception. Hillsdale, NJ: Lawrence Erlbaum Associates; 1991. (Original work published in French in 1964)

Namy LL, Smith LB, Gershkoff-Stowe L. Young children's discovery of spatial classification. Cognitive Development. 1997; 12:163–185.

Needham A. The role of shape in 4-month-old infants' segregation of adjacent objects. Infant Behavior and Development. 1999; 22:161–178.

Needham A. Object recognition and object segregation in 4.5-month-old infants. Journal of Experimental Child Psychology. 2001; 78:3–24. [PubMed: 11161419]

Needham A, Baillargeon R. Object segregation in 8-month-old infants. Cognition. 1997; 62:121–149. [PubMed: 9141904]

Needham A, Baillargeon R. Effects of prior experience in 4.5-month-old infants' object segregation. Infant Behavior and Development. 1998; 21:1–24.

Needham, A.; Baillargeon, R.; Kaufman, L. Object segregation in infancy. Rovee-Collier, C.; Lipsitt, L., editors. Vol. 11. Greenwich, CT: Ablex; 1997. p. 1-44.Advances in infancy research

Needham, A.; Dueker, G.; Lockhead, G. Infants' formation and use of categories to segregate objects. 2003. Manuscript submitted for publication

Nelson K. Some evidence for the cognitive primacy of categorization and its functional basis. Merrill-Palmer Quarterly. 1973; 19:21–39.

Nelson K. Concept, word and sentence: interrelations in acquisition and development. Psychological Review. 1974; 81:267–285.

Oakes, L. The role of comparison in category formation in infancy. Paper presented at the biennial meeting of the Society for Research in Child Development; Minneapolis, MN. 2001 Apr.

Pick, A. Perceptual learning, categorizing, and cognitive development. In: Dent-Read, C.; Zukow-Goldring, P., editors. Evolving explanations of development: ecological approaches to organism-environment systems. Washington, DC: American Psychological Association; 1997. p. 335-370.

Pieraut-Le Bonniec G. From visual-motor anticipation to conceptualization: reaction to solid and hollow objects and knowledge of the function of containment. Infant Behavior and Development. 1985; 8:413–424.

Quinn PC. The categorical representation of visual pattern information by young infants. Cognition. 1987; 27:145–179. [PubMed: 3691024]

Quinn, PC.; Eimas, PD. Perceptual organization and categorization in young infants. Rovee-Collier, C.; Lipsitt, LP., editors. Vol. 10. Norwood, NJ: Ablex; 1996. p. 1-36.Advances in infancy research

Richards DD, Goldfarb J, Richards AL, Hassen P. The role of functionality in the categorization of well-defined concepts. Journal of Experimental Child Psychology. 1989; 47:97–115.

Rovee-Collier C. The development of infant memory. Current Directions in Psychological Science. 1995; 8:80–85.

Rovee-Collier C. Dissociations in infant memory: rethinking the development of implicit and explicit memory. Psychological Review. 1997; 104:467–498. [PubMed: 9243961]

Salapatek, P. Infant perception: from sensation to cognition. New York: Academic Press; 1975. Pattern perception in early infancy; p. 133-248.

Slater A, Johnson SP, Kellman PJ, Spelke ES. The role of three-dimensional cues in infants' perception of partly occluded objects. Early Development and Parenting. 1994; 3:187–191.

Slater A, Morison V, Somers M, Mattock A, Brown A, Taylor D. Newborn and older infants' perception of partly occluded objects. Infant Behavior and Development. 1990; 13:33–49.

Spelke, ES. Perception of unity, persistence, and identity: thoughts on infants' conceptions of objects. In: Mehler, J.; Fox, R., editors. Neonate cognition. Hillsdale, NJ: Erlbaum; 1985. p. 89-113.

Spelke ES, Breinlinger K, Macomber J, Jacobson K. Origins of knowledge. Psychological Review. 1992; 99:605–632. [PubMed: 1454901]

Spelke ES, Kestenbaum R, Simons DJ, Wein D. Spatiotemporal continuity, smoothness of motion and object identity in infancy. British Journal of Developmental Psychology. 1995; 13:113–143.

Teller, DY.; Bornstein, MH. Infant color vision and color perception. In: Salapatek, P.; Cohen, L., editors. From sensation to perception. Vol. 1. Orlando, FL: Academic Press; 1987. Handbook of infant perception

Traeuble, B.; Pauen, S. Functional play activities within an object-examination task. Paper presented at the International Conference on Infant Studies; Brighton, UK. 2000 Jul.

Tremoulet PD, Leslie AM, Hall GD. Infant individuation and identification of objects. Cognitive Development. 2001; 15:499–522.

Wang, S.; Baillargeon, R. Priming infants to attend to height information in covering events. 2003. Manuscript in preparation

Wilcox T. Object individuation: infants' use of shape, size, pattern, and color. Cognition. 1999; 72:125–166. [PubMed: 10553669]

Wilcox T, Baillargeon R. Object individuation in infancy: the use of featural information in reasoning about occlusion events. Cognitive Psychology. 1998a; 37:97–155. [PubMed: 9878104]

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

Wilcox T, Chapa C. Infants' reasoning about opaque and transparent occluders in an individuation task. Cognition. 2002; 85:B1–B10. [PubMed: 12086715]

Wilcox T, Schweinle A. Object individuation and event mapping: infants' use of featural information. Developmental Science. 2002; 5:87–105.

Wilcox T, Schweinle A. Infants' use of speed information to individuate objects in occlusion events. Infant Behavior and Development. 2003; 26:253–282.

Wilcox, T.; Schweinle, A.; Chapa, C. Object individuation in infancy. Fagan, F.; Hayne, H., editors. Vol. 3. Mahwah, NJ: Lawrence Erlbaum Associates; 2003. p. 193-243.Progress in infancy research

Xu F, Carey S. Infants' metaphysics: the case of numerical identity. Cognitive Psychology. 1996; 30:111–153. [PubMed: 8635312]

Xu F, Carey S. The emergence of kind concepts: a rejoinder to Needham & Baillargeon (2000). Cognition. 2000; 74:285–301. [PubMed: 10640573]

Xu, F.; Carey, S.; Quint, N. The emergence of kind-based object individuation in infancy. 2003. Manuscript submitted for publication

Xu F, Carey S, Welsh J. Infants' ability to use object kind information for object individuation. Cognition. 1999; 70:137–166. [PubMed: 10349761]

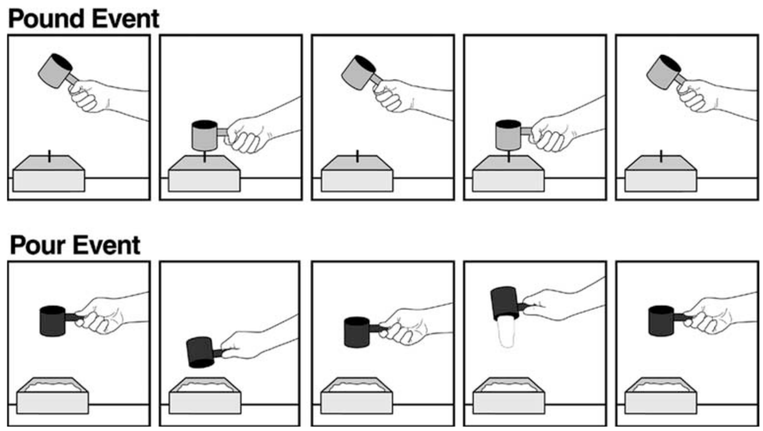

Fig. 1.
Schematic drawing of the pound and pour pretest events of Experiment 1. The container used in the pound event was green and the container used in the pour event was red.

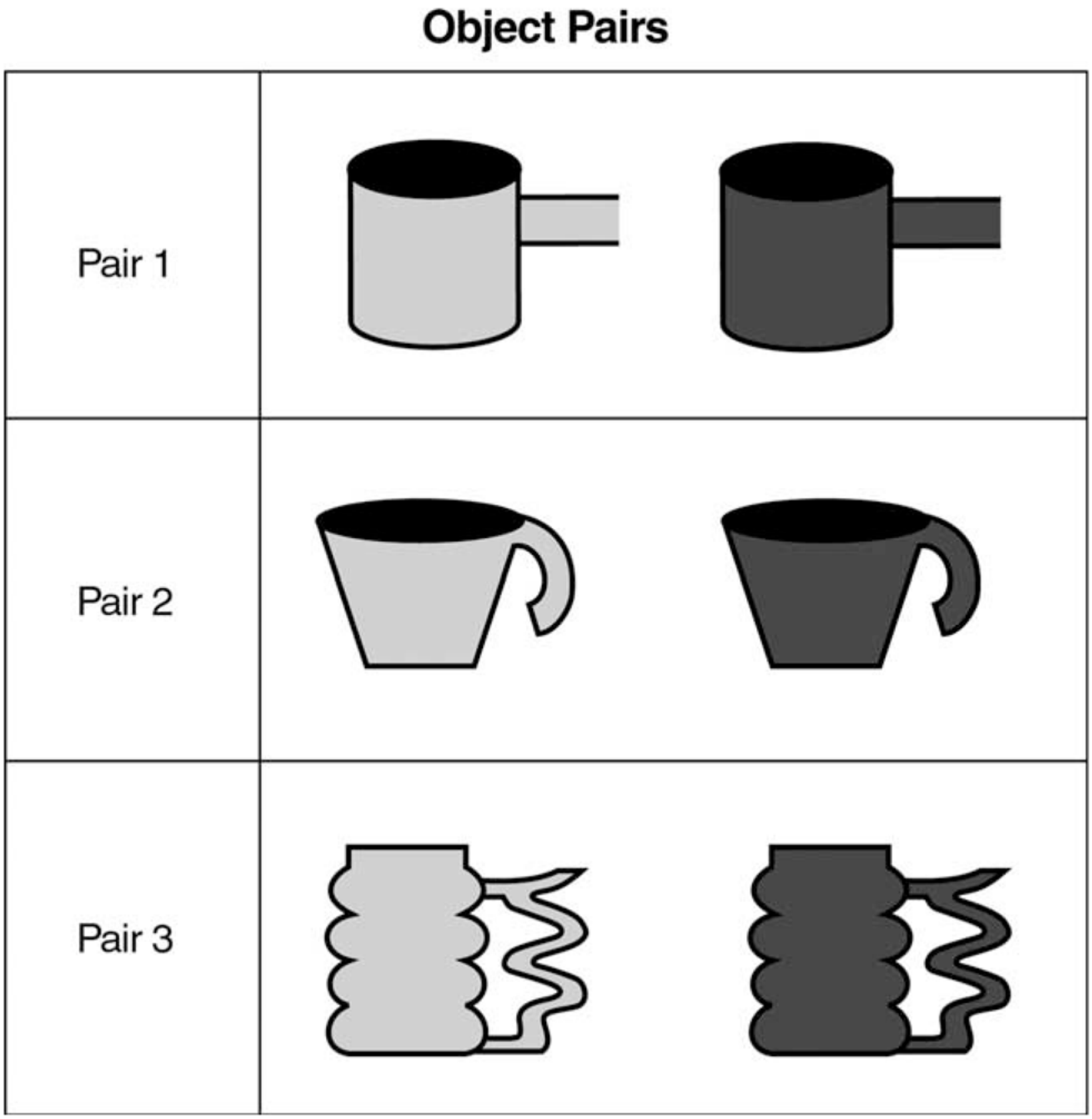

Fig. 2.
Schematic drawing of the container pairs used in Experiments 1–3. The containers on the left were green and the containers on the right were red. The third container pair was used only in the three-exemplars condition of Experiment 3.

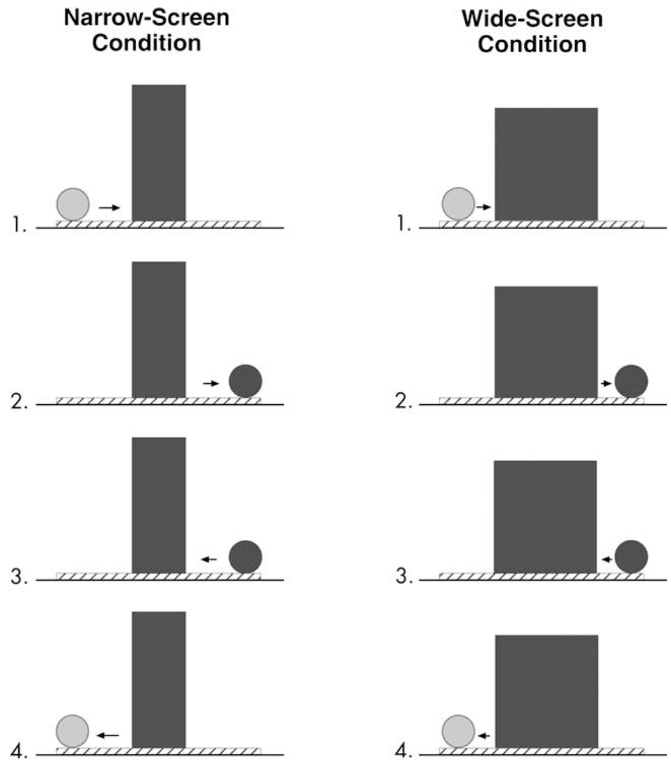

Fig. 3.
Schematic drawing of the test events in the narrow- and wide-screen conditions of Experiments 1–3. The ball to the left of the screen was green and the ball to the right of the screen was red.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

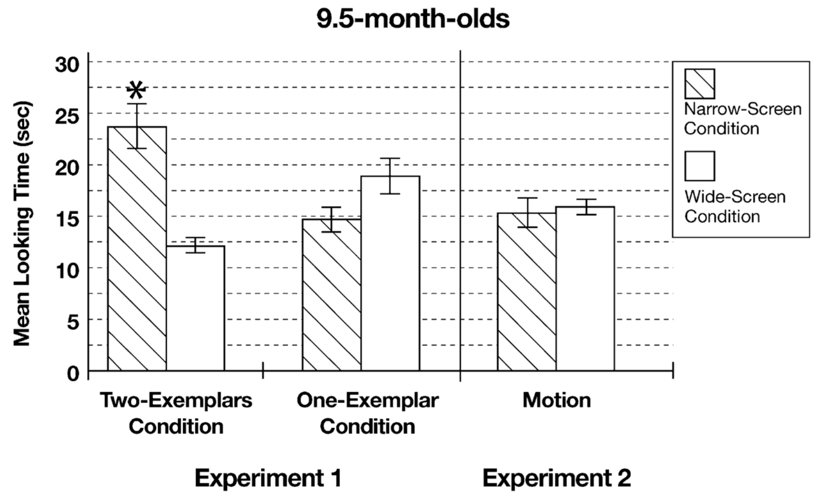

Fig. 4.
Mean looking times (and standard errors) of the infants in Experiments 1 and 2 to the test events.

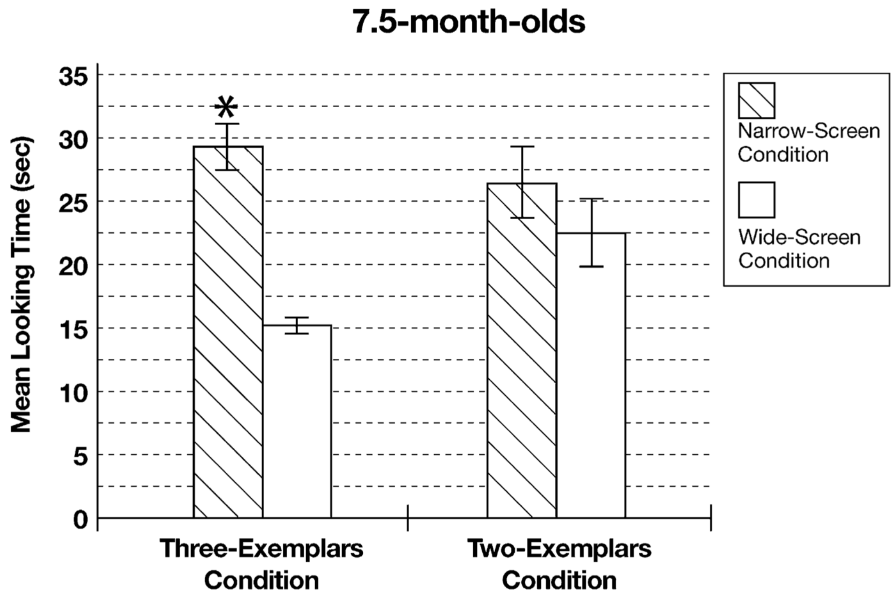

Fig. 5.
Mean looking times (and standard errors) of the infants in Experiment 3 to the test events.

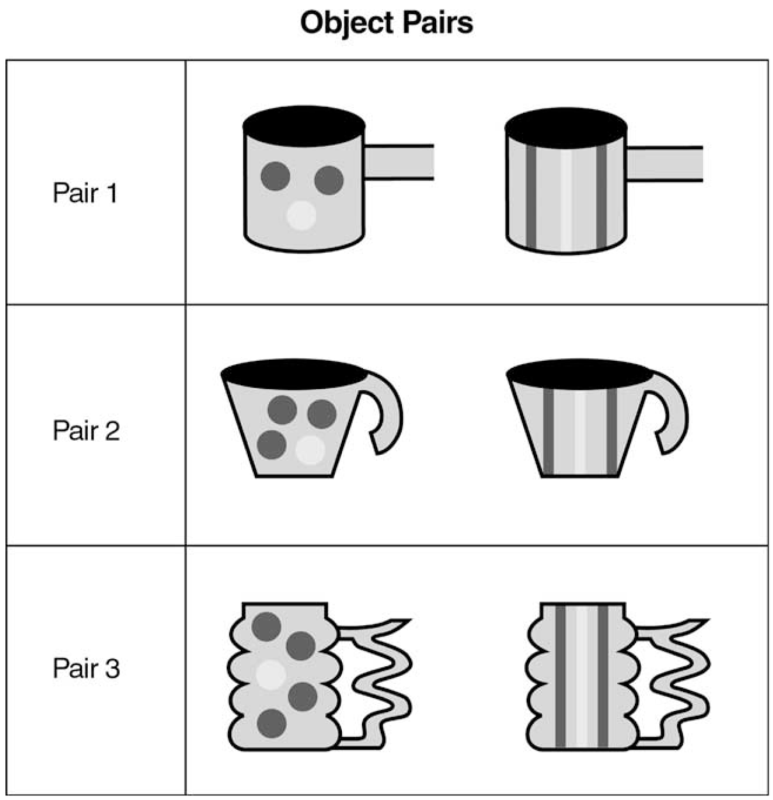

Fig. 6.
Schematic drawing of the three container pairs used in Experiments 4 and 5.

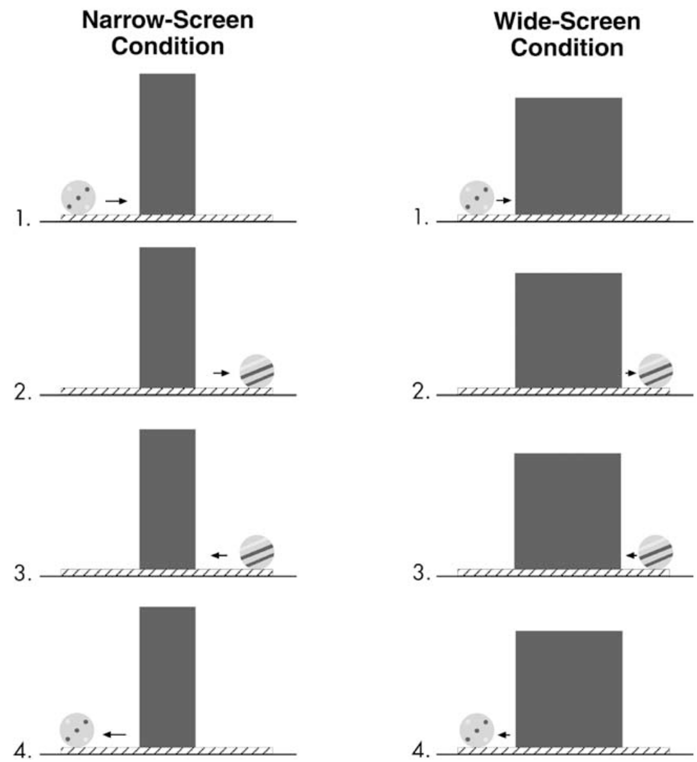

Fig. 7.
Schematic drawing of the test events in the narrow- and wide-screen conditions of Experiments 4 and 5.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

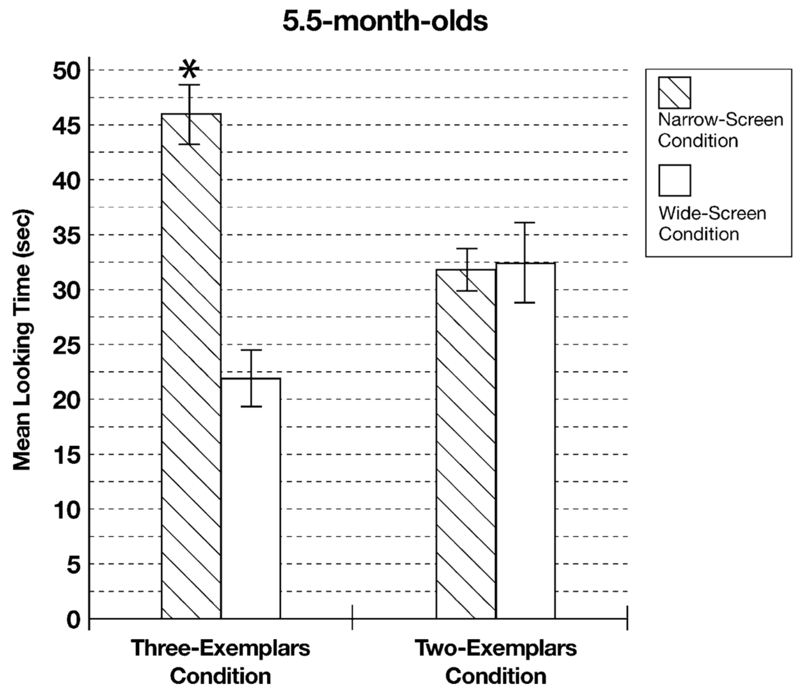

Fig. 8.
Mean looking times (and standard errors) of the infants in Experiment 4 to the test events.

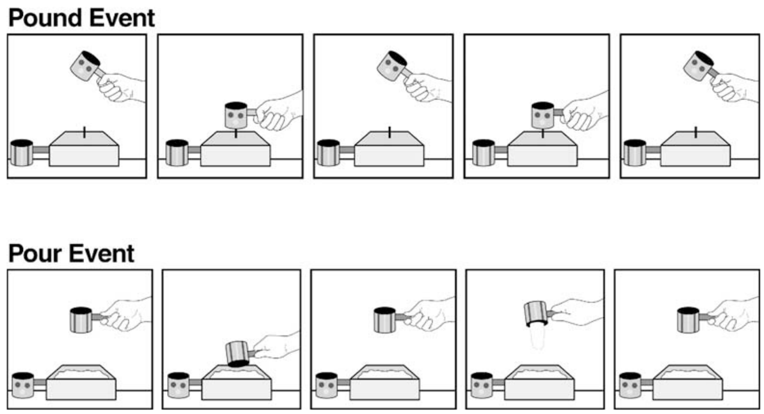

Fig. 9.
Schematic drawing of the pound and pour pretest events of the simultaneous-presentation condition of Experiment 5.

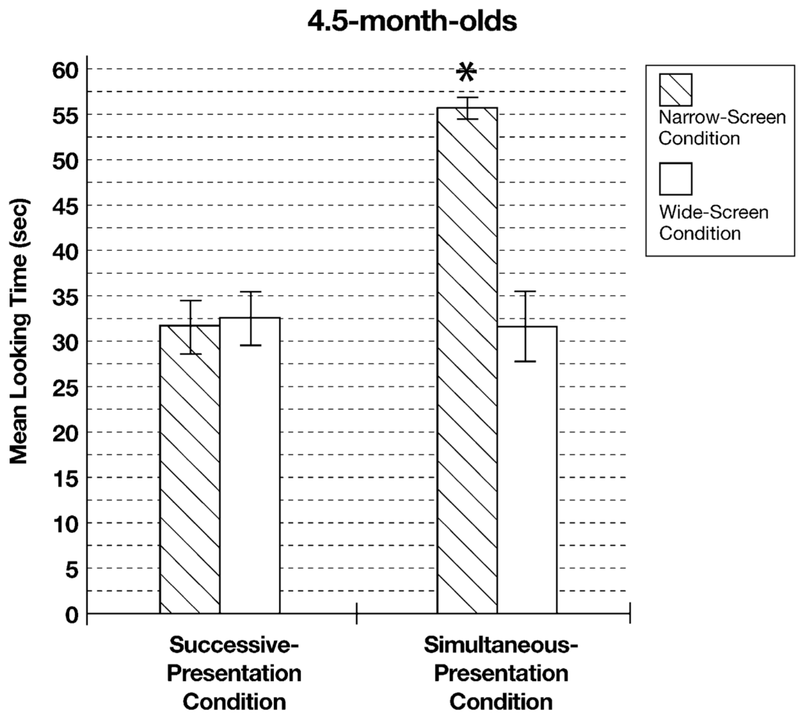

Fig. 10.
Mean looking times (and standard errors) of the infants in Experiment 5 to the test events.