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Priming Infants to Use Pattern Information in an Object Individuation Task: The Role of Comparison

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There is evidence that 4.5-month-olds do not always use surface pattern to individuate objects but that they can be primed to attend to pattern differences through select experiences. For example, if infants are first shown events in which the pattern of an object predicts its function (dotted containers pound and striped containers pour), they will attend to pattern differences in a subsequent individuation task. However, 4.5-month-olds must see multiple exemplars of the pound and pour events and view the dotted and striped containers together during the events. These results suggest that it is the formation of event categories, in which pattern is linked to object function, that supports pattern priming and that direct comparison of the exemplars facilitates the extraction of event categories. The present research investigated conditions that support the comparison process in 4.5-month-olds. The results revealed that the comparison process was initiated only when the dotted and striped containers were seen directly adjacent to each other; if the containers sat far apart, so that infants had to shift their gaze to compare them, event categories were not extracted. In addition, it was comparison of the two patterned containers, and not comparison of the two function events, that was critical to the formation of event categories. These results join a growing body of research indicating the importance of comparison to category formation in infants and reveal the impact of categorization and comparison processes on object individuation in infancy.

Keywords: infants, object individuation, categorization, comparison

There is now a great deal of evidence that young infants perceive objects as solid bounded entities that persist when perceptual contact is lost and hold expectations for the way that objects should move and interact (Baillargeon, 1998; Baillargeon, Li, Ng, & Yuan, 2009; Spelke, 1990; Spelke & Kinzler, 2007). At the same time, infants' representational capacities change significantly during the first year. Initially, representations contain only very basic information about objects and their interactions (e.g., information about force, mechanics, spatiotemporal coordinates) and become more elaborate as infants attend to a wider range of information (Baillargeon et al., 2009; Mandler, 1992; Spelke & Kinzler, 2007). One intriguing finding is that there is sometimes a discrepancy between infants' capacity to perceive information and the extent to which they use this information when interpreting physical events (Baillargeon, 1998; Needham & Ormsbee, 2003; Mandler, 2008; Wang & Baillargeon, 2008; Wilcox, Schweinle, & Chapa, 2003; Wilcox & Woods, 2009). Discrepancies are typically observed earlier in the first year and, with time and experience, become resolved. For example, by at least 3.5 months infants can detect differences in object height, but it is not until about 12 months that infants attend to height information when interpreting uncovering events (Wang, Baillargeon, & Paterson, 2005). Likewise, by at least 4.5 months infants can detect differences in pattern and color, but it is not until 7.5 and 11.5 months, respectively, that infants use these differences to individuate objects (Wilcox, 1999; Wilcox, Woods, Chapa, & McCurry, 2007). Researchers studying other cognitive abilities and domains of knowledge have also observed discrepancies between the kind of information that infants can perceive and that which they use (e.g., Quinn & Eimas, 1997), suggesting that this phenomenon is not specific to object representation and physical reasoning.

What mechanisms or processes facilitate infants' use of perceptually available but unemployed information? What leads infants to include a wider range of information in their object representations and then use this information when interpreting physical events? One experimental approach has been to identify experiences that alter the type of information to which infants attend (e.g., Baillargeon, 2004; Needham, 2000; Needham, Barrett, & Peterman, 2002; Wang & Baillargeon, 2005; Wilcox, Woods, Chapa, & McCurry, 2007). If we can identify experiences that increase infants' sensitivity to select sources of information and the conditions under which this information is transferred to new situations, we will gain insight into the processes by which learning occurs. For example, Wilcox and her colleagues (Wilcox & Chapa, 2004; Wilcox, Woods, & Chapa, 2008) have reported that infants younger than 7.5 months will attend to pattern information and infants younger than 11.5 months to color information in an

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individuation task if they are first given experiences that highlight the value of attending to these differences. In one experiment 5.5-month-olds were shown events in which the pattern of an object predicted the function in which the object would engage (i.e., dotted containers pounded a nail and striped containers poured salt). Next, infants' ability to individuate two different patterned objects, a dotted ball and a striped ball, was tested in an individuation task. The 5.5-month-olds who saw the pound–pour pretest events used pattern differences as the basis for individuating the objects (i.e., a dotted and a striped ball) in the test events. In order for priming to occur, however, two conditions must be met. First, infants must see multiple exemplars of the pattern–function priming event. That is, infants must see three pairs of pound–pour events with three different pairs of dotted and striped containers. If infants see three pairs of pound–pour events with the same pair of containers, priming is not supported. Second, the actions in which the containers engage must be functionally relevant. If the containers engage in distinct motions (i.e., dotted containers move up and down and striped containers tip forward and backward) but these actions are not functionally relevant (i.e., causally related to a function outcome), priming is not supported. These findings suggest that viewing the pound–pour events with multiple exemplars leads infants to form event categories in which the pattern of an object is linked to its function, an aspect of the physical world to which infants are already sensitive (Booth, 2000, 2006; Booth & Waxman, 2002; Pieraut-Le Bonniec, 1985; Freeman, Lloyd, & Sinha, 1980). It is this process that increases infants' sensitivity to pattern differences, which is then carried forward into the subsequent individuation task.

It is important to clarify here what is meant by *event categories*. Some researchers (Gentner & Kurtz, 2005) have suggested that there are two kinds of categories: entity and relational. Entity categories are formed on the basis of similarities between category members or shared object properties. For example, all members of the spoon category share similar features (e.g., a rigid concave surface with a rigid extension). The properties relevant to entity categories can be perceptual (e.g., shape and size) or conceptual (e.g., nonobvious properties that specify object kind). Most categorization research with infants has focused on the development of entity categories. In contrast, relational categories are formed on the basis of a common relational structure between entities and their attributes rather than on the characteristics of the entities alone. For example, when a concave surface with a rigid extension (i.e., a spoon) is used as a tool by an agent to perform a specific function (i.e., stir pudding), it is the relation between the object, the features of the object, and the function that the object performs that forms the relational structure. When children see several events that share similar relational structures, a relational category is formed (see Gentner & Kurtz, 2005, for a more detailed analysis of entity and relational categories). In the priming experiments of Wilcox and Chapa (2004), it was the identification of the relation between surface pattern and object function that was critical to pattern priming. Containers that were dotted in pattern were used to pound a nail, and those that were striped in pattern were used to scoop and pour salt. Once the relation between pattern information and object function was identified, infants extracted event categories (striped containers pound and dotted containers scoop/pour). The extraction of these categories led to heightened sensitivity to pattern difference, and this carried over to the test trials. (It is possible that heightened sensitivity to function differences was also obtained, but this has yet to be tested.) Follow-up studies have demonstrated that the same kinds of factors that influence the formation of entity categories also influence the formation of relational event categories (Wilcox & Chapa, 2004; Wilcox et al., 2008). For example, multiple and varied exemplars of the feature–function relation are required in order for an event category to be extracted. In addition, the more varied the exemplars seen in the feature–function events, the more abstract the event representation that is formed.

Most relevant to the present research is the facilitative effect of comparison on feature priming. There is evidence that 4.5-month-olds, like 5.5-month-olds, can be primed to attend to pattern differences by viewing the pound–pour events, but only when they are given the opportunity to see the two containers together during the events (Wilcox & Chapa, 2004). To illustrate, during the pound event with the dotted container, the striped container sat nearby; during the pour event with the striped container, the dotted container sat nearby (in previous experiments only the container involved in the event was present on the stage). This finding is consistent with a large body of research demonstrating the importance of the comparison process. In children and adults, comparison facilitates learning across a wide range of tasks and domains of knowledge, including analogical reasoning, categorization, and spatial mapping (adults: Gentner, 1983; Gentner & Gunn, 2001; Gentner & Medina, 1998; Markman & Gentner, 1997, 2000; children: Gentner & Namy, 1999, 2004, 2006; Gentner & Toupin, 1986; Klibanoff & Waxman, 2000; Kotovsky & Gentner, 1996; Waxman & Klibanoff, 2000). In infants, comparison has been identified as important to the formation of entity categories and word learning (Namy, Smith, & Gershkoff-Stowe, 1997; Needham, 2001; Needham, Dueker, & Lockhead, 2005; Oakes & Ribar, 2005; Quinn, 1987).

How does the comparison process work? According to Gentner and her colleagues, the comparison process is one of structural alignment (Gentner, 1983; Gentner & Markman, 1994; Gentner & Medina, 1998; Markman & Gentner, 1997, 2000). Event representations are structured: They contain entities, attributes, function, and a relational structure between two or more of these. Comparison of two events involves the alignment of their representational structures. The closer the events match in their structure (i.e., the more commonalities that exist between the structures), the easier it is to align the structures and identify differences. The abstraction of similarities and differences between instances allows perceivers to establish rules and expectations that guide the way in which they apply knowledge and interpret new situations.

In the previous research of Wilcox and her colleagues, there were a number of commonalities that existed between the pound and the pour event: Both events involved containers (entities) that were identical in appearance except for their surface pattern (attributes) and engaged in causal and meaningful actions (function). In addition, there was a relation between object attributes and object function (dotted containers pounded and striped containers poured). According to the structural alignment approach, the 4.5-month-olds benefitted from viewing the containers together during the pretest events because it highlighted the fact that the two containers had different surface patterns and made obvious that surface pattern was directly related to the function in which the container engaged. Once infants were able to align the two events and extract the predictive validity of pattern information, they demonstrated sensitivity to pattern information in the subsequent individuation task. The purpose of the present studies is to provide converging evidence for the facilitative effect of comparison on the priming process and to identify conditions in which comparison is most effective. For example, will comparison of other components of the priming event besides the containers support priming? What exactly are infants comparing (e.g., the two patterns, the two functions, or both) during the pretest events? The end goal is to better understand the processes that contribute to increased sensitivity to pattern differences in an object individuation task and, as a result, the mechanisms that support changing object knowledge.

Experiment 1A

Experiment 1A investigated the extent to which comparison of event components other than the containers themselves, such as information about the functions in which the containers would engage, supports pattern priming. A procedure similar to that of Wilcox and Chapa (2004) was used except that, rather than see the pound and pour events on alternating pretest trials, infants saw the pound and pour events alternating within a pretest trial (see Figure 1 and Figure 2). This allowed for both function boxes (the pound-box and the pour-box) to be in view and directly adjacent throughout each pretest trial. In one condition, the container currently engaged in a function, and the other container was present during the pretest trials (direct comparison condition). In the other condition, only the container currently engaged in a function was in view; the other container was hidden (no-comparison condition). Hence, in both conditions reminders of the objects' functions (i.e., the pound-box and the pour-box) were always in view, but only the infants in the direct comparison condition saw the dotted and the striped container at the same time. The question was whether direct comparison of the function boxes, in the absence of direct comparison of the containers, would support pattern priming.

The pound–pour events were followed by the narrow-screen individuation task of Wilcox and Baillargeon (1998a, 1998b). Infants saw a dotted ball and a striped ball emerge successively to opposite sides of a wide or a narrow screen (see Figure 3). If infants were to use the pattern difference to individuate the balls, and recognize that both balls can fit behind the wide but not the narrow screen at the same time, they would show prolonged looking to the narrow-screen test event. Hence, longer looking to the narrow- than to the wide-screen test event could be taken as evidence that the infants individuated the objects involved in the event.

Method

Participants. Participants were 40 healthy full-term infants, 20 boys (M = 4 months, 18 days; range = 3 months, 25 days to 5 months, 2 days). A priori power analyses indicated that 40 infants were sufficient to obtain power greater than .99 at an effect size (delta) equal to 1.0. Parents reported their infant's race/ethnicity as Caucasian (n = 31), Hispanic (n = 4), Black (n = 2), or of mixed race (n = 3). Additional infants were tested but eliminated from analysis because of crying (n = 2) and procedural problems (n = 7). Two infants contributed only one test trial because of fussiness. Ten infants were pseudorandomly assigned to each of four groups formed by crossing condition (direct comparison or noncomparison) and test event (narrow screen or wide screen). In this and subsequent experiments, the infants' names were obtained from birth announcements and commercially pro-

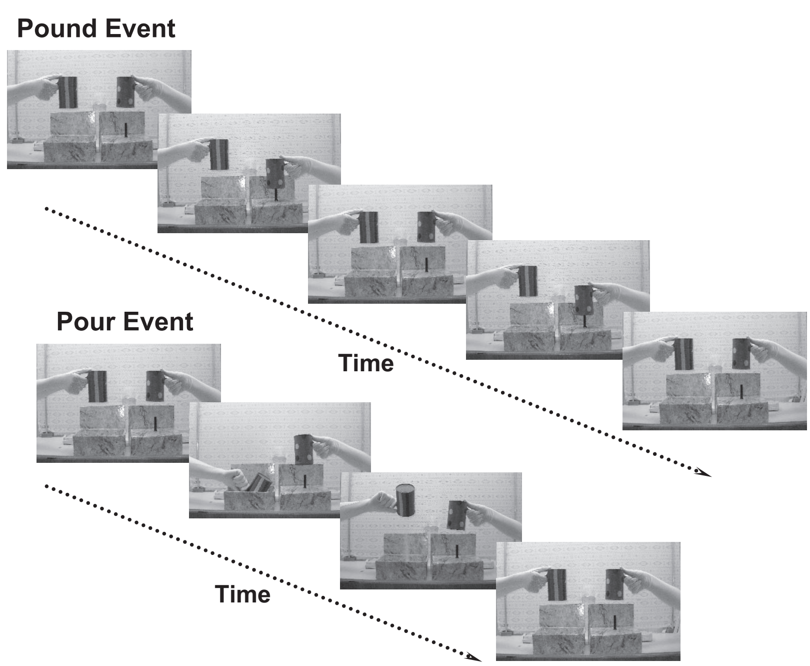

Figure 1. The pretest events of Experiment 1A: the pound and pour events of the comparison condition. In each condition, the two events were seen alternating within each of three trials.

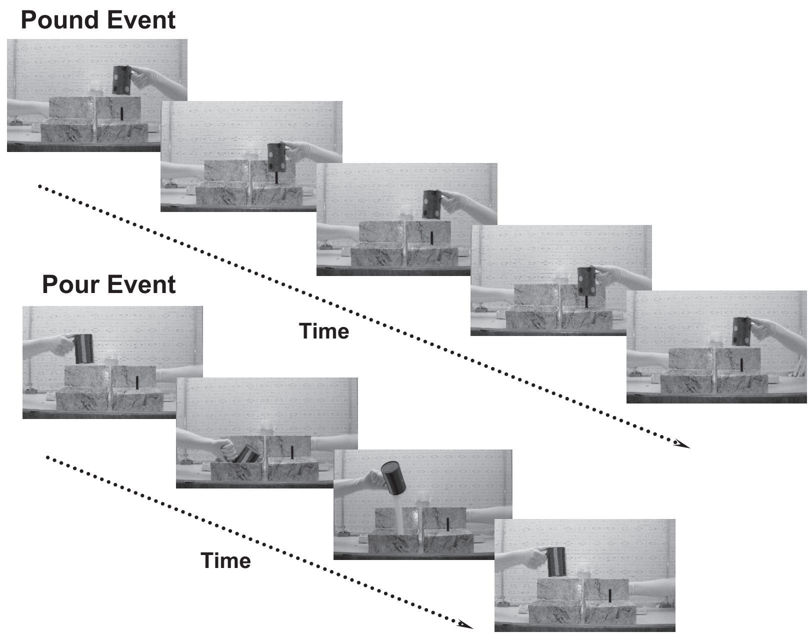

Figure 2. The pretest events of Experiment 1A: the pound and pour events of the no-comparison condition. In each condition, the two events were seen alternating within each of three trials.

duced lists. Parents were contacted by letters and follow-up phone calls and were offered $5 for their participation.

Apparatus. The apparatus and stimuli were identical to that of Wilcox and Chapa (2004, Experiments 4 and 5). The apparatus was a wooden cubicle 213 cm high, 105 cm wide, and 43.5 cm deep. The floor and walls were cream colored or covered with low-contrast patterned contact paper. A muslin shade was lowered over an opening in the front wall of the apparatus at the end of each trial. A platform 1.5 cm tall, 60 cm wide, and 19 cm deep sat at the back wall, centered between the side walls. Two muslin-covered

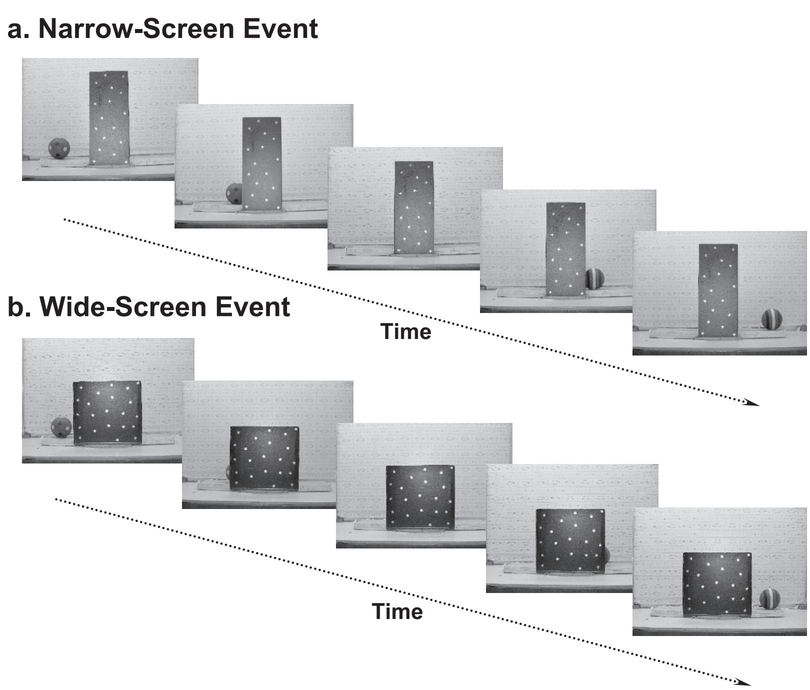

Figure 3. The (a) narrow-screen and (b) wide-screen test events of Experiments 1A, 1B, and 1C. Each infant saw one of the two test events.

frames, 214 cm high and 68 cm wide, stood at an angle to either side of the apparatus, concealing two observers and isolating infants from the experiment room. In addition to room lighting, a 20-W fluorescent bulb was affixed inside each of the apparatus walls.

Three pairs of containers were used in the pretest events (see Figure 4). The containers of each pair were identical in appearance except for their pattern: One had yellow, red, and blue dots, and the other had yellow, red, and blue stripes. The function boxes (pound-box and pour-box) were 8 cm high, 19.5 cm wide, and 15.75 cm deep, with one open side and covered with green marbled contact paper. The pound-box was placed with open side down and had a 5.5-cm-tall black wooden peg protruding upward at the center. The pour-box was placed with open side up and was filled with salt (it did not have a peg). The function boxes sat 2.5 cm apart, pound-box on the right, directly in front of the platform and centered on the stage. Attached to the back of each function box was a cardboard barrier covered in the same contact paper. In the direct comparison condition, the container not in use was held stationary in front of the cardboard barrier; in the no-comparison condition, the container not in use was held stationary behind the cardboard barrier.

The balls used in the familiarization and test events were 10.25 cm in diameter, green, and had either the dotted or the striped pattern seen on the containers. Each ball was mounted on a clear Plexiglas base with a 6-cm-long handle that protruded through a gap between the back wall and floor of the apparatus; the opening was concealed with cream-colored fringe. Using the Plexiglas handle, an experimenter, concealed behind the apparatus, moved the balls below the platform.

Embedded in the center of the platform was a metal bilevel shelf with an upper and lower level 16 cm apart; each shelf was 12.7 cm wide and 13 cm deep. The bilevel, which allowed both objects to be behind the screen simultaneously, was lifted and lowered by means of a handle protruding through an opening in the apparatus's back wall, allowing the balls to emerge successively from behind the screen.

The familiarization screen consisted of yellow matte board (30 × 41 cm). The narrow (15.5 × 41 cm) and wide (30 × 33 cm) test screens were made from dark blue matte board decorated with small gold stars. The screens were mounted on a wooden stand centered in front of the platform.

Events. Each experimental session included pretest, familiarization, and test events. Two experimenters (E1 and E2) produced the events. Each wore a white glove on his or her right hand and followed a precise script, using a metronome for timing. The numbers in parentheses indicate the time (in s) taken to produce the actions described.

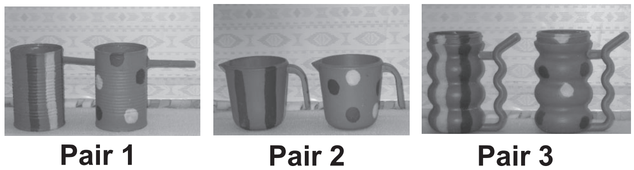

Figure 4. The three pairs of dotted and striped containers used in the three pretest trials of both conditions.

Direct comparison narrow-screen condition. Infants saw three pretest events. At the start of the first pretest event, E1 held the dotted can by its handle, approximately 17.5 cm above the pound-box, open side up; E2 held the striped can in a similar manner above the pour-box. First, E1 used the dotted can to pound the peg two times (2 s), raised the can to the starting position (2 s), pounded the peg two times (2 s), and raised the can to the starting position (2 s), where it was held stationary (2 s). Next, E2 lowered the striped can to scoop salt from the box (2 s), raised the can to its starting position (2 s), tilted the can to pour out the salt (2 s), and then raised the can to its starting position (2 s), where it was held stationary (2 s). This 20-s sequence was repeated continuously until the end of the trial. The second and third pretest trials were identical to the first, except that the dotted and striped cans were replaced with the dotted and striped measuring cups and squiggly cups, respectively.

Following the pretest events, infants saw a *familiarization event*. At the start of each familiarization trial, the dotted ball sat at the left end of the platform. The familiarization screen stood upright and centered in front of the platform, and the striped ball sat on the lower shelf of the bilevel. Once the infant looked at the ball for 1 s, the ball paused (1 s) and then moved behind the screen until it rested on the upper shelf of the bilevel (2 s). The bilevel was then lifted (1 s) so that the striped ball on the lower shelf could emerge from behind the screen and move to the right end of the platform (2 s). This 6-s sequence was then seen in reverse. The balls moved at a rate of 12 cm per s. The 12-s event sequence just described was repeated continuously until the trial ended.

Next, 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.

Direct comparison wide-screen condition. The pretest, familiarization, and test events were identical to those in the direct-comparison narrow-screen condition with one exception: In the test event the narrow screen was replaced with the wide screen.

No-comparison narrow- and wide-screen conditions. The pretest, familiarization, and test events were identical to those of the direct comparison narrow- and wide-screen conditions with one exception. During the pretest events the container currently not in use (i.e., the striped container during the pound event and the dotted container during the pour event) was held *behind* rather than in front of the cardboard barrier attached to the back of the box.

Procedure. Infants 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 all trials.

Infants saw the three pretest events appropriate for their condition on three successive trials. Each trial ended when the infant (a) looked away for 2 consecutive s after having looked for at least 20 cumulative s or (b) looked for 60 cumulative s without looking away for 2 consecutive s. 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 s after having looked for at least 12 cumulative s or (b) looked for 60 cumulative s without looking away for 2 consecutive s. Infants saw the test event appropriate for their condition on two successive trials. Test trial termination criteria were the same as for the familiarization trials except that minimum looking time was 6 (rather than 12) s. Two observers, who were naïve to the experimental conditions,[1] monitored infants' looking behavior online through peepholes in the frames to either side of the apparatus. Each observer held a game pad connected to a Dell computer and depressed a button when the infant attended to the event. Interobserver agreement for this and the following experiments averaged 92%.

Preliminary analyses were conducted for each experiment reported to test for within-subject effects of trial and between-subject effects of sex. No reliable differences emerged, so the data are collapsed across these two factors.

Results

Pretest trials. Infants' mean looking times (averaged across the three pretest trials) were analyzed by means of an analysis of variance (ANOVA) with comparison type (direct comparison or no comparison) and test event (narrow screen or wide screen) as between-subjects factors. The main effect of comparison type was significant, $F(1, 36) = 7.22$, $p = .011$, $\eta_p^2 = 0.17$. The infants in the no-comparison condition ($M = 58.7$, $SD = 2.9$) looked longer during the pretest events than did those in the direct comparison condition ($M = 53.8$, $SD = 7.7$). The main effect of test event, $F(1, 36) < 1$, and the Comparison Type × Test Event interaction, $F(1, 36) = 1.26$, $p = .269$, were not significant. Mean pretest looking times were as follows: direct comparison narrow screen ($M = 52.1$, $SD = 8.8$) and wide screen ($M = 55.5$, $SD = 6.3$) and no comparison narrow screen ($M = 59.1$, $SD = 1.6$) and wide screen ($M = 58.4$, $SD = 3.8$).

Familiarization trials. Infants' mean looking times (averaged across the six familiarization trials) were analyzed in the same manner as the pretest trials. The main effects of comparison type and test event, and the interaction between these two factors, were not significant, all Fs$(1, 36) < 1$, indicating that the infants in the four conditions did not differ reliably in their mean looking times: direct comparison narrow screen ($M = 35.0$, $SD = 11.5$) and wide screen ($M = 39.6$, $SD = 11.1$) and no comparison narrow screen ($M = 36.4$, $SD = 12.7$) and wide screen ($M = 33.9$, $SD = 13.3$).

Test trials. Infants' mean looking times during the two test trials were averaged and are displayed in Figure 5. Given that the pretest data yielded a significant main effect of comparison type, the test data were subjected to an analysis of covariance (ANCOVA) with comparison type and test event as factors and pretest looking times as a covariate. The purpose of this analysis was to compute test results after adjusting for group differences in pretest looking times. The main effects of comparison type, $F(1, 35) < 1$, and test event, $F(1, 35) = 1.39$, $p = .246$, were not significant. The interaction between comparison type and test event was significant, $F(1, 35) = 4.30$, $p = .045$, $\eta_p^2 = .11$.[2] The infants in the direct comparison condition looked longer at the narrow-screen ($M = 34.3$, $SD = 13.0$) than at the wide-screen ($M = 21.2$, $SD = 11.4$) test event, Cohen's $d = 1.07$. A Mann–Whitney nonparametric test confirmed that the distributions of these two groups were reliably different, $U = 20$, $p = .023$ (two tailed). In contrast, the infants in the no-comparison condition looked about equally at the narrow-screen ($M = 24.7$, $SD = 9.7$) and wide-screen ($M = 28.3$, $SD = 13.3$) test events, Cohen's $d = 0.31$.

One might be concerned that the infants in the direct comparison condition were more likely to experience pattern priming simply because they had more time to view the dotted and striped containers during the pretest trials. Recall that in the direct comparison condition both containers were visible during the entire pretest trial but in the no-comparison condition each container was in view for only half the trial. More time to encode the containers might lead to better memory for the features of the objects. Although possible, there are reasons to doubt this interpretation. First, there is evidence from color priming experiments with 9-month-olds that modifications to encoding time do not significantly influence priming performance (Wilcox et al., 2008). Second, there is evidence that age-related changes in memory cannot easily account for infants' propensity to form more abstract categories when they are allowed to directly compare exemplars (Oakes & Ribar, 2005). Third, the infant memory literature suggests that the memory demands associated with seeing the exemplars successively, as opposed to simultaneously, is well within infants' memory capabilities (e.g., Rovee-Collier, 1997, 1999). However, because this evidence is suggestive rather than definitive, this question will be revisited in the General Discussion section.

Additional results. Color–function studies conducted with 9.5-month-olds have revealed that the actions in which the objects engage in the pretest events must be functionally relevant in order for color priming to occur (Wilcox & Chapa, 2004). Although we assume that the same holds true for pattern priming with younger infants, to test this assumption we assessed 20 additional 4.5-month-olds, 10 male (M = 4 months, 21 days; range = 4 months, 1 day–4 months, 15 days) using the procedure of the direct comparison condition of Experiment 1with one main difference. In the pretest events the dotted and striped containers performed their motions to the right and left sides of the pound-box and pour-box, respectively so that the containers never came in contact with the nail (pound event) or the salt (pour event). To equate the auditory components of the motion pound–pour events to those of the original pound–pour events as much as possible, we inserted a metal ball into the dotted containers; 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. Likewise, a Plexiglas box filled with tiny beads was inserted into the striped 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 salt in the pouring events.

The infants in the two conditions looked about equally during the pretest, narrow-screen $M = 59.9$, $SD = 0.3$ and wide-screen $M = 58.1$, $SD = 3.3$, $t(1, 18) = 1.64$, $p = .118$, familiarization,

[1] In Experiments 1A–1C infants saw the dotted ball–striped ball test event with a narrow or a wide screen. Observers were asked to guess, at the end of each test session whether the infant saw a narrow- or a wide-screen test event. Of the 100 infants tested, 91 primary observers recorded a guess. Of the 91 guesses recorded, 47 were correct, a performance not significantly different from chance (cumulative binomial probability, $p > .05$).

[2] The test data from Experiment 1A were also analyzed without pretest trials as a covariate, and the same pattern of results was obtained. The main effects of comparison type, $F(1, 36) < 1$, and test event, $F(1, 36) = 1.55$, $p = .221$, were not significant. The interaction between comparison type and test event was significant, $F(1, 36) = 4.83$, $p = .034$, $\eta_p^2 = .12$.

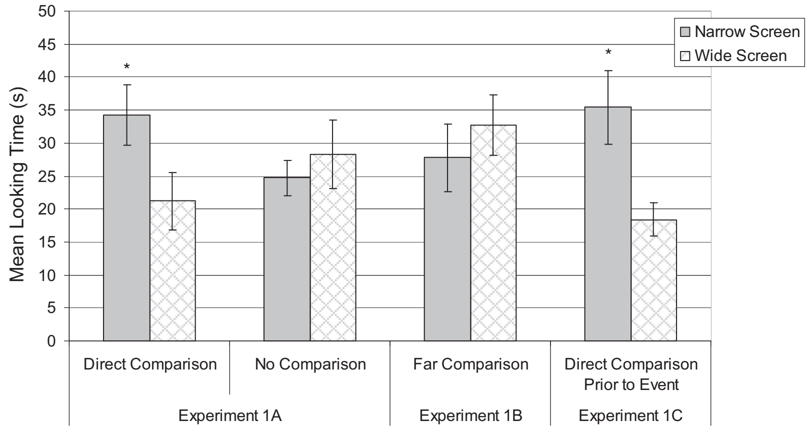

Figure 5. Infants' mean looking times during the narrow-screen and wide-screen test events of Experiments 1A, 1B, and 1C. Error bars signify standard error. Asterisks indicate a significant difference in infants' mean looking time to the narrow- and wide-screen events ($p > .05$).

narrow-screen $M = 34.0$, $SD = 7.0$ and wide-screen $M = 37.0$, $SD = 11.4$, $t(1, 18) < 1$, and test, narrow-screen $M = 31.3$, $SD = 12.2$ and wide-screen $M = 34.0$, $SD = 12.2$, $t(1, 18) < 1$ events. These test results indicate that the infants failed to use the pattern difference to individuate the test objects when the actions seen in the pretest events were not functionally relevant. The test data were also analyzed together with the test data of the direct comparison condition of Experiment 1A using an ANOVA with condition (direct comparison or motion direct comparison) and test event (narrow or wide screen) as between-subjects factors. The Condition × Test Event interaction was significant, $F(1, 36) = 4.18$, $p = .048$, $\eta_p^2 = 0.10$, indicating that the infants in the motion direct comparison condition responded differently to the test events than did the infants in the direct comparison condition.

Discussion

When the two containers were presented together during each pretest trial, so that the infants could compare the dotted container used in the pound event with the striped container used in the pour event, the infants successively used the pattern difference in the subsequent individuation task. In contrast, when the infants saw the containers one at a time during the pretest trials, so that the container used in the pound event was never seen with the container used in the pour event, the infants failed to individuate the dotted and striped balls in the individuation task. This outcome is consistent with that of Wilcox and Chapa (2004), who also found that 4.5-month-olds required direct comparison of exemplars in order to benefit from a pattern priming procedure. What is novel about these findings is that during the pretest trials the pound-box and the pour-box, which sat directly next to each other, were always visible, providing continuous cues that the containers engaged in two distinct functions. Yet these function cues, alone, did not support pattern priming.

Additional results revealed that the containers must engage in distinct functions in order for pattern priming to occur. When the containers were used to perform distinct actions (moving up and down next to the nail, or tilting forward and backward next to the salt), but the actions were not functionally relevant (the container did not pound the nail or scoop/pour salt), pattern priming was not supported. This outcome is consistent with other reports that feature-function priming is specific to object function and extends this to younger infants and pattern features. Why are infants particularly sensitive to function-events? Object function is deeply embedded in our everyday experiences with objects, and infants (as well as children and adults) find function-related events particularly salient. Infants and young children use function-related information to make inferences about what physical properties an object should possess, how it can be acted on, and the ontological category to which it belongs (Booth, 2000, 2006; Booth & Waxman, 2002; Freeman et al., 1980; Kemler Nelson, 1995, 1999; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Kemler Nelson, Russell, Duke, & Jones, 2000; Madole & Cohen, 1995; Pieraut-Le Bonniec, 1985). Furthermore, information about an object's function can facilitate learning new information about the object. Not only is function salient, it is a means by which infants can draw inferences about novel objects and acquire new information about already familiar objects (e.g., Baldwin, Markman, & Melartin, 1993; Booth & Waxman, 2002). Given this evidence, it is not surprising that function is an effective priming mechanism.

One question that these results raise, however, is whether the containers need to be directly adjacent during the function events in order for the comparison process to be engaged. There is evidence that young infants are more likely to detect relevant similarities and differences between objects and use this information to interpret physical events when the objects sit directly next to each other so that they can be easily compared (Baillargeon, 1998). Experiment 1B investigated the importance of spatial layout to the comparison process.

Experiment 1B

To test the extent to which the containers need to be directly adjacent during the function in order for pattern priming to be supported, the direct comparison condition of Experiment 1A was used with one modification: The pound and pour events were seen on the right and left sides of the apparatus, respectively. In order to view the dotted container and the pound-box, the infant had to look to the right of midline; to view the striped container and the pour-box, the infant had to look to the left of midline. Hence, the infants had ample opportunity to compare the two containers as they looked back and forth between the events, but direct comparison was not possible. The performance of the infants in Experiment 1B will be compared to that of the direct-comparison infants of Experiment 1A.

Method

Participants. Participants were 20 healthy full-term infants, 10 boys (M = 4 months, 23 days; range = 4 months, 0 days–5 months, 4 days). Two additional infants were tested but eliminated from analysis because of crying. Parents reported their infant's race/ethnicity as Caucasian (n = 18) or Hispanic (n = 2). Ten infants were pseudorandomly assigned to each of two groups: narrow screen or wide screen.

Apparatus, events, and procedure. The apparatus, events, and procedure were identical to those of Experiment 1A with one exception: The pound-box sat with its right edge 20 cm from the right wall of the apparatus, and the pour-box sat with its left edge 20 cm from the left edge of the apparatus, so that the events were separated by a large spatial gap.

Results

Pretest trials. Infants' mean looking times were analyzed together with those of the direct comparison condition of Experiment 1A using an ANOVA with comparison type (direct or far) and test event (narrow or wide screen) as between-subjects factors. The main effects of comparison type and the Comparison Type × Test Event interaction were not significant, both $F(1, 36)$s < 1, nor was the main effect of test event, $F(1, 36) = 2.27$, $p = .141$, $\eta_p^2 = .06$. Mean looking times in Experiment 1B were 51.4 s (SD = 11.5) in the narrow-screen condition and 56.3 s (SD = 7.3) in the wide-screen condition.

Familiarization trials. Infants' mean looking times were analyzed in the same manner as were the pretest trials. The main effects of test event and the Comparison Type × Test Event interaction were not significant, both $F(1, 36)$s < 1. The main effect of comparison type was significant, $F(1, 36) = 5.05$, $p = .031$, $\eta_p^2 = .12$. The infants in the direct comparison condition (M = 37.3, SD = 11.2) looked longer during the familiarization trials than did those in the far comparison condition (M = 30.0, SD = 9.0). Mean looking times in Experiment 1B were 29.7 s (SD = 9.8) in the narrow-screen condition and 30.2 s (SD = 8.7) in the wide-screen condition.

Test trials. Given that the familiarization data yielded a significant main effect of comparison type, infants' mean looking times to the test event (see Figure 5) were subjected to an ANCOVA. The factors were comparison type and test event, and the covariate was infants' mean familiarization looking times. The main effects of comparison type, $F(1, 35) = 2.25$, $p = .142$, and test event, $F(1, 35) = 1.82$, $p = .186$ were not significant. The interaction between comparison type and test event was significant, $F(1, 35) = 6.29$, $p = .017$, $\eta_p^2 = .16$.[3] Whereas the infants in the direct comparison condition looked reliably longer at the narrow-screen than at the wide-screen test event (see results of Experiment 1A for effect size and nonparametric statistics), the infants in the far comparison condition looked about equally at the narrow-screen (M = 27.8, SD = 14.6) and wide-screen (M = 32.7, SD = 14.1) test event, Cohen's d = 0.32.

Discussion

The infants in Experiment 1B (far comparison), unlike the infants in Experiment 1A (direct comparison), were not primed to use pattern differences in the individuation task. Having access to both the containers on the stage throughout the pretest trial did not lead infants to extract an event category linking pattern to function; infants needed to see the containers side by side. There are at least two possible explanations for this outcome. One possibility is that close spatial proximity of the containers and the function boxes made clear to infants that the two containers/functions were to be compared: When the containers were seen on opposite sides of the apparatus, the extent to which they were related was ambiguous. In other words, a close spatial relation leads infants to consider other relations between the containers. Another possibility is that the comparison process itself is made easier when the exemplars can be compared without moving the head or eyes. Shifting attention from one side of an apparatus to the other may disrupt the comparison process. Further research will be needed to distinguish between these two equally plausible possibilities.

Now that we have established that direct comparison of exemplars is required to support pattern priming, we turn to the question of what infants are comparing during this process. Recall that in Wilcox and Chapa (2004), directly comparing containers within a pound or pour event, but not viewing one container at a time, supported pattern priming. Experiment 1A revealed that direct comparison of the containers and the function boxes, but not direct comparison of the function boxes alone, supported pattern priming. These results demonstrate that direct comparison of the containers was necessary to support pattern priming but left ambiguous whether direct comparison of the containers was sufficient to support pattern priming. Do infants need access to information about object function during the comparison process in order to link surface pattern to object function?

Experiment 1C

To assess whether direct comparison of the patterned containers, in the absence of a function cue, is sufficient to support pattern priming, we altered the procedure of Experiment 1A so that the containers were seen together but not during a function event. This allowed infants to directly compare the container but did not allow comparison of both containers to a function box. If direct comparison of the two containers, in the absence of function cues, would be sufficient to support pattern priming then the infants in Experiment 1C, like the infants in the direct comparison condition of Experiment 1A, should evidence sensitivity to pattern differences in the individuation task.

[3] The test data from Experiment 1B were also analyzed without pretest trials as a covariate and the same pattern of results was obtained. The main effects of comparison type and test event were not significant, both $Fs(1, 36) < 1$. The interaction between comparison type and test event was significant, $F(1, 36) = 4.55$, $p < .04$, $\eta_p^2 = .11$.

Method

Participants. Participants were 20 healthy full-term infants, 9 boys (M = 4 months, 21 days; range = 4 months, 2 days to 5 months, 4 days). Three additional infants were tested but eliminated from analysis because of crying (n = 1), procedural error (n = 1), and observer difficulty (n = 1). Parents reported their infant's race/ethnicity as Caucasian (n = 18), Hispanic (n = 1), or Black (n = 1). Ten infants were pseudorandomly assigned to one of two groups: narrow screen or wide screen.

Apparatus, events, and procedure. The apparatus, events, and stimuli were identical to that of Experiment 1A except for the pretest events (see Figure 6). First, infants saw three pairs of pound–pour trials. Each trial was 30 s and consisted of only one event, pound or pour; that event was repeated until the end of the trial. Hence, the total time each event (pound or pour) was available for viewing was the same as for Experiment 1A (one half of each of three 60-s trials for a total of 90 s) and Experiment 1C (three of six 30-s trials for a total of 90 s). This procedure was similar to that of Wilcox and Chapa (2004) and was implemented to ease production of the events: Alternation of pound and pour events within a trial would require removal of one function box and insertion of the other function box every 10 s. Second, only one container and its corresponding function box was present in the apparatus at a time. Third, prior to each pair of pretest events, infants saw the containers of those events sitting 2.5 cm apart at the center of the stage. To summarize, infants saw three sets of three pretest trials, and each set contained a comparison, a pound trial, and a pour event.

Results

Pretest trials. Given procedural differences, mean pretest looking times in Experiment 1C could not be compared to those of Experiment 1A. Infants' looking times during Trials 1, 4, and 7 (comparison events) were averaged and analyzed using a one-way ANOVA. The main effect of test event was not significant, $F(1, 18) < 1$ (narrow screen M = 21.0, SD = 5.6 and wide-screen M = 18.8, SD = 6.6). Mean looking times during Trials 2, 5, and 8 (pound events) and Trials 3, 6, and 9 (pour events) were averaged and analyzed in the same manner, with no significant main effect of test event for either the pound trials, $F(1, 18) = 2.90$, $p = .106$ (narrow screen M = 29.0, SD = 1.8; wide-screen M = 26.0, SD = 5.2), or the pour trials, $F(1, 18) < 1$ (narrow screen M = 27.3, SD = 3.1; wide-screen M = 28.3, SD = 3.9). These data suggest that the infants found the pound and pour events equally interesting.

Familiarization trials. Infants' mean looking times were analyzed together with those of the direct comparison condition of Experiment 1A using an ANOVA with experiment (Experiment 1A or 1C) and test event (narrow- or wide-screen) as between-subjects factors. The main effects of experiment, $F(1, 36) = 1.09$, $p = .304$, and test event, $F(1, 36) < 1$, and the Experiment × Test Event interaction, $F(1, 36) < 1$, were not significant. Mean looking times in Experiment 1C were 33.5 s (SD = 11.2) in the narrow-screen condition and 33.2 s (SD = 14.4) in the wide-screen condition.

Test trials. Infant's mean looking times (see Figure 5) were analyzed in the same manner as in the familiarization trials. The

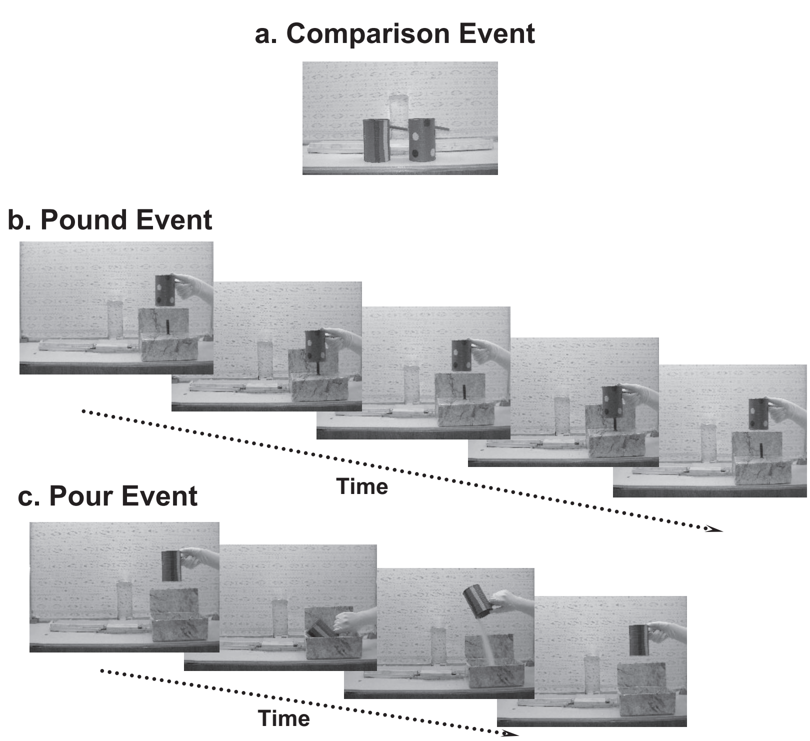

Figure 6. The (a) comparison, (b) pound, and (c) pour pretest events of Experiment 1C. The same three pairs of containers used in Experiments 1A and 1B were used in Experiment 1C. Infants saw three sets of comparison/pound/pour events.

main effect of test event was significant, $F(1, 36) = 12.73$, $p = .001$, $\eta_p^2 = .26$. The infants looked longer at the narrow- than at the wide-screen test event. The main effect of experiment and the Experiment × Test Event interaction, both $F(1, 36)\text{s} < 1$, were not significant. Infants' mean looking times in Experiment 1C were 35.4 s ($SD = 17.9$) in the narrow-screen condition and 18.4 s ($SD = 8.9$) in the wide-screen condition, Cohen's $d = 1.21$. A Mann–Whitney nonparametric test confirmed that the distributions of these two groups were reliably different, $U = 21.0$, $p = .029$ (two tailed).

Discussion

In Experiment 1C infants saw the dotted and striped containers side by side prior to each pair of pound and pour events but not during the pound and pour events. This manipulation supported pattern priming, revealing that infants did not need to directly compare the two containers within the context of the function event to identify the relation between pattern differences and object function: Direct comparison of the containers alone was sufficient. The results suggest that seeing the two containers together prior to the pound–pour event highlighted the pattern difference between the containers, allowing infants to readily map the pattern difference onto object function during the pound and pour events.

General Discussion

The present experiments investigated the conditions under which young infants extract the relation between surface pattern and object function during physical events and, as a result, show increased sensitivity to pattern information in a subsequent object individuation task. The results revealed that infants were primed to use pattern differences to individuate objects after first viewing an event in which the pattern of an object predicted the function in which it would engage (dotted containers pounded and striped containers poured). However, priming was observed only when the two patterned objects (dotted and striped containers) could be directly compared during the function events. When there was a spatial or temporal gap between the presentations of the two containers, pattern priming was not obtained. In addition, pattern priming was observed when simultaneous presentation of the two containers occurred prior to, rather than during, the function events. This outcome indicates that while direct comparison of the containers is critical to pattern priming, it does not need to occur within the context of the function events. Collectively, these results reveal specific conditions under which infants' sensitivity to pattern differences can be enhanced by viewing pattern-function events.

Comparison, Categorization, and Object Individuation

More generally, the present results highlight the interplay between comparison and categorization processes and demonstrate ways in which these processes can influence infants' capacity to individuate objects. First, these findings reveal the importance of comparison to the formation of categories in young infants and provide converging evidence for the proposal that comparison is a general learning mechanism. A growing number of developmental studies have identified the comparison process as critical to early learning (Gentner & Namy, 1999, 2004, 2006; Gentner & Toupin, 1986; Klibanoff & Waxman, 2000; Kotovsky & Gentner, 1996; Loewenstein & Gentner, 2001; Namy et al., 1997; Needham, 2001; Needham et al., 2005; Oakes & Ribar, 2005; Quinn, 1987; Waxman & Klibanoff, 2000). For example, Kotovsky and Gentner (1996) reported that when 4-year-olds are allowed to directly compare within-dimension visual stimuli (little–medium–big), they are more likely to identify the same relational pattern in another dimension of visual stimuli (light–shaded–dark) than when direct comparison is not allowed. Likewise, Gentner and Namy (1999) reported that 4-year-olds are more likely to extend labels given to target objects to new objects on the basis of conceptual similarities, compared with perceptual similarities, if they are first given the opportunity to directly compare the two target objects. These data suggest that direct comparison of the items in one set of stimuli leads young children to detect the common higher order relational structure within that set and then map that structure in another set of stimuli. Studies conducted with children, along with those conducted with adults (Gentner, 1983; Gentner & Gunn, 2001; Gentner & Medina, 1998; Markman & Gentner, 1997, 2000), demonstrate across a wide range of tasks and ages that comparison not only facilitates the identification of relational structures but also influences the way that new information is processed. The findings obtained in the current studies build on previous results by (a) revealing that comparison supports the formation of relational categories, just as it supports the formation of entity categories, (b) demonstrating that this learning mechanism is at play even in the early months of life, and (c) revealing that the outcome of these processes (comparison and categorization) can alter the type of information to which infants attend when tracking the identity of objects. More specifically, direct comparison of the dotted and striped containers allowed infants to extract the relation between surface pattern and object function during the pound–pour events, which then increased infants' sensitivity to pattern differences during the test events. This is a powerful mechanism for making sense of common but ambiguous sources of information and facilitates infants' use of that information in new situations.

Second, these results provide insight into how the comparison process works with infants and how this is similar, in many ways, to that of children and adults. One way infants and children/adults are similar is that comparison facilitates identification of similarities and differences and, as a result, aids structural alignment (Markman & Gentner, 1997). For example, when adults are asked to compare two visual scenes and rate how similar the scenes are to each other, they are more likely to identify the relational structures of the two scenes and the extent to which these structures map onto that of a third scene than when they are asked to simply rate the two scenes' aesthetic value (Markman & Gentner, 1993) That is, the process of directly comparing visual scenes increases the likelihood that adults extract the relational structures of the scenes and use this information to interpret other scenes. In the pound–pour experiments, instead of asking the infants to verbally compare the two containers involved in the events (which, of course, would not be an effective procedure), we initiated the comparison process by placing the containers directly next to each other. In this case, engaging in the comparison process highlighted the difference in surface pattern and facilitated structural alignment of the pound and pour events. Once the structures of the two function events were aligned and the relation between pattern and function was identified, the predictive value of pattern information became clear. This was carried forward into the test events allowing infants to individuate the objects on the basis of pattern differences.

Third, we return to the issue of the role that memory plays in the formation of event categories. Can infants' failure to form event categories when containers are seen successively rather than simultaneously be better explained by memory limitations than by comparison limitations? Perhaps in successive presentation conditions infants are unable to recall, as they view one event, which container they saw previously, making it impossible to link surface features to object function. Maybe infants simply need more time to view objects. In the discussion of Experiment 1A a number of reasons to doubt a memory explanation were provided (e.g., additional encoding time typically does not influence feature-function priming, and age-related changes in memory do not fully account for infants' ability to form more abstract categories). However, the outcome of Experiment 1B also addresses this question. Recall that in Experiment 1B both containers and their respective function-boxes were always in view, even though they did not sit directly adjacent. In this condition, the infants had unlimited access to both containers, relieving memory demands. Yet the infants still failed to link pattern differences to object function. This outcome supports the conclusion that seeing the containers side by side facilitates feature priming because it invites infants to attend to the similarities and differences between the two containers and then to form event categories on the basis of these differences, and not because infants have longer to encode the containers, enhancing memory for the appearance of the containers. This is not to say that memory demands never play a role in the comparison process, because one can imagine cases in which memory would play a role. What we are suggesting is that the priming results reported here are better attributed to facilitation of comparison than to facilitation of memory.

Final Comments

The pattern-function priming results join a growing body of literature demonstrating that infants can be led, through select experiences, to attend to information to which they typically do not attend to when interpreting physical events (Baillargeon, 2004; Needham, 2000; Needham et al., 2002; Wang & Baillargeon, 2005; Wilcox et al., 2007). For example, Needham (2000) documented manipulatory experiences that facilitate object segregation in 3.5-month-olds, Wang and Baillargeon (2005) identified experiences that facilitate 8-month-olds' use of height information when interpreting uncovering events, and Wilcox et al. (2007) reported multisensory experiences that can increase infants' sensitivity to color information in an object individuation task. Collectively, this body of research suggests that infants' object representations are not static but are affected, at least to some extent, by recent experiences. Identification of the kinds of experiences that can alter the type of information to which infants attend when forming object representations and that infants then bring to bear when interpreting events involving those objects reveals a great deal about the factors that influence the content of infants' object representations. The long-range goal of this research is to identify the conditions under which infants integrate new information into their object representations and then transfer this knowledge to other situations, the basis for which learning occurs more generally.

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