JOURNAL OF COGNITION AND DEVELOPMENT, *6*(3), 307–323

Object Individuation in 10-Month-Old Infants Using a Simplified Manual Search Method

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Several investigators find that infants fail to use property information to individuate objects until 12 months of age (e.g., Xu & Carey, 1996), although others find that infants successfully employ property information in the service of object individuation at 9.5 months (e.g., Wilcox & Baillargeon, 1998a). This study investigated methodological differences between 2 sets of studies that may help to resolve this apparent conflict. It was hypothesized that infants younger than 12 months rely heavily on spatiotemporal information and it overrides any conflicting property information. In 2 experiments, we used a simplified manual search procedure much like Wilcox and Baillargeon's (1998a) simplified looking time procedure by reducing the number of alternations of the objects. Results suggest that when the spatiotemporal evidence specifying a single object that changes properties is weaker, 10-month-old infants succeed in using property information for object individuation.

Object individuation is the process of establishing how many distinct objects are involved in an event. It is an important perceptual and cognitive ability because humans (as well as other animals) represent distinct objects and track them through time and space in many situations. For example, we reach into our cupboard for our coffee mug every morning, assuming that the same mug is there each day. If we open the cupboard and a mug with a different color appears in front of our eyes, we would be surprised since we don't think of cups as objects that can change color. Our next thought is, "Well, someone must have played a trick on me. It is a differ-

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ent mug." In language use, to know whether a proper name such as Joanne applies, we have to decide whether it is the same person who shows up in the office on Monday and Tuesday. The person's appearance may change dramatically on these two days but as long as we think it is the same individual, the name Joanne applies. Conversely, if Joanne shows up on Monday and Joanne's evil twin shows up on Tuesday, the name Joanne does not apply despite the fact that we cannot distinguish Joanne from her evil twin on the basis of appearance. To establish representations of distinct objects, human adults use several sources of information in the service of object individuation, including spatiotemporal information, property information, and kind information.

Spatiotemporal information includes information about location and motion. For example, objects travel on spatiotemporally connected paths—when spatiotemporal discontinuity is detected, adults conclude that there are two distinct objects. Property information refers to perceptual features of objects such as color, texture, and size (e.g., a red ball and a green ball seen on a different occasion are two distinct objects). Kind information refers to our knowledge about categories of objects (e.g., adults conclude that a book and a cup seen on different occasions are two distinct objects).

Abundant evidence suggests that young infants are able to use spatiotemporal information to individuate objects (Aguiar & Baillargeon, 1999; Spelke, Kestenbaum, Simons, & Wein, 1995; Wynn, 1992; Xu & Carey, 1996; among others). More controversial is the question of when infants begin to use property or kind information for object individuation. Xu and Carey (1996) presented 10- and 12-month-old infants with displays in which two objects (e.g., a ball and a cup) appeared alternately from behind opposite sides of an occluder. On the test trials, the occluder was removed to reveal either two objects (an expected outcome) or only one object (an unexpected outcome). If the infants had established representations of two distinct objects using property or kind information, they should look longer at the unexpected outcome of a single object. Twelve-month-olds, but not 10-month-olds, did so. In contrast, when spatiotemporal evidence was provided—if both objects were visible *simultaneously* for a few seconds—10-month-olds looked longer at the unexpected outcome of a single object. Xu and Carey suggested that it is not until about 12 months of age that infants are able to use property or kind information for object individuation.

Converging evidence comes from Van de Walle, Carey, and Prevor (2000). Instead of measuring looking time, these investigators employed a manual search procedure. In their studies, infants were presented with a box into which they could reach but could not see. Infants looked on as the experimenter removed and then replaced objects from the box. In one-object trials, the experimenter removed and replaced a single object multiple times. In two-object trials, the experimenter repeatedly removed and replaced two different objects in succession. The infants were then allowed to retrieve an object from the box. After they retrieved the object, it was taken away and the duration and number of subsequent reaches into the box were recorded. On one-object trials in which infants should expect the box to be empty, both 10- and 12-month-olds reached only cursorily. On two-object trials in which infants should have expected there to be a second object in the box, only 12-month-olds searched persistently for the missing object (which had been secretly removed). Again, when unambiguous spatiotemporal evidence of two objects was provided by showing both objects simultaneously, both 10- and 12-month-olds searched persistently for the missing object. Thus, evidence from two different methodologies suggests that the ability to use property–kind information to individuate objects emerges between 10 and 12 months of age (see also Wilcox & Baillargeon, 1998a, and Xu, 2003, for a review).

However, conflicting evidence comes from Wilcox and Baillargeon (1998a) using a modified looking time procedure with 9.5-month-old infants in an event-mapping task.[1] Instead of objects emerging and disappearing behind an occluder alternately, their objects traveled on single trajectories. Half the infants saw a box travel behind an occluder and a ball emerge from the other side (box–ball condition); the other half of the infants saw the same event except that a ball appeared on both sides of the occluder (ball–ball condition). The screen was then lowered to reveal nothing behind it. Wilcox and Baillargeon found that 9.5-month-old infants looked longer in the box–ball condition than in the ball–ball condition, suggesting that they were able to use property information to infer the presence of two objects (see also Wilcox & Schweinle, 2002).

There are at least three potentially meaningful methodological differences between these studies. First, both Xu and Carey (1996) and Van de Walle et al. (2000) used complex objects, such as trucks, cups, ducks, and bottles, although Wilcox and Baillargeon (1998a) used simple objects—a red ball and a blue box. Second, Xu and Carey and Van de Walle et al. presented infants with events in which the objects were seen to emerge alternately and repeatedly from a single location (e.g., duck, ball, duck, ball, duck, ball), although Wilcox and Baillargeon showed infants events in which the objects were seen to alternate only once (e.g., box, ball). A third difference, related to the second, is that Xu and Carey and Van de Walle et al. presented infants with objects (regardless of their identity) between 6 and 14 times. Wilcox and Baillargeon showed infants only two discreet appearances of objects.

[1]Wilcox and Baillargeon (1998b) and Wilcox (1999) reported two sets of event-monitoring experiments in which the occluder was never removed to reveal any objects to the infants. They interpreted their results as showing that even 4.5-month-old infants were able to use property information for object individuation. However, Xu, Carey, and Quint (in press) provided an alternative interpretation for these results, namely that the infants may have simply established a single object and the changing properties was the source of their longer looking times. This alternative interpretation was supported by a psychophysical experiment with adults. Here we will only discuss the event-mapping experiments.

Why might these differences be important? One possibility is that the relatively simple objects that Wilcox and Baillargeon (1998a) used reduced the information processing demands, and thus allowed these young infants to more easily compare the two objects and note their property differences. Recent evidence from Bonatti, Frot, Zangl, and Mehler (2002) suggested this is unlikely. These investigators used the same methodology as did Xu and Carey (1996) but instead of using complex objects, they presented 10-month-old infants with simple objects—a ball and a cylinder. They found that despite the simplicity of the objects, 10-month-old infants still failed to use property information for object individuation.

Another possibility, suggested by Xu (2003), is that *multiple alternations of objects* may provide the infants with evidence specifying a single object that changes properties while hidden. In both Xu and Carey (1996) and Van de Walle et al. (2000), the infants were shown two objects emerging alternately and repeatedly from the same spatial location, appearing in a back and forth, oscillating cycle (e.g., duck, ball, duck, ball, duck, ball). We propose that as objects repeatedly alternate and appear from a single location, infants are in fact provided more and more spatiotemporal information suggesting that the event involves one object, persisting through occlusion and changing properties as it does so. For 10-month-olds, who rely heavily on spatiotemporal information, the procedures employed by Xu and Carey and Van de Walle et al. may have led them to infer the presence of a single object despite the differences in perceptual properties. That is, strong spatiotemporal evidence specifying a single object changing properties may take precedence over conflicting property information specifying two distinct objects. In Wilcox and Baillargeon's (1998a) procedure, the infants were shown only one object in the initial phase of the trial. That object traveled once behind an occluder and (in the box–ball trials) was replaced only once by an object with different perceptual properties. Thus, infants in this task saw the objects alternate only one time. Perhaps this event provided young infants with weaker spatiotemporal evidence of a single object changing properties and that information was less likely to override conflicting property information.

If this interpretation is correct, we can consider the relationship among the three studies reviewed in the following way (Figure 1): Using a looking time measure and *multiple alternations of objects*, Xu and Carey (1996) found that 10-month-olds failed to use property information to individuate objects. Van de Walle et al. (2000), also using multiple alternations of objects, found similar results using a manual search measure. Wilcox and Baillargeon (1998a), using a looking time measure and *a single alternation of objects,* found 9-month-olds making use of property information. If it is the weaker spatiotemporal evidence of a single object provided by their procedure that allowed younger infants to succeed in using property information, a similar modification to the manual search paradigm should result in earlier success in that task as well.

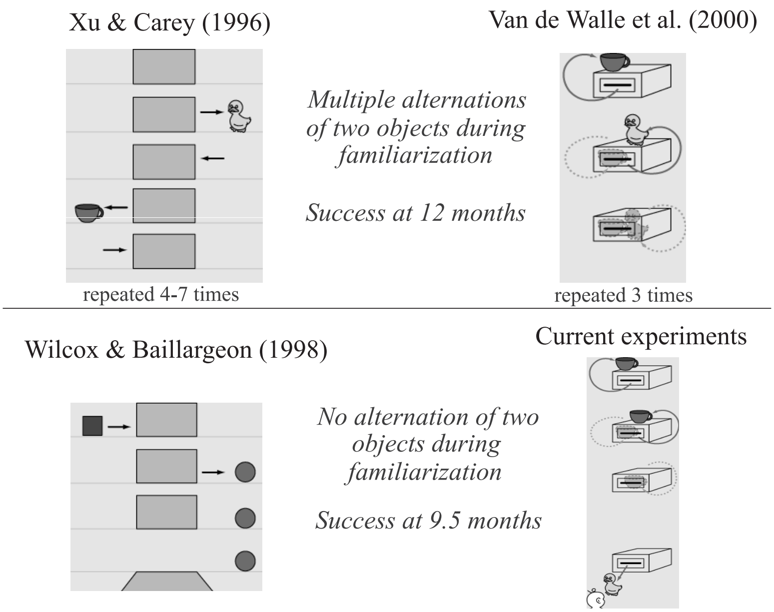

FIGURE 1 Procedures of Xu and Carey (1996), Van de Walle et al. (2000), Wilcox and Baillargeon (1998a), and the current experiments.

In Experiment 1, we sought to modify the manual search procedure used by Van de Walle et al. (2000) such that the spatiotemporal and property information available to the infants was similar to that provided by Wilcox and Baillargeon's (1998a) looking time procedure. To that end, we employed a manual search procedure based on a task devised by Tinkelpaugh (1928); LeCompte and Gratch (1972); and Uller, Leslie, and Carey (2000). Infants always saw only one object removed from and replaced in the box. The experimenter removed and replaced the object only two times before the infant was allowed to retrieve an object from the box. On half the trials, the object the infant retrieved was the same as the object she had been shown (no-switch [NS] trials). On the other half of trials, the object the infant retrieved was different from the object she had been shown (switch [S] trials, Figure 2). By showing the infant only one object in the initial phase of the test trials, thus reducing the number of alternations to one, we hoped to reduce potentially conflicting spatiotemporal and property information. If our manipulation succeeds in weakening the spatiotemporal information specifying one object that changes properties, 10-month-old infants might succeed in using property information to individuate objects in a manual search task. If the infants thought a second object is in the box on the S trials, they should persist in searching for it. Therefore the critical measure was whether infants searched longer on the S trials than on the NS tri-

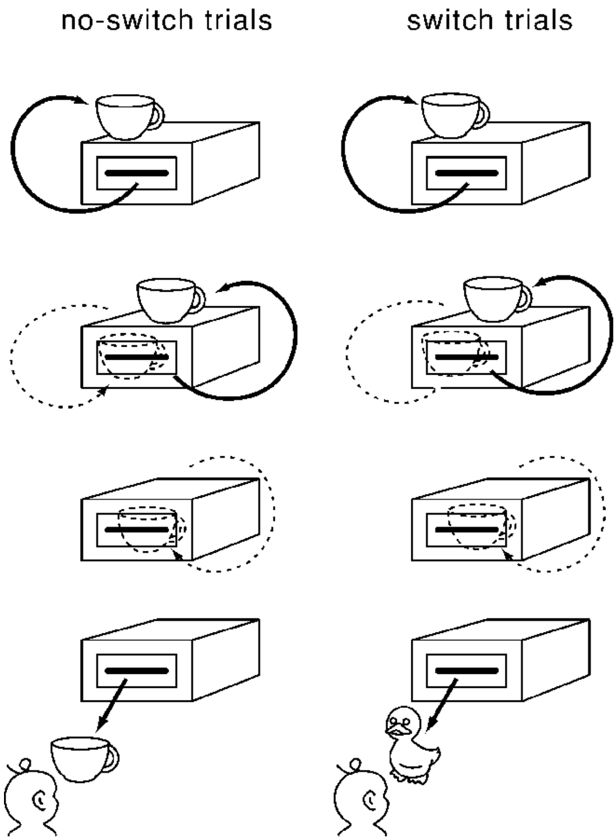

FIGURE 2 Schematic representation of the events in Experiment 1.

als after they had retrieved one object from the box and the box was now empty. We chose to test 10-month-old infants in this experiment rather than 9.5-month-olds as Wilcox and Baillargeon did because pilot testing suggested that the manual search procedure was too demanding for the younger infants.

The second goal of Experiment 1 was motivated by a finding in Xu and Carey (1996). In two experiments, they found that infants who understood two or more of the words for the objects (according to parental report) performed significantly better than the ones who understood none or one of the words. Although younger infants have been shown to succeed in simplified looking time tasks apparently without the support of object labels (Wilcox & Baillargeon, 1998a), ages of success in manual search tasks in general have been shown to be somewhat later (e.g., Baillargeon, Spelke, & Wasserman, 1985; Piaget, 1954). If simplified manual search tasks place heavier demands on infants than simplified looking time tasks, their performance might be improved by use of objects for which the infants already understand the words or by use of highly familiar objects. To investigate this possibility, in this study we collected parental reports on both word comprehension and object familiarity and the test objects for each infant were chosen accordingly.

In Experiment 2, we equated the total number of presentations of objects as well as the overall duration of the experiment, making it more comparable to the procedure used in Van de Walle et al. (2000). We sought a replication of the basic findings of Experiment 1.

EXPERIMENT 1

Method

Participants

Thirty full-term infants participated (*M* age = 10:4 [months:days], range = 9:16 to 10:15; roughly half girls, half boys). Most infants came from a middle-class, non-Hispanic White background with about 15% Asian, Hispanic, or African American infants. In addition, 6 infants were excluded for failure to reach into the box, 4 for experimenter error, 2 for fussiness, and 2 because English was not spoken in their homes.

All infants were recruited by obtaining public birth records and from a commercially available mailing list of parents in the greater Boston area. Families were contacted by letter followed by a telephone call. All infants received a token gift for their participation.

Materials and Apparatus

A box was constructed from .25-in. (.6 cm) thick foam core. It measured 13 in. (33 cm) deep, 10 in. (25.3 cm) wide, and 7 in. (17.8 cm) tall. The front surface of the box had an opening 6 in. (15.2 cm) wide and 3 in. (7.6 cm) tall, covered by white spandex material with a 6-in. (15.2 cm) horizontal slit. The back surface also had a 6 × 3 in. (15.2 cm × 7.6 cm) opening covered by a black felt flap.

Seventeen small, graspable objects were used in the study: 2 familiarization objects and 15 possible test objects from which 9 test objects were selected for each infant. The objects were similar in size but varied considerably in shape, texture, and color. The familiarization objects were a colorful plastic key ring and a pink kaleidoscope. The possible test objects were a yellow rubber duck, a green plastic train, a purple shoe, a shiny metallic pan, a toy bottle, a small book, a yellow car, a toy apple, a toy pear, a toy banana, a small orange cup, a fuzzy yellow ball, a toy baby, a brown plastic bear, and a yellow and green spoon. These were chosen in hopes of obtaining a suitable range of objects such that some (e.g., cup or shoe) would be familiar to most infants, although others (e.g., pear or train) would likely be unfamiliar to most infants.

All parents completed a language questionnaire. They were asked to indicate which object labels for the 15 possible test objects the infant understood. They were asked to provide a confidence rating on a scale from 1 (*low confidence*) to 5 (*high confidence*). Additionally, they were asked to rate how familiar their infant was with all 15 possible test objects by indicating how often their infant sees or plays with the object using the range of the following scale: 5 (*very often, more than 2 times per day*), 4 (*somewhat often, 1 to 2 times per day*), 3 (*occasionally, 3 to 4 times per week*), 2 (*not very often, 1 to 3 times per week*), 1 (*rarely, less than once per week*).

Nine test objects were chosen for each infant based on the parents' responses. Three objects were chosen that the infant had labels for and that were familiar to the infant (familiar–label triplet), three that the infant did not have labels for but were familiar (familiar–no label triplet), and three that the infant did not have labels for and were unfamiliar (unfamiliar–no label triplet). For each triplet, two of the objects were chosen at random for the S trial, the remaining object for the NS trial.

The infants sat in a high chair in front of a table. Parents were seated behind a curtain and watched the infant on a TV monitor. The experimenter sat at the table to the infant's right. All objects were kept behind the table, out of sight of the infant. One video camera focused on the front face of the box and recorded only the infant's reaching behavior. The video camera was connected to a TV monitor placed behind a curtain in the corner of the room. An observer watched the infant on the TV monitor. The video was recorded without sound and provided no information about what objects had been shown to the infant. Observers scoring the videotapes were unaware of the type and order of trials. A second video camera recorded the entire scene.

Design and Procedure

The experiment consisted of two phases: familiarization and test. The familiarization phase was followed by three pairs of test trials. Each pair of test trials consisted of one trial in which the object the infant retrieved was the same as the object the infant was shown (NS trials) and one trial in which the retrieved object was different from the object the infant was shown (S trials).

Familiarization phase. The purpose of the familiarization trials was to acquaint the infant with the box and the procedure. During these trials, the infant was given verbal encouragement to reach into the box and praise when objects were retrieved. The objects that the babies retrieved were always the same objects they were shown. The first familiarization object was always the key ring; the second was the kaleidoscope. On the first familiarization trial, the experimenter placed the box at the far end of the table, out of reach of the infant. She then reached through the slit, removed the key ring and placed it on top of the box. She verbally directed the infant's attention to the object three times ("See this? Look at that! Watch this!") before placing it back into the box. The object was left partially protruding through the slit to encourage reaching. The experimenter then slid the box toward the infant. If the infant retrieved the object, the experimenter cheered. The infant was allowed to play with the object for 5 sec, after which it was taken away. The box was left in front of the infant for another 5 sec. Then, regardless of the infant's reaching behavior, the experimenter picked up the box, shook it and said, "It's empty! There's nothing in there!" The box was then removed from the table. The second familiarization trial using the kaleidoscope was identical to the first except that the object was placed entirely inside the box before the box was presented to the infant.

Test phase. Each infant received six test trials, three NS trials, and three S trials presented in the order NS, S, S, NS, NS, S or S, NS, NS, S, S, NS. Order of test trials and order of object type (familiar–label, familiar–no label, unfamiliar–no label) were counterbalanced across participants.

For the NS trials, the experimenter placed one object (e.g., a cup) in the box out of the infant's view. The box was placed on the table out of reach of the infant. The experimenter reached into the box, removed the object, and placed it on top of the box. The infant's attention was verbally directed to the object three times ("See this? Look at that! Watch this!"). The object was then placed back in the box. It was removed again, placed on top of the box, and referenced three more times. The object was then placed back in the box and the box was moved forward to within reaching distance of the infant. When the infant retrieved the object (e.g., the cup), the box was moved out of reach of the infant, and she was allowed to play with the object for 5 sec. During that time the experimenter referenced the object three times, saying, "Look what you got! Look at that! See that?" The object was then taken away and placed out of the infant's view. The box was moved back within reach of the infant and left in place for 10 sec, during which the experimenter smiled at the infant. The duration of search into the box was recorded. The interval was timed by an observer hidden behind a screen watching the infant on a TV monitor. The observer began timing when the front edge of the box reached a mark 1.5 in. (3.8 cm) from the edge of the table. The observer signaled the end of the interval by squeaking a toy. At the observer's signal, the box was removed from the table.

For the S trials, the experimenter placed two objects in the box before placing it on the table. One object was placed near the front of the box (e.g., a cup); the experimenter held the other inside the box near the opening at the back (e.g., a toy duck), well out of reach of the infant. The procedure was identical to the NS trial except that after the last presentation, when the object was returned to the box for the final time, the experimenter surreptitiously removed the object she had been showing the infant through the back flap (e.g., the cup) and replaced it with the object she had been holding at the back of the box (e.g., the toy duck). The box now contained one object that was different from the one the infant had been familiarized with. The infant was then allowed to retrieve the object (the toy duck).

The critical question was not whether the infant reached into the box again after the first object had been retrieved but once the infant has reached into the box and found nothing, what would she do? If the infant did not expect an object to be in the box, we predicted that she would likely reach, find nothing, and withdraw (NS trials). If, however, the infant did expect to find an object, when she reached into the box and found nothing, we predicted that the infant would search the box more persistently (S trials). We predicted that if the weaker spatiotemporal information provided by our task allowed the infants to make use of property information to individuate the objects, they should search the box more persistently (longer duration) following the S trials than the NS trials.

Data Analysis

Although two dependent measures, number of reaches and duration of search, were coded, we will focus on the duration of search measure for the following reason. Once the infants in this study retrieved an object from the box, it was taken away and the box was left in place. In this situation, infants would often reach back into the box, as we have left them little else to do. Thus, by design, we expected infants to reach into the box whether they believed a second object should be inside or not. The critical question was not whether the infant reached into the box again but once the infant has reached into the box and found nothing, whether she would search persistently for a second object. Therefore, we believe that search duration provided a more interpretable measure of infants' expectations than number of reaches.

Duration of search was coded from the videotape. Following Van de Walle et al. (2000), an infant's behavior was considered to be a reach when the third knuckles of the hand were inside the slit in the spandex that covered the opening at the front of the box. Observers were unaware of the test trial order and the trial type. A second observer independently coded duration of search for half of the infants. The average interobserver reliability was 94% (range = 90%–97%).

Because the infant and the experimenter were face to face during the study, the concern arose that the experimenter may be unintentionally influencing the infant's behavior through her facial expression, body movements, or tone of voice. Therefore, two observers who were unaware of our hypotheses were asked to view videotapes of 30 randomly chosen test trials that showed both the experimenter and the infant. The portion of the screen that showed the box and the objects was covered. The observers were asked to guess whether the trial was a S trial or a NS trial. Results of a binomial test revealed that the observers were no more accurate than chance (53% correct, $p = .86$).

Results

Preliminary analyses found no effects of order of test trials or order of object type or trial pair (1–3). Subsequent analyses collapsed over these variables.

The average confidence rating for objects that parents indicated their infant knew a label for was 3.60. The average ratings of familiarity for objects used in the familiar–label trials; familiar–no label trials; and not familiar–no label were 4.60, 4.43, and 1.31, respectively.

A *t* test revealed that infants searched longer on the S trials ($M = 2.1$ sec, $SD = 2.0$) than on the NS trials ($M = 1.5$ sec, $SD = 1.9$), $t(29) = 2.15$, $p < .05$. Nonparametric analyses confirmed this finding. Twenty-two of the 30 infants searched longer following S trials than NS trials, Wilcoxon $z = 2.67$, $p < .01$.

Because the stimuli were chosen for each infant based on parental report, not all infants had a full complement of objects representing all three of the object types specified by our design. Seventeen infants had all three triplets. Of the remaining 13 infants, 5 did not have any objects that their parents rated as familiar–label. These 5 infants received two familiar–no label triplets and one unfamiliar–no label triplet. Seven infants had no objects that their parents rated as familiar–no label. Of these, 4 received two familiar–label triplets and one unfamiliar–no label triplet and 3 received one familiar–label triplet and two unfamiliar–no label triplets. One infant had no objects rated as unfamiliar–no label. This infant received two familiar–label triplets and one familiar–no label triplet.

Thus to investigate the possible effects of object type, analyses were conducted using data provided by the subset of 17 infants who had complete object type triplets. A 2 (trial type) × 3 (object type) analysis of variance was conducted, with both trial type and object type as within subjects variables. This analysis revealed no main effects and no significant interaction (all *F*s < 1).

Discussion

Infants searched the box reliably longer on the S trials than on the NS trials, suggesting that 10-month-old infants were able to use property information in an object individuation task when conflicting spatiotemporal information was weak. Additionally, whether or not the infants comprehended labels for the objects and whether the objects were familiar to them did not seem to affect patterns of search. Because only a subset of the infants had the full complement of the three object types, these results should be interpreted with caution.

However, an alternative explanation could account for these results. Van de Walle et al. (2000) showed infants two objects that alternately emerged from and returned to the box three times each for a total of three alternations (i.e., six presentations) of objects. In simplifying the manual search procedure, we reduced not only the number of times the objects alternated but also the number of times any object emerged from and returned to the box. As a result, the information processing demands of our task may have been less and the length of each trial was considerably shorter. Thus, perhaps it was not the number of alternations per se that accounted for the pattern of successes and failures, but simply the fact that we showed the initial object fewer times and shortened the procedure considerably. To address this possibility, in Experiment 2 the number of times the initial object emerged and returned to the box was increased from two to six as in Van de Walle et al. (2000).

It was our hope that this manipulation would not only serve to equate the number of object tokens seen by the infants but also the overall duration of the trials, thus making the study more comparable to Van de Walle et al. (2000). Because it was difficult to find three triplets based on object familiarity and word comprehension for almost half of the infants in Experiment 1, we elected not to include this manipulation in Experiment 2.

EXPERIMENT 2

Method

Participants

Thirty full-term infants participated (*M* age = 10:4, range = 9:16 to 10:15; roughly half girls, half boys). Participants were recruited as described in Experiment 1. Ethnicity and socioeconomic status of these participants was comparable to those in Experiment 1. In addition, 9 infants were excluded for failure to reach during test trials, 1 for failure to retrieve initial objects, and 2 for fussiness.

Materials and Apparatus

The apparatus was identical to that described in Experiment 1. The materials were a subset of those used in Experiment 1. As before, the familiarization objects were the key ring and the kaleidoscope. The test objects were the duck, the shoe, the bear, the cup, the book, and the car. Each infant was shown all six test objects.

Design and Procedure

The familiarization phase of Experiment 2 was identical to that of Experiment 1. The test phase of Experiment 2 differed from Experiment 1 in the following ways. First, each initial object was removed from and placed back in the box six times rather than two. Second, because the length of the test trials was increased, the test phase was shortened to two pairs of test trials. As in Experiment 1, both pairs of test trials consisted of one trial in which the object the infant retrieved was the same as the object the infant was shown (NS trials), and one trial in which the retrieved object was different from the object the infant was shown (S trials). Test trials were presented in the order NS, S, S, NS or S, NS, NS, S. The order of the test trials and the order of the objects were counterbalanced across participants. Additionally, across participants, each object was as likely to appear in a S trial as in a NS trial.

Coding was carried out as in Experiment 1. The observer was unaware of the type and order of the test trials. A second observer independently coded duration of search for half of the infants. The average interobserver reliability was 92% (range 89% to 95%).

Results

Preliminary analyses found no effects of order of test trials or trial pair (1 or 2). A *t* test revealed that infants searched longer on the S trials (M = *2.2 sec,* SD = 2.1) than the NS trials (M = 1.3 sec, SD =1.8), $t(29) = 2.23$, $p < .05$. Nonparametric analyses confirm the main effect of trial type. Twenty-one of the 30 infants searched longer following S trials than NS trials, Wilcoxon $z = 2.47$, $p < .05$.

Discussion

Experiment 2 replicated the basic findings of Experiment 1. Even when the number of presentations of objects and the overall duration of the trial were increased, 10-month-old infants succeeded in using property information for object individuation. We suggest that the number of alternations of objects may have been an important factor in understanding the pattern of successes and failures in these tasks.

GENERAL DISCUSSION

This research attempts to understand some conflicting results in the literature on object individuation in infancy with a new, simplified manual search method. Using a looking time measure, and *multiple alternations of objects*, Xu and Carey (1996) found that infants younger than 12 months failed to individuate objects on the basis of property differences. Using a manual search measure, and *multiple alternations of objects*, Van de Walle et al. (2000) also found that infants younger than 12 months failed to use property information to individuate objects. In contrast, Wilcox and Baillargeon (1998a) used a looking time measure but presented infants with a simplified event in which objects traveled on trajectories with *a single alternation*. They found that 9.5-month-olds successfully made use of property differences to individuate objects. This study yielded similar results at 10 months with a manual search task in which infants were presented with *a single alternation of the objects*. Thus the number of alternations of object may be an important factor in predicting infants' successes and failures in these tasks. Future studies may provide an even stronger test of this idea by manipulating the number of alternations within a single experiment, perhaps including one, two, three, or more alternations.

It is important to note that number of alternations is *not* analogous to Wilcox and Baillargeon's (1998a) reversals. Reversals refer to changes in the direction of motion of a single object either behind the occluder or in full view of the infant. Wilcox and Baillargeon found that the addition of a single reversal to their event mapping procedure (modified box–ball condition of Exp. 8) compromised 9-month-old infants' ability to individuate the objects. In terms of reversals, the current procedure includes three. Nevertheless, 10-month-olds succeeded in this task. Further research is needed to reconcile these findings.

We suggest that the procedures employed by Xu and Carey (1996) and Van de Walle et al (2000) presented infants with conflicting information: spatiotemporal information specifying a single object that changes properties, and property information specifying two objects. For the younger infants this conflict was resolved in favor of the spatiotemporal information. That is, 10-month-old infants were persuaded by the spatiotemporal information to conclude that the event involved only one object that changes properties. When positive spatiotemporal evidence of a single object changing properties is reduced or eliminated, as it was in our study and in Wilcox and Baillargeon (1998a), infants are able to correctly infer the number of objects involved in these events using property information at an earlier age. Taking together all four sets of studies, a developmental picture emerges. At around 10 months of age, infants have a fragile ability to use property information for object individuation but strong spatiotemporal evidence can override property information. By 12 months, infants have a much more robust ability to use property information for object individuation, even when spatiotemporal information provides conflicting evidence.

These experiments also explored a new methodology for studying object individuation in infancy. Instead of a looking time measure, we used a simplified manual search measure. Infants were trained to reach into a box to retrieve objects. During the familiarization phase, a single object (e.g., a toy car) was pulled out of the box and replaced. On the test trials, the infant retrieved one object from inside the box—it was either the same object as the one she had seen before or a completely different object (e.g., a toy duck). This object was then taken away and the infant was left facing the box. Not surprisingly the infant reached into the box again, since she had no object to play with. The box was in fact empty—any additional objects had been removed surreptitiously through a back flap. The infant found nothing inside the box. What did she do at this point? The methodology rests on the assumption that if the infant had used property information to individuate objects, she will search more persistently (i.e., longer duration) for a second object if the first object she had retrieved was different from the one she had been shown during familiarization than if the first object she had retrieved was the same as the one she had been shown during familiarization. Because the box was empty during the critical second search, the infant did not receive any feedback. It was up to the infant how long she continued to search the box.

One might argue for the following alternative interpretation of longer search times on the S trials: Perhaps the infants were aroused on retrieving a different object. The arousal led them to search longer inside the box.[2] Some indirect evidence from 12-month-old infants suggests that this is an unlikely explanation. Xu, Cote, and Baker (in press) presented infants with a box similar to the one we used in the present studies. The experimenter looked into the box and used one or two words to label its content (e.g., “Look, a fep! Look, a zav!”). The results showed that infants searched longer for a second object after hearing two words than after hearing one word. The objects were not shown to the infants during the labeling phase, so it was not possible to argue that the infants’ longer search time on two-word trials was the result of arousal after retrieving a different object on the first try.

As in Van de Walle et al.’s (2000) studies, we found that despite the high demands of the manual search procedure, 10-month-old infants succeeded in our task, just as 9.5-month-olds succeeded in the simplified looking time task of Wilcox and Baillargeon (1998a). Unlike some previous studies that found earlier success with looking time measures than with manual search measures (e.g., Baillargeon, Spelke, & Wasserman, 1985; Piaget, 1954), we found convergence of the two methodologies in these studies. Further research is needed to fully understand both the convergence and the divergence between looking time and manual search measures.

Van de Walle et al. (2000) and Xu and Carey (1996) found that by 12 months, infants were able to use property or kind information to override strong spatiotemporal information in a complex object individuation task. Both Wilcox and Baillargeon (1998a) and the experiments reported here found that at around 10 months simplifying the experimental procedures can facilitate the use of property information. Are there other sources of information that could help these younger infants succeed? Using the same complex object individuation task as Xu and Carey (1996), Xu (2002) found that 9-month-old infants succeeded when given two distinct labels for the objects. Perhaps labeling can come to the rescue when infants are overwhelmed by the strong spatiotemporal information. One possibility is that two distinct labels suggest to the infants that two distinct kinds of objects are behind the occluder. In addition, Bonatti et al. (2002) found that when given a very salient kind contrast between a human doll head and a toy dog head, 10-month-old

[2] We thank an anonymous reviewer for this suggestion.

infants succeeded. Thus when object kind distinctions are conveyed by distinct labels, or when presented with kind distinctions that are already functional (e.g., human vs. nonhuman), infants can override strong spatiotemporal information in favor of kind information.

Lastly, how do we understand these results in the broader context of object individuation and object tracking? Several researchers have proposed that an object-tracking system develops first in infants, then a kind-based system of object individuation develops later (Carey & Xu, 2001; Xu, 2003, in press). Furthermore, the object-tracking system has been identified with the mechanism of object-based attention in adults (e.g., object files, Kahneman, Treisman, & Gibbs, 1992; or FINSTs, Trick & Pylyshyn, 1994; Leslie, Xu, Tremoulet, & Scholl, 1998). The object-tracking system relies primarily on spatiotemporal information to establish representations of distinct objects and it can keep track of up to three or four of them simultaneously. The kind-based system, however, is fully conceptual and it relies on our representations of kinds. This system relies primarily on kind membership to establish representations of distinct objects. Property information is secondary in the kind-based system because it is kind-relative (e.g., a green ball and a red ball seen on two different occasions are two distinct objects whereas a green leaf and a red leaf seen on different days in the fall may not be).

What is the role of property information in the object-tracking system? According to the object-based attention and apparent motion literature, when spatiotemporal information is weak, property information plays a role in object individuation; when spatiotemporal information is strong, it overrides property information (see Nakayama, He, & Shimojo, 1995, for a review). Both Wilcox and Baillargeon (1998a) and this study addressed this issue directly with infants. The relative contribution of spatiotemporal and property information converges nicely with the findings in the object-based attention literature, providing further support for the claim that both research communities are studying the same underlying mechanism. These parallel findings will enable developmental psychologists to further characterize the representations we discover early in development.

ACKNOWLEDGMENTS

This research was supported by NSF Grant (BCS-9910729) to F. Xu.

We thank Judy Hall, Joanne Miller, Cristina Sorrentino, Elizabeth Spelke, and two anonymous reviewers for helpful discussion or comments on earlier versions of the manuscript. We also thank members of the Northeastern University and University of British Columbia Infant Cognition Laboratories for their help in data collection and coding. We are grateful to all the parents and infants who participated in our studies.

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