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Infants' ability to use object kind information for object individuation

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Abstract

The present studies investigate infants reliance on object kind information in solving the problem of object individuation. Two experiments explored whether adults, 10- and 12-month-old infants could use their knowledge of ducks and cars to individuate an ambiguous array consisting of a toy duck perched on a toy car into two objects. A third experiment investigated whether 10-month-old infants could use their knowledge of cups and shoes to individuate an array consisting of a cup perched on a shoe into two objects. Ten-month-old infants failed to use object kind information alone to resolve the ambiguity with both pairs of objects. In contrast, infants this age succeeded in using spatiotemporal information to segment the array into two objects, i.e. they succeeded if shown that the duck moved independently relative to the car, or the cup relative to the shoe. Twelve-month-old infants, as well as adults, succeeded at object individuation on the basis of object kind information alone. These findings shed light on the developmental course of object individuation and provide converging evidence for the Object-first Hypothesis [Xu, F., Carey, S., 1996; Xu, F., 1997b]. Early on, infants may represent only one concept that provides criteria for individuation, namely *physical object*; kind concepts such as *duck*, *car*, *cup*, and *shoe* may be acquired later in the first year of life. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

Perceiving the world in terms of distinct three-dimensional objects is one of our most fundamental cognitive capacities. The study of object perception may be divided into two enterprises: explaining object recognition (i.e. recognizing a given object as a member of a known kind) and explaining object individuation (i.e. representing a given visual scene in terms of distinct objects). In addition, the question of the relations between object recognition and object individuation arises. For example, according to Marr (1982), prior to both individuation and recognition the visual system constructs a representation of continuous surfaces. He speculated that it is only after we recognize objects of particular kinds that we are able to parse the layout into individual objects. Similarly, there is a philosophical tradition which holds that it is in principle impossible to individuate objects without knowing what kinds the objects belong to (Geach, 1957; Gupta, 1980; Wiggins, 1980; Hirsch, 1992). Our knowledge of the kinds of things there are in the world certainly helps us establish representations of the distinct objects in a visual scene; our knowledge of ducks and cars, for example, leads to a representation of two objects rather than one when a toy duck sits on top of a toy car with no clear boundary between them.

Although kind information is most definitely useful in object individuation, it is not always necessary. Several other types of knowledge play a role, the most fundamental of which is spatiotemporal information. Physical objects are bounded, coherent wholes which maintain their integrity as they move through space on spatiotemporally continuous paths (Spelke, 1990). Therefore, the most unambiguous evidence that an array contains two distinct objects is provided when they are simultaneously visible and separated in space, and indeed very young infants use such information to establish representations of distinct objects (Baillargeon and Graber, 1987; see also Xu and Carey, 1996 for a demonstration with older infants). Problems of object individuation arise under conditions where perceptual access to boundaries or to spatiotemporal continuity is lost. Two conditions that generate ambiguity are of particular interest to the present discussion: ambiguity arises in cases of shared boundaries, which is often called the problem of segregation or segmentation (Needham et al., 1997). Upon seeing a complex display such as what is shown in Fig. 1, one might ask: is that duck-on-a-car one object or two? Ambiguity also arises in cases of successive appearances of objects. When an object disappears from view followed by an object reappearing, the question of object individuation arises: is there one object or two involved in this event?

Under such ambiguous conditions, very young infants have been shown to exploit spatiotemporal information, if available, to individuate objects. Kellman and Spelke (1983) showed that infants as young as 4 months use patterns of relative motion of the visible parts of a stimulus to determine whether this stimulus consisted of one or two objects. Similarly, Spelke et al. (1995) found that 4-month-olds analyzed the path of motion according to the principle that objects trace spatiotemporally continuous paths to determine the number of objects involved in an ambiguous event. In their studies, two screens are separated in space and objects emerged from the left side of the left screen and returned behind it, followed by an identical object emer-

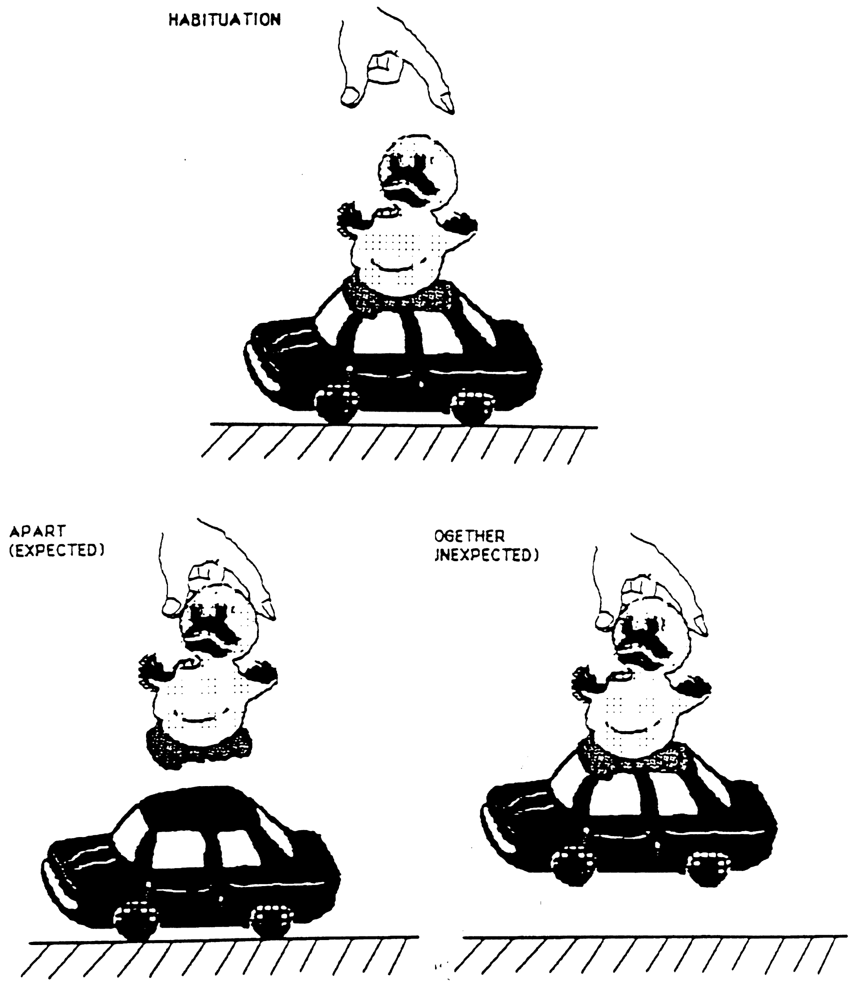

Fig. 1. Schematic representation of the habituation event and the outcomes of Experiment 1.

ging from the right side of the right screen and returned behind it. If no object appeared between the screens, infants inferred that two distinct objects must be involved in the event (Baillargeon and Graber, 1987; Xu and Carey, 1996).

Other types of physical knowledge also play a role in infants' object individuation. For example, Needham and Baillargeon (1997) showed that infants rely on support relations to resolve ambiguous displays. In one study, 8-month-old infants were shown a stationery display consisting of a box and a cylinder adjacent to each other. When the cylinder was suspended in mid-air (as opposed to lying on the floor of the apparatus) and appeared to be supported by the box, infants used the support relation to determine that they were parts of a single object: given that the cylinder was supported by one side of the box, it had to be connected to the box.

Similarly, Needham and Baillargeon (1997) showed that knowledge of the solidity principle (one object cannot pass through another) can be used by 8-month-olds to disambiguate displays. If a thin piece of metal can be inserted between two adjacent parts of a display, infants use that information to determine that there are two objects.

Static configurational information also plays a role in how infants individuate objects, although these effects are generally weaker than those that rely on physical or spatiotemporal information and are modulated by the complexities of the objects and experience with particular objects (see Needham et al., 1997 for a comprehensive review of these studies). In a series of studies, Needham (1998) found that when given a display of two featurally dissimilar objects adjacent to each other, a box and a hose, 7.5-month-old infants, but not 4.5- and 6.5-month-old infants, segmented the array into two objects. This result obtained when the hose was curved and the connecting surface between the two objects was only partially visible to the infants. Further, Needham showed that it was the complexity of the display which caused difficulties for the younger infants. When they simplified the display by using a straight hose and making the connection of the two objects completely visible to the infants, both 4.5- and 6.5-month-old infants parsed the array into two objects.

In another series of studies, Needham and Baillargeon (1998) demonstrated that infants can use yet another source of information in segmenting ambiguous displays into separate objects. Seeing part of an ambiguous display alone helps infants individuate adjacent objects. For example, after seeing the box standing alone on the stage for 5 s or after seeing the hose alone on the stage for 15 s, 4.5-month-old infants would parse the more complex array into two objects when shown the same box adjacent to the hose. Most strikingly, the effect of experience with the box helps the infants individuate objects even when the box was shown to the infants as young as 4.5 months in their homes 24 hours prior to the experiment.

It is clear from the literature reviewed above that young infants use many different strategies to solve the object individuation problem, and the resources they bring to bear are enhanced in various ways by learning during the first year of life. Whereas the studies by Needham and her colleagues certainly show sensitivity to perceptual differences among what might be parts of a single object or what might be two distinct objects (e.g. the blue, square part vs. the yellow, corrugated, curved part), none of the studies reviewed above addresses directly whether and when infants use object kind information in the context of object individuation.

By kind information, we mean information derived from classifying the stimuli according to antecedently represented categories in long-term memory. The distinction between kind representations (such as vehicle, animal, dog or chair) and property representations (such as blue, heavy, round or big) is not easy to draw – and it is an empirical question whether this distinction applies to infant object representations. If such a distinction can be sustained, kind representations may be seen to differ from property representations along some if not all of the following dimensions: kind representations are candidate meanings for count nouns which label object categories (Waxman and Markow, 1996); kind representations are stable, accessible, and long-term (Mandler, 1992); kind representations pick out functionally significant categories (Baldwin et al., 1993); and kind representations support category-based induction (Gelman and Markinan, 1986; Baldwin et al., 1993; Mandler and McDonough, 1996).

The objects used in the studies reviewed above were almost always fashioned into simple regular geometric shapes, and were not members of functional, namable kinds. Even Needham and Baillargeon's elegant box-hose studies did not actually use a box (it was a blue, rectangular object) or a hose (it was a yellow, corrugated, cylindrical object). There is considerable controversy concerning when infants first represent kind concepts. Visual habituation studies (e.g., Cohen and Younger, 1983; Quinn et al., 1993; Eimas and Quinn, 1994; Behl-Chadha, 1996) show that infants as young as 3 or 4 months habituate to discriminable stimuli from a single basic level or global basic category (e.g. dog or animal) and recover interest when shown stimuli of contrasting categories (e.g. cat or vehicle). However, these studies may reveal sensitivity to visual similarity alone, possibly abstracted during the habituation procedure itself. If infants have established long-term representations of kinds such as duck, car, cup, or ball, they should be able to use these representations to recognize objects as members of such kinds, and one would expect them to use these representations to help solve the object individuation problem.

Contrary to this expectation, Xu and Carey (1996) provide evidence that membership in kinds such as cup, bottle, ball, book, duck/animal, and truck/vehicle does not guide object individuation until the last few months of the first year. In these studies, ambiguity concerning the number of objects in the scene was introduced by showing the objects one at a time emerging from behind an occluder then returning behind the occluder. For example, in one of the experiments, 10-month-old infants were habituated to events in which a very familiar object, say a ball, appeared from behind a screen to one side of the stage and returned, then another very familiar object, say a bottle, appeared from behind the same screen to the other side of the stage and returned. The question was whether the infants would infer from the kind change that there must be two numerically distinct objects behind the screen. When the screen was removed, the infants were shown the expected outcome of two objects, namely a ball and a bottle, or the unexpected outcome of only one of the two objects, a ball or a bottle. Surprisingly, the 10-month-old infants did not look longer at the unexpected outcome: their pattern of looking did not differ from their baseline preference for two objects on baseline trials, as if there was not sufficient information to make a judgment. In contrast, when 10-month-old infants were given spatiotemporal information by simply showing them the two objects simultaneously for a brief 2 or 3 s at the beginning of the familiarization event, they looked longer at the unexpected outcome of one object when the screen was removed. It is not until 12 months of age that the majority of the infants in Xu and Carey's studies succeeded at using kind information alone to individuate objects.

Although various control experiments showed that Xu and Carey's method was sensitive, there are lingering doubts about the claim that infants do not use kind information in object individuation until about 12 months of age. To succeed in Xu and Carey's task, infants must be able to recall the representation of the first object, including details of its features, and compare this recalled representation with that of the currently visible second object in order to arrive at a representation of two distinct objects. None of the object segmentation studies reviewed above placed such episodic, short-term memory demands for recalling the details of a complex object and comparing them to those of a currently visible complex object.[1] Typically the stimuli were either completely and continuously visible or occluded only at the boundary between them. However, recent studies by Wilcox and Baillargeon (1998, in press) give some evidence that when a simpler paradigm is used to reduce information processing demand (event-monitoring as opposed to event-mapping, or event-mapping without the reversal of the trajectory), infants much younger than 10 months succeed in using the differences in object features to infer two distinct objects, under conditions of full occlusion of the first object when the second becomes visible. These objects, however, are simple shapes, not members of functionally relevant kinds.

The present study seeks to further test the hypothesis that infants do not use kind information for object individuation until about 12 months of age, using a paradigm that reduces the information processing load, in particular the short-term memory demands. Perhaps when the information processing demand is reduced in the experiment, infants would succeed earlier in using kind information for object individuation. We adapt the object segmentation paradigm of Spelke et al. (1993), using objects that clearly belong to namable kinds as opposed to nonsense shapes. Consider the following display: a toy duck with a flat bottom perching on the flat top of a toy car (Fig. 1). The duck has all the typical features of a duck, e.g. a duck's bill, eyes, distinct shape etc.; the car is a typical car with wheels, doors, metallic shine, etc. Adults perceive this display as unambiguous: we see a duck sitting on top of a car and we do not expect the two objects to be connected (this is confirmed in the preliminary experiment). Gestalt principles do not clearly specify the boundaries of the objects – cues such as violation of good continuation and good form are only weakly provided in such complex stimuli. While color changes between the duck and the car, it also changes between the car and the wheels, or the body of the car and its windows. Although the boundary between the duck and the car is marked by cues which specify distinct parts of an object, so too is the boundary between the top of the car and the rest of the car body, the car and its wheels, the head of the duck and the body of the duck, and so forth. Our knowledge about specific kinds of objects tells us that there are two objects in this array; perhaps because the perceptual evidence for distinct objects is ambiguous, we need to draw on our knowledge of object kind.

We use the duck-car display and ask whether 10-month-old infants can use object kind information to successfully individuate objects. The contrast between a toy duck and a toy car was chosen for several reasons. First, duck and car are basic level kinds, in Rosch and Mervis's sense (Rosch et al., 1976) and many have assumed that the infants' first kinds are basic level kinds (Macnamara, 1987). Second, others have argued that infants begin with more global kind distinctions, such as bird vs. vehicle,

[1]When the infants were asked to use their experience 24 h prior to the experiment in a object individuation task, as in Needham and Baillargeon (1998), a simple bright blue box with white squares was used. The memory demands in that study involves recognition, not models of objects in short-term memory.

or animal vs. vehicle (Mandler, 1992; Mervis, 1987), and duck and car also contrast as these levels. Finally, under the assumption that infants' first words for objects map onto kind concepts, the fact that 'duck' and 'car' are among children's early words (Fenson et al., 1991) suggests that they may be among the first kind concepts infants represent. Thus we are probing whether infants already represent kinds such as duck and car prior to learning words for them.

In Experiment 1, the infants are habituated to a display that consists of a duck perching on top of a car with a hand suspended right above the display without touching it. During the test trials, the hand grasps the head of the duck and lifts it up. In the expected outcome, the duck is lifted but the car stays in place. In the unexpected outcome, the car is lifted along with the duck as if they were parts of one complex object. If infants have segmented the display into two objects, they should look longer at the unexpected outcome in which the car is lifted along with the duck. It is important to note that both objects are in plain view throughout the experiment, so the infants will not have to actively retrieve their representation of the first object upon seeing the second in order to arrive at a representation of two distinct objects. If the findings of Xu and Carey (1996) reflect the inability of 10-month-old infants to use kind information for object individuation, they should fail to use the differences between the toy duck and the toy car to set up a representation of two distinct objects, whereas 12-month-old infants will succeed. Given Needham and Baillargeon's findings that experience with one part of an ambiguous stimulus helps in the object individuation problem, we include a condition in which infants are shown the duck alone, and allowed to handle it, as well as the car alone, and allowed to handle it, prior to habituation to the duck-on-the-car. If infants truly lack antecedent duck/animal or car/vehicle kind representations, then such a small amount of experience might not be sufficient to help them in the object individuation task. In contrast, if infants do represent these kinds antecedently, the representation should be primed and would be expected to facilitate individuating the duck from the car in the ambiguous duck-car display.

Before beginning the infant studies, a preliminary study tested adults' perception of the display as two distinct objects.

2. Preliminary experiment

The preliminary experiment sought to confirm that adults would use kind information to individuate the duck-car display as a duck and a car. After viewing the display for 5 s, adults were asked to judge how many objects there were and what would happen if the duck underwent motion. The training trials and the procedure were adapted from Spelke et al. (1993).

2.1. Method

2.1.1. Participants

Twelve adults (5 female and 7 male; mean age 25) from the university staff and student community participated in the study. None of the subjects had taken a course in perception or had any knowledge of the current research with infants.

2.2. Materials

A white coffee mug and a metal fork were used in the training trials. Two toys were used in the test trial: A bright yellow toy duck with an orange bill, feet, and eyes and a fluorescent green toy car with blue and yellow wheels and orange and blue decals. The toy duck was approximately $6 \times 6 \times 9$ cm in size and the toy car was $11 \times 5 \times 5$ cm.

2.3. Design and procedure

Subjects were seated about 66 cm from a puppet stage on which the display was placed. They were told that we were interested in adults' immediate impression of displays that we would present to infants. They would view each display for 5 s before answering questions. Each subject completed a three-page questionnaire. On one of the training trials, an empty coffee mug was placed on the stage. In the other training trial, the same mug containing a fork (only the upper half of the fork was visible to the subjects) were placed on the stage one at a time. Subjects were asked a series of questions. (1) 'How many objects do you see?' (2) 'How strong is your impression of one object on this scale, where 1 means a very weak impression of one object and 7 means a very strong impression of one object?' (3) 'Does this (pointing to the handle of the mug without touching it) appear to be connected to this (pointing to the bowl of the mug)?' For the second training trial, the bowl of the mug and the upper half of the fork were pointed to, respectively. (4) 'How strong is your impression of a connection on this scale?' (5) 'If I were to grasp this (pointing to the handle of the mug) and lift it from here to here (moving the finger about 10 cm above the initial position), what would happen to this (pointing to the bowl of the mug)?' For the second training trial, the upper half of the fork and the bowl of the mug were pointed to, respectively. (6) 'How strong is your impression that it will move?' (7) 'What object(s) do you see in this display?' Next the experimenter put on the duck-car display, and lowered the curtain. After viewing it for about 5 s, the same series of questions were asked. She pointed to the mid-point of the duck and the body of the car for the connectedness and motion questions. Otherwise the procedure was identical to the training trials.

2.4. Results and discussion

On the training trials, all subjects answered 'one object' when shown the empty mug and 'two objects' when shown the same mug containing a fork. They also reported that the handle of the mug was connected to the body of the mug whereas the fork was not. Subjects clearly understood what the task was about. When shown the duck-car display, all subjects reported ‘two objects’ when asked how many objects they saw. Subjects had a weak impression of one object; the mean rating for strength of impression of one object was 2.0, significantly different from the neutral rating of 4 ($t(11) = -9.381$, $P < 0.0001$). Eleven of the 12 subjects reported that the duck and the car were not connected; the remaining one said ‘maybe’. The mean rating of the strength of connection was 2.0, significantly different from the neutral rating of 4 ($t(11) = -9.381$, $P < 0.0001$). All subjects reported that the car would stay in place if the duck were grasped and lifted up. The mean rating of strength of impression of the car moving was 2.5, significantly different from the neutral rating of 4 ($t(11) = -3.924$, $P < 0.005$). All subjects reported that they saw ‘a toy/rubber duck and a toy car’.

Adults’ verbal ratings showed that the duck-car display evoked clear and strong impression of two objects. The participants judged that the two objects were not connected and when the duck was lifted the car would remain in place. There was also no ambiguity as to which kinds the objects belonged to. Having confirmed that adults interpreted the duck-car display as two distinct objects, we then turned to a test of the hypothesis that 12-month-old infants, but not 10-month-old infants, would use kind information to parse this ambiguous display into two objects.

3. Experiment 1

Experiment 1 assesses whether infants can use object kind information to individuate objects, as did the adults in the preliminary experiment. The experiment consisted of two phases: a habituation phase in which the infants saw the display of the duck perched on the car and a test phase in which the duck was lifted. In the apart (expected) outcome, only the duck was lifted; in the together (unexpected) outcome, the duck-car was lifted as a single object. Five experimental conditions were included: a baseline condition to assess the infants’ intrinsic preference for the apart or together outcome. The four experimental conditions contrasted types of information (static vs. movement, provided during the habituation phase) and whether the infants handled the objects prior to the experiment. In the movement condition, the duck was moved laterally off the car, thus providing the infants with spatiotemporal evidence for two distinct objects. In the static condition, the infants were shown only the static array of the duck perched on the car, as in the preliminary experiment. The other two experimental conditions were identical to these two except that the infants played with each of the two objects prior to the habituation phase. If 10-month-old infants do not have an antecedent representation of kinds such as duck and car, or cannot use such information in object individuation, then we would expect them to be able to exploit the spatiotemporal information provided in the movement condition to parse the display into two distinct objects, but not the object kind information provided in the static condition, whether or not they handled the objects prior to the habituation phase.

3.1. Method

3.1.1. Participants

A total of 100 full-term infants participated in the study (56 boys and 44 girls), ranging from 9 months 12 days to 10 months 20 days (mean age 10 months 3 days). Equal numbers of infants were randomly assigned to one of five conditions (mean ages were 10 months 2 days for the baseline condition, 10 months 6 days for the static-no handling condition, 10 months 0 days for the movement-no handling condition, 10 months 5 days for the static-handling condition, and 10 months 1 day for the movement-handling condition). Eleven additional infants were excluded from the sample due to fussiness (7), experimenter error (3), or equipment failure (1). All infants were recruited by obtaining their birth records from townhalls in the Greater Boston area and subsequently contacting their parents by mail and telephone. They were primarily middle class and non-Hispanic white, with about 10% of Asian, African–American, or Hispanic backgrounds. Participation was compensated by a token gift (a T-shirt, a bib, or a sippy cup) with an institute logo.

3.2. Materials

The same toy duck and toy car used in the preliminary experiment were used in this experiment. An informal survey with parents showed that both kinds of toys were familiar to 10-month-old infants.

3.3. Apparatus

The events were presented on a three-sided, 76 × 31 × 13 cm stage with a light blue top surface. A black curtain hung behind the stage to make the object and background contrast prominent and to conceal the movement of the experimenter. Another black curtain hung over the front part of the stage to conceal the video camera under the stage as well as to prevent the experimenter from seeing the infant's face. The actual display area measured 76 cm in width and 24 cm in height. Black curtains also concealed the observer, who sat to the right of the stage and monitored the infant's looking. The observer could not see what was presented on the stage and was blind to which condition the infant was in. A push button was connected to a microcomputer which recorded the looking times. White noise masked any sounds produced by the movements of the experimenter. The stage was lit from above and from the two sides; otherwise the room was dark. The infant sat in a high chair, about 66 cm from the stage, with eye level slightly above (about 5 cm) the floor of the stage. The parent sat next to the infant with his/her back toward the stage, and was instructed not to look at the displays, so as not to influence the infant's response, and not to attempt to draw the infant's attention in any way. The parent was instructed to 'smile and be natural' whenever the infant looked at him or her. A video camera was set up under the stage, focusing on the infant's face and recording the entire session. The videotape record provides no information about what is presented on the stage so an observer scoring from the videotapes will be completely blind to the condition or the order of the trials.

3.4. Design and procedure

Equal number of infants participated in five conditions: static-no handling condition, movement-no handling condition, static-handling condition, movement-handling condition, and baseline condition. After the infant and the parent were seated, the experimenter turned on the video camera. The experimenter then tapped or waved on the center top, the center bottom, and both ends of the stage to draw the infant's attention to the empty stage as well as to define the window of looking for the observer. During this calibration process and throughout the experiment, only the experimenter's hand was visible to the infant.

3.5. Static-no handling condition

3.5.1. Habituation phase

For each habituation trial, a black curtain was raised to cover the entire stage area from view. After a 3 s pause (the time required to change displays in the test trials), the curtain was lowered to show the toy duck sitting on top of the toy car (Fig. 1).

The experimenter then reached in with her right hand, stopping about 2 cm right above the head of the duck. When the hand stopped, the experimenter drew the infant's attention. 'Look at this, (infant's name). Now.' The word 'now' was used to signal the observer to start timing in all trials. The infant's looking was then monitored. A trial ended when the infant looked away for 2 continuous seconds after looking for at least 0.5 s, as determined by the release of the observer's button. At the end of the trial, the experimenter lifted her hand, then the curtain was raised to cover the stage. After a 3 s pause, the curtain was lowered and the next trial began. The habituation criterion was defined as the sum of looking time of the last three trials being half or less than the sum of looking time of the first three habituation trials, where the sum of the first three trials was greater or equal to 12 s. Habituation trials continued until the infant met the habituation criterion or until 14 trials had been completed. Half of the infants saw the duck-car display where the duck was glued onto the car (this is how the unexpected outcome was created) during habituation; half saw the display where the two were not glued together. An informal survey showed that adults could not discriminate these two displays. These habituation trials familiarized the infant with the objects and the presence of a human hand. They also encouraged the infant to anticipate the test event when the hand grasped the duck and lifted it.

3.5.2. Test phase

When the habituation trials ended, the curtain was again raised to cover the stage. After a 3 s pause, the test trials began. The curtain was lowered to reveal the duck-car display. The experimenter reached in and grasped the top of the duck's head and lifted it 7 cm vertically at the speed of about 7 cm/s. The hand then stopped in midair, holding the top of the duck. The infant's attention was then drawn. 'Look, (infant's name)' and looking time was monitored. After the infant looked away, the hand put the duck back on top of the car (or the duck and the car onto the stage floor) and the curtain was raised to cover the entire stage. After a 3 s pause the next test trial began. The infant saw two outcomes alternately. In the expected outcome (for adults), the duck was lifted and suspended in midair while the car stayed stationary on the stage. In the unexpected outcome (for adults), the duck as well as the car were lifted and suspended in midair together (Fig. 1). There were six test trials for each infant. The order of outcome was counterbalanced across infants.

3.6. Movement-no handling condition

3.6.1. Habituation phase

The habituation trials in the movement-no handling condition were the same as the ones in the static-no handling condition with one important difference. During each trial, after the curtain was lowered, the hand reached in, grasped the top of the duck's head, and slid the duck off the car horizontally about 10 cm such that the bottom of the duck no long overlapped with the top of the car. The duck was then returned to its initial position. The hand then stopped about 2 cm above the head of the duck as in the static-no handling condition. The infant's attention was drawn. 'Look (infant's name)', and looking time was monitored. All other details of the habituation phase were the same as in the static-no handling condition.

3.6.2. Test phase

The test trials in the movement-no handling condition were identical with those of the static-no handling condition. There were six trials and the order of outcome was counterbalanced across subjects.

3.6.3. Static-handling condition

The procedure for this condition was identical to the static-no handling condition, except for one important difference. After the infant and the parent were seated and prior to drawing the infant's attention to the stage, the experimenter brought out the duck and the car, one at a time, to the infant and let the infant play with each toy for about 30 s. The infant never saw the two objects at the same time. The first object was removed from view before the second one was introduced. All infants were required to at least touch each object; the vast majority of them took the objects in their hands and manipulated/mouthed them. Almost all infants lost interest in the toy by the end of the 30 s period, letting it drop or turning their attention to their parents or the experimenter. The order of which object was introduced first was counterbalanced across subjects. The procedure then unfolded exactly as in the static-no handling condition. The infants were habituated to the stationary display of the duck perching on top of the car, then they were shown six test trials as in the static-no handling condition.

3.7. Movement-handling condition

The procedure for this condition was exactly the same as in the movement-no handling condition, with one important difference. Prior to drawing the infant's attention to the stage, the experimenter brought out the duck and the car, both at once, to the infant and let the infant play with them. The infant was given each toy (with the other toy in view) for about 20 s, then she was given both toys for another 20 s. The vast majority of the infants spontaneously grasped both toys. Almost all infants lost interest in the toys at the end of the 60 s period, ceasing to hold or manipulate them, and turning their attention elsewhere. The rest of the procedure was identical to that of the movement-no handling condition. The infants were habituated to the stationary duck-car display with the hand poised above the duck, after the duck had been moved laterally off the car and returned to position. Six test trials followed the habituation phase.

3.8. Baseline condition

The baseline condition measured whether infants had an intrinsic preference for either of the outcome displays. Infants were shown the outcomes of the six test trials. They never saw the display resting on the floor of the stage. Each time when the curtain was lowered, the infant saw the final outcome of a test trial: a hand holding the duck in mid-air with the car stationary on the floor of the stage, or the duck and the car in mid-air. The infant's looking time was recorded. The order of outcome was counterbalanced across subjects.

3.9. Results

Eighty-seven of the 100 infants in this study were off-line observed by an observer who was completely blind to the condition and order of outcomes of the experiment (the remaining 13 infants were not on video due to experimenter error or equipment failure). Interscorer reliability was 92.5%.

3.10. Habituation trials

Table 1 lists the average number of habituation trials, and the average habituation criterion (defined as 50% of the sum of the first three trials) for each of the four experimental conditions. A 2×2 analysis of variance examined the effects of condition (static vs. movement) and prior handling (handling vs. no handling) on the number of habituation trials. There were no main effects or interactions. Similarly, there were no main effects or interactions in an ANOVA which examined the effects of the same two variables on the habituation criterion.

In sum, encoding the duck-car display in the static condition was no less efficient than doing so in the movement condition, and manipulating the duck and the car for 30 s each immediately prior to habituation had no measurable effect on the course of habituation.

Table 1
Average number of habituation trials and habituation criteria

	Expt. 1				Expt. 2	Expt. 3	
	Static-no Handling	Movement-no Handling	Static-handling	Movement-handling	Static	Move-ment	Static
Average number of habituation trials	8.8	8.7	8.5	8.0	–	8.4	9.9
Average habituation criterion(s)	14.0	15.3	19.7	13.5	18.1	13.3	10.1

3.10.1. Test trials

The principal findings are shown in Fig. 2. An alpha level of 0.05 was used for all statistical tests. Initial ANOVAs revealed no effects of sex, order of outcome, or habituation display (glued-together vs. separate). Subsequent analyses collapsed over these factors.

The main results of Experiment 1 were that the infants had a small preference for the apart outcome in the baseline, and they failed to overcome this preference in the static condition but succeeded in doing so in the movement condition. Furthermore, there was no effect of handling.

An analysis of variance examined the effects on looking times with condition

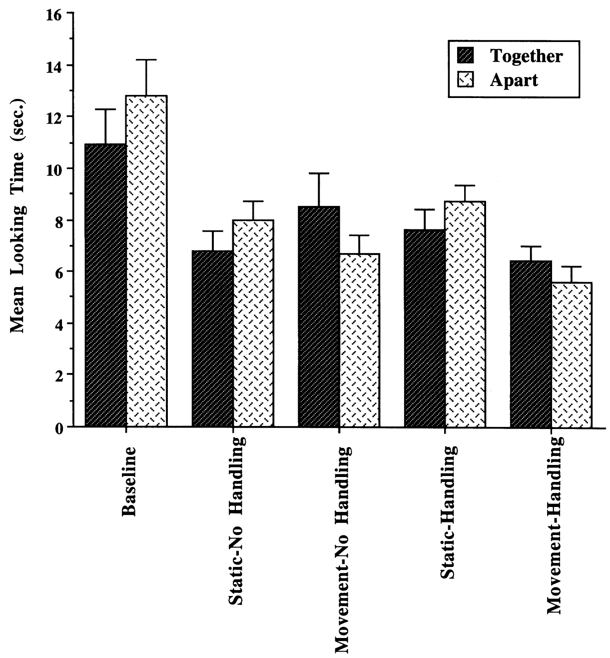

Fig. 2. Mean looking times of the baseline, static, and movement conditions in Experiment 1.

(static-no handling, movement-no handling, static-handling, movement-handling, and baseline) and outcome (together or apart) as variables. There was a main effect of condition, due to the overall longer looking times in the baseline condition, presumably because infants in this condition did not go through a habituation phase ($F(4,95) = 7.368$, $P < 0.0001$). There was no main effect of outcome. More importantly, there was a condition by outcome interaction ($F(4,95) = 2.518$, $P < 0.05$).

Next a planned 2 × 2 × 2 ANOVA examined the effects of condition (static vs. movement), handling (handling vs. no handling before habituation), and outcome (together vs. apart) on looking times. There was an interaction between condition and outcome, $F(1,76) = 8.002$, $P < 0.01$. The infants in the movement conditions looked longer at the together outcome (M_a = 6.1 s, SD = 2.9; M_t = 7.55 s, SD = 4.5) whereas those in the static conditions did not (M_a = 8.5 s, SD = 2.9; M_t = 7.3 s, SD = 3.6). There was no main effect of handling ($F(1,76) = 0.176$, $P > 0.6$) and no three-way interaction between handling, condition, and outcome ($F(1,76) = 0.425$, $P > 0.5$). That is, handling the objects prior to habituation did not effect infants' looking time patterns on the test trials. Given this finding, subsequent analyses collapsed over the handling factor.

Three planned ANOVAs were then performed to compare each of the experimental conditions (static and movement, collapsing over handling) with the baseline condition and the two experimental conditions with each other. Each of the ANOVAs examined the effects of condition and outcome on looking times. In the baseline/static condition ANOVA, there was no interaction between condition and outcome, $F(1,58) = 0.407$, $P > 0.5$; the infants' looking time pattern did not differ from their baseline preference. The infants looked longer at the apart outcome on all three pairs of test trials of the static condition (trial pair 1: M_a = 11.4 s, M_t = 8. 9 s; trial pair 2: M_a = 7.2 s, M_t = 6.6 s; trial pair 3: M_a = 6.7 s, M_t = 6.3 s). In contrast, in the baseline/movement condition ANOVA, there was an interaction between condition and outcome, $F(1,58) = 6.300$, $P < 0.02$. The infants looked longer at the together outcome on all three pairs of test trials (trial pair 1: M_a = 7.7 s, M_t = l0.5 s; trial pair 2: M_a = 5.9 s, M_t = 6.0 s; trial pair 3: M_a = 4.7 s, M_t = 5.8 s). There was also an interaction between condition and outcome comparing the static and the movement conditions, $F(1,78) = 8.147$, $P < 0.01$.

Non-parametric tests confirmed that the looking time patterns of the movement condition differed from the baseline condition and the static condition. Fifteen out of 20 infants (75%) in the baseline condition and 27 out of 40 infants (68%) in the static conditions looked longer at the apart outcome. A Mann–Whitney *U* test showed that the static condition was not different from the baseline condition, $z = -1.255$, $P = 0.21$. In contrast, only 12 out of 40 (30%) of the infants in the movement conditions looked longer at the apart outcome. A Mann–Whitney *U* test showed that this pattern is different from that of the baseline condition ($z = -2.697$, $P < 0.01$) and from the static condition ($z = -2.997$, $P < 0.005$).

3.11. Discussion

The first main finding of Experiment 1 was that 10-month-old infants succeeded in using spatiotemporal information, but failed to use kind information, in object individuation. In the static condition, in which only kind differences provided evidence that there were two objects in the array, infants' looking time pattern was not different from that of the baseline condition. Infants behaved as if they had no clear expectations about whether the car should move with the duck or not. In contrast, in the movement condition in which spatiotemporal information provided evidence that there were two distinct objects, the infants overcame their baseline preference for the apart outcome and looked longer at the unexpected outcome of the two objects moving together.

The paradigm of Xu and Carey (1996) and that of the present experiment make very different information processing demands of the infant. In order to determine how many objects were involved in Xu and Carey's (1996) studies, infants need to recall a representation of the first object held in short-term memory upon seeing the second, and to compare these two representations. Experiment 1 required no recall of a previously seen object; both objects are continuously visible during habituation. In spite of these differences, the results of Experiment 1 converge with the findings of Xu and Carey (1996) in support of the hypothesis that object kinds such as duck and car (or animal and vehicle) do not yet provide criteria for individuation and numerical identity at 10 months of age.

The second main finding of Experiment 1 is the absence of any effects of handling the objects prior to the experiment – either on habituation rate or on looking times to the outcome events. The infants in the static-handling condition saw each object alone, moving independently, and handled it for 30 s; yet they still failed to show longer looking time on the test trials when the duck-car moved as a single object. This is particularly surprising given Needham and Baillargeon's (1998) finding that seeing a part of an ambiguous display for at little as 5 s helps the infant parse the display later on. However, details of the Needham and Baillargeon's results also give a possible explanation for why the present study showed no effect of handling. In their studies, the infants needed more time to process the object if the object was more complex, e.g. they needed to see the box for 5 s standing alone on the stage in order to parse the box-hose display into two objects in the experiment, but they needed to see the hose alone for 15 s in order for this experience to help with disambiguating the box-hose display. Perhaps the complexities of the objects in Experiment 1, the duck and the car, made the task more difficult. This line of reasoning is consistent with the hypothesis that infants at this age do not represent kinds such as duck and car, which are, after all, perceptually complex and variable. One role representations of kinds might be expected to play is to support recognition of instances of those kinds on separate occasions. If infants antecedently represented the kinds duck and car, we would expect those representations to be primed during handling, and that these primed representations would support encoding during habituation and segmentation of the ambiguous display. That such priming did not occur is consistent with the hypothesis that infants have no antecedent representations of these kinds.

Xu and Carey (1996) found that 12-month-old infants succeeded at using kind information for object individuation. Experiment 2 tests the prediction that 12-

month-olds could similarly succeed in the static-no handling condition of Experiment 1.

4. Experiment 2

Experiment 2 included two conditions: a static condition and a baseline condition. The static condition is similar to the static-no handling condition of Experiment 1. Since handling did not have any measurable effects in Experiment 1, we did not include a handling condition in this experiment.

4.1. Method

4.1.1. Participants

Forty full-term infants participated in this study (17 girls, 23 boys) with a mean age of 12 months, 13 days, ranging from 12 months 1 day to 12 months 25 days. Equal number of infants were randomly assigned to either the baseline or the static condition (mean age 12 months, 15 days and 12 months, 11 days, respectively). All infants were recruited from the Greater Boston area as in Experiment 1. None had participated in Experiment 1. An additional six infants were excluded due to fussiness (four), parental interference (one), or experimenter error (one).

4.2. Materials and apparatus

The materials and apparatus were identical to those in Experiment 1.

4.3. Procedure

4.3.1. Baseline condition

The procedure for this condition was identical to the baseline condition in Experiment 1.

4.3.2. Static condition

The procedure was identical to the static-no handling condition of Experiment 1, except for one modification. Previous studies have shown that a full habituation procedure is too long for 12-month-olds. Therefore Experiment 2 used a fixed number of familiarization trials. Each infant was shown the stationary display six times.

4.4. Results

Thirty-six of the 40 infants were off-line observed by an observer who was completely blind to the order of outcome (the remaining four infants did not have a video record due to equipment failure). The interscorer reliability averaged 94.1%.

The habituation criterion is included in Table 1; no average number of habituation trials is reported because all 12-month-olds received six familiarization trials. The habituation criterion does not differ from the corresponding conditions in Experiment 1.

The main finding of Experiment 2 was that in the experimental condition, 12-month-olds looked longer at the unexpected outcome of the two objects moving together, overcoming a baseline tendency to look longer at the two objects when they were apart (Fig. 3).

An alpha level of 0.05 was used for all statistical tests. An analysis of variance examined the effects of condition (baseline vs. static) and outcome (apart vs. together) on looking times. There was an interaction between the two variables, $F(1,38) = 7.118$, $P < 0.02$. The infants looked slightly longer at the apart outcome in the baseline; they reversed that preference on the test trials of the static condition and looked longer at the unexpected outcome of moving together (baseline: $M_a = 9.8$ s, SD = 4.5 s; $M_t = 8.2$ s, SD = 3.8 s; static-no handling condition: $M_a = 8.5$ s, SD = 3.9 s; $M_t = 10.8$ s, SD = 5.4 s). The preference for the unexpected outcome (moving together) holds for all three pairs of test trials in the static condition (pair 1: $M_a = 10.0$ s, $M_t = 14.3$ s; pair 2: $M_a = 8.5$ s, $M_t = 9.7$ s; pair 3: $M_a = 6.1$ s, $M_t = 8.0$ s).

Non-parametric tests confirmed that the patterns of looking in the baseline condition (13 out of 20 infants, 65%, looked longer at the apart outcome) differed from those in the static condition (four out of 20 infants, 20%, looked longer at the apart outcome; Mann–Whitney *U*, $z = -2.57$, $P < 0.01$).

4.5. Discussion

In Experiment 2, 12-month-old infants succeeded in using kind information in

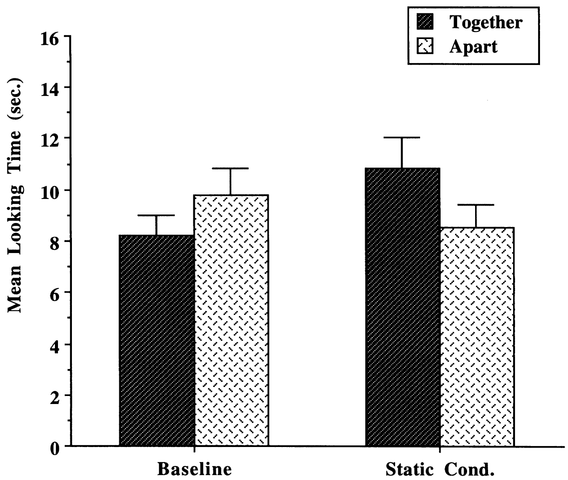

Fig. 3. Mean looking times of the baseline and static conditions in Experiment 2.

object individuation. After having been familiarized with the ambiguous and static duck-car display, when the duck was then lifted from above, they looked longer at what for adults is the unexpected outcome of the duck and the car moving together. This result is important for two reasons. First, taken together, Experiments 1 and 2 provide converging evidence for Xu and Carey's (1996) hypothesis that kind distinctions come to subserve object individuation some time between 10 and 12 months of age. The convergence of the two sets of results is somewhat surprising, given the reduced memory demands of these experiments relative to those in Xu and Carey (1996). In the present studies, infants were not required to retrieve from memory the representation of the first object upon seeing the second; the two objects were visible throughout the experiment. Even with such reduced memory demand, 10-month-old infants failed to use familiar kinds such as duck and car to segment the duck-car display into two distinct objects, whereas 12-month-old infants succeeded in doing so.

Second, the success of the 12-month-old infants in the static condition is of methodological significance, for it confirms that infants in this age range can overcome their baseline tendency to look longer at the apart outcome, as does the success of 10-month-old infants in the movement condition of Experiment 1. The failure of the l0-month-olds in the static condition of Experiment 1 is not simply a null result due to the insensitivity of the measure.

Xu and Carey (1996) found that 10-month-old infants failed to use a wide variety of kind contrasts for object individuation – from global contrasts such as animal and vehicle to highly familiar functional kinds such as bottle and cup. A limitation of Experiments 1 and 2 is that only one kind contrast was probed (duck and car). As one anonymous reviewer noted, l0-month-olds may have seen pull-toys which consist of an animal riding a vehicle, and on such toys, the animal is often connected with the vehicle. Perhaps the young infants did not look longer at the moving together outcome because they had had experience with animal-vehicle objects. This seems unlikely given that 12-month-old infants, who presumably have had more experience with pull-toys than 10-month-olds, looked longer at the moving together outcome. Still, in order to establish some generality of our findings, Experiment 3 investigates whether 10-month-old infants will draw on another kind contrast, that between two functional kinds, cup and shoe, for object individuation. These two kinds are highly familiar to 10-month-old infants; they are among the first words infants comprehend; and certainly infants have had no experience with objects composed of a cup attached to a shoe.

It is also possible that the movement conditions of Experiment 1 provided more information relevant to the task, than the spatiotemporal evidence that the objects moved relative to each other at their boundary. The spatiotemporal information was provided by moving the duck laterally completely off the car before each habituation trial. These infants were shown for a brief moment that the two objects were not adjacent to each other, albeit in a different configuration from the apart outcome on the test trials. It is possible that for these infants the apart outcome was not as novel as it was for the infants in the static condition, who had never seen the two objects not adjacent during habituation. Experiment 3 investigates whether success in the movement conditions of Experiment 1 may have reflected novelty of the together outcome, rather than use of spatiotemporal information to segment the display. In the movement condition of Experiment 3, spatiotemporal information was provided by moving the cup laterally relative to the stationary shoe, but at least 50% of the bottom surface of the cup overlapped with the top of the shoe. Thus the cup remained adjacent to the shoe throughout habituation.

5. Experiment 3

This experiment attempts to replicate the basic results of Experiment 1 with a different pair of objects. Since there were no effects of handling in Experiment 1, we included only the no handling conditions in this experiment: the static condition, the movement condition, and a baseline condition.

5.1. Method

5.1.1. Participants

Thirty-six full-term infants participated in the study (20 girls and 16 boys), ranging from 9 months, 17 days to 10 months, 15 days (mean age 10 months, 1 day). Equal number of infants (with sex roughly balanced) were randomly assigned to one of three conditions (mean ages were 10 months 3 days for the static-no handling condition, 10 months 3 days for the movement-no handling condition and 9 months 27 days for the baseline condition). Five additional infants were excluded due to fussiness (four) or parental interference (one). All infants were recruited from the Greater Boston area as in the previous experiments.

5.2. Materials

Two stimuli were used: a baby shoe with red, green, blue and white stripes and white shoelaces, and a sippy cup with two handles and vertical yellow and orange stripes and green dots.

The shoe was about $12.5 \times 6 \times 5$ cm in size; the sippy cup was $11 \times 8 \times 7.5$ cm in size. Informal survey with adults showed that adults perceive the shoe-on-top-of-cup display as a shoe and a cup, and parents reported that both kinds of objects were familiar to 10-month-old infants.

5.3. Apparatus

The same puppet stage was used. The setup was identical to that of Experiment 1.

5.4. Design and procedure

5.4.1. Static condition

The procedure for this condition was identical to the corresponding static-no handling condition of Experiment 1, except for the stimuli: a cup sitting on top of a shoe. There was no obvious boundary between the two.

5.4.2. Movement condition

The procedure for this condition was identical to the corresponding movement-no handling condition of Experiment 1, except for one important difference. During each habituation trial, the hand lifted the cup and moved it horizontally. Instead of moving the cup off the shoe completely, as in previous experiments, the hand moved the cup left then right, always keeping at least 50% of the bottom surface of the cup overlapping with the top surface of the shoe.

5.4.3. Baseline condition

The baseline was identical to the baseline condition of Experiment 1. The infants were shown the final outcomes of the test trials, without habituation and without ever seeing the cup-shoe resting on the stage floor.

5.5. Results

The main findings of Experiment 3 are shown in Fig. 4. The results are essentially identical to those of Experiments 1. In the static condition, infants still failed to look longer at the together (unexpected) outcome; in the movement condition, however, infants did look longer at the together (unexpected) outcome.

An alpha level of 0.05 was used in all statistical tests. Initial ANOVAs revealed no effects of sex or habituation display (glued-together vs. separate). Subsequent analyses collapsed over these factors.

5.5.1. Habituation trials

Table 1 lists the average number of habituation trials and the average habituation criterion for both the static and the movement conditions. *t*-Tests revealed no differ-

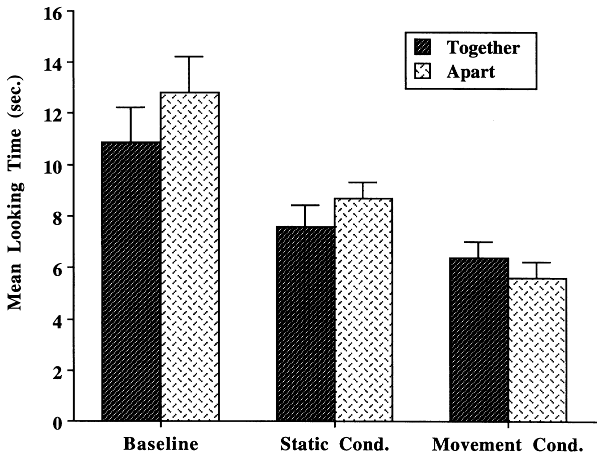

Fig. 4. Mean looking times of the baseline, static and movement conditions in Experiment 3.

ences between the two conditions on either number of habituation trial or the habituation criterion ($P > 0.1$).

5.5.2. Test trials

Planned ANOVAs compared each of the experimental conditions with the baseline condition and with each other.

An analysis of variance was performed with condition (baseline vs. static) as a between-subject variable and outcome (apart vs. together) as the within-subject variable. There were neither main effects nor an interaction between the two variables, $F(1,22) = 0.004$, $P = 0.953$. Infants looked equally at the two outcomes in both conditions (baseline: $M_a = 5.4$ s, SD = 3.4 s, $M_t = 5.3$ s, SD = 1.6 s; static: $M_a = 5.9$ s, SD = 3.6 s, $M_t = 5.7$ s, SD = 3.7 s). The pattern of looking for the three pairs of test trials in the static condition is as follows: pair 1: $M_a = 7.4$ s, $M_t = 7.0$ s; pair 2: $M_a = 5.6$ s, $M_t = 5.3$ s; pair 3: $M_a = 5.4$ s, $M_t = 4.6$ s). Overall the infants did not look longer at the unexpected outcome of the two objects moving together in the static condition. Their looking time pattern did not differ from that of the baseline condition. Non-parametrically, five of the 12 infants in the baseline and five of the 12 infants in the static condition looked longer at the together outcome.

A second analysis of variance was performed with condition (baseline vs. movement) as a between-subject variable and outcome (apart vs. together) as the within-subject variable. There was a main effect of condition. Infants looked longer in the baseline (M = 5.4 s, SD = 2.5 s) than in the movement condition (M = 3.7 s, SD = 2.0 s), $F(1,22) = 4.386$, $P < 0.05$. There was also an interaction between the two variables ($F(1,22) = 4.305$, $P < 0.025$, one-tailed). On the test trials of the movement condition, infants looked longer at the unexpected together outcome (baseline: $M_a = 5.4$ s, SD = 3.3 s; M = 5.3 s, SD = 1.6 s; movement: $M_a = 2.8$ s, SD = 1.3 s; $M_t = 4.7$ s, SD = 2.1 s). This pattern of looking holds for two of the three test trial pairs in the movement condition (pair 1: $M_a = 2.7$ s, $M_t = 6.9$ s; pair 2: $M_a = 2.6$ s, $M_t = 3.5$ s; pair 3: $M_a = 3.6$ s, $M_t = 3.2$ s).

Non-parametric tests confirmed the difference between the pattern of looking in the baseline and the movement condition. Five of the 12 infants in the baseline condition looked longer at the together outcome whereas 10 of the 12 infants in the movement condition did so (Mann–Whitney *U*, $z = -1.704$, $P = 0.08$).

A third ANOVA compared the two test conditions with condition and outcome as variables. There was a marginally significant main effect of condition. Overall infants looked longer in the static-no handling condition (M = 5.8 s, SD = 3.6 s) than in the movement-no handling condition (M = 3.8 s, SD = 2.0 s). More importantly, there was a significant interaction between the two variables ($F(1,22) = 3.085$, $P < 0.05$, one-tailed). Infants looked about equally at the two outcomes in the static condition but they looked longer at the unexpected outcome in the movement condition.

Non-parametric tests confirmed the difference between the static and the movement conditions. Five of the 12 infants looked longer at the together outcome in the static condition whereas 10 of the 12 infants did so in the movement condition (Mann–Whitney *U*, $z = -1.703$, $P = 0.08$).

5.6. Discussion

Using a different pair of stimuli, Experiment 3 replicated the findings of Experiment 1. In the movement condition the two objects were never fully separated during habituation, so the apart outcome was novel in this condition as well as in the static condition. Ten-month-old infants apparently used the relative motion to individuate the two objects in the display and could hold on to the segmented representation during subsequent habituation to the ambiguous cup-shoe display.

The 10-month-old infants succeeded in using spatiotemporal information to individuate the cup-shoe display into two distinct objects, but failed to do so when only kind information was provided. Even when the stimuli are familiar functional kinds which are virtually never seen connected in real life, infants failed to display their knowledge of these kinds in this object individuation task.

6. General discussion

In the present studies, 10-month-old infants failed to draw on categorization of the objects such as a duck and a car, or a cup and a shoe, to build representations of the displays as consisting of two independently moving objects, whereas 12-month-old infants succeeded in doing so. These studies placed very different information processing demands on the infant from Xu and Carey's (1996) method. The studies did not involve occlusion at all, and thus did not require the child to compare a visible object with a representation of a previously seen object currently held in short-term memory. In spite of these differences between the two paradigms, the results converge: in both series of studies, 10-month-old infants succeeded in using spatiotemporal information but not kind membership for object individuation, whereas 12-month-old infants are able to use kind membership for object individuation. Particularly striking is the failure in the handling condition in Experiment 1. Prior exposure to the duck alone or the car alone for 30 s did not ensure success of the 10-month-old infants.

Although the present studies were designed to reduce the information processing demands on the infant relatively to Xu and Carey (1996), it is of course possible that we introduced other sources of difficulty that may have masked the infant's competence in using kind membership for object individuation. An anonymous reviewer suggested two possibilities.

First, it is possible that the developmental change between 10 and 12 months is not the result of a change in the representations of objects, but rather the result of a procedural difference between the tasks given to the two age groups. Recall that in both Experiments 1 and 3, 10-month-old infants were tested in a full habituation procedure, whereas the 12-month-olds in Experiment 2 were tested with six familiarization trials. It is possible that full habituation gave the younger infants more misleading spatiotemporal evidence that there was a single object in the array. This possibility can be addressed by comparing the infants who habituated in six trials for both age groups with the ones who did not. Some 10-month-old infants as well as some 12-month-old infants habituated in six trials, so by the time the test trials started, these infants had been habituated to the same extent. Analyses of variance revealed no difference between the 10-month-old infants who habituated in six trials (21 out of 52 in the static conditions of Experiments 1 and 3) and the ones who did not ($P > 0.1$) and no difference between the 12-month-old infants who habituated in six trials (7 out of 20) and the ones who did not ($P > 0.1$) (Table 2).

These analyses do not support the hypothesis that the difference in performance between the 10- and 12-month-olds was due to the l0-month-olds' greater experience with the static duck/car or cup/shoe array during habituation. Nonetheless, even if this hypothesis had been supported, it would not detract from the conclusion we draw from these studies. That is, this alternative hypothesis presupposes that 10-month-old infants do not have access to kind representations such as cup, shoe, duck and car that support object individuation. We adults might see an ink bottle sitting on top of a book on a desk for several months without moving, yet, we still draw upon our knowledge of books and ink bottles to see the display as consisting of two objects, and we would still be surprised if we picked up the ink bottle and the book moved with it, as if they were parts of a single object.

Second, there is also a procedural difference between the static and the movement conditions in Experiments 1 and 3, other than the infants being given spatiotemporal information in the movement condition but not in the static condition. During the habituation phase, the hand never touched the objects in the static condition but it did so in the movement condition. For the infants in the static condition, the first time they see the hand touching the object was on the test trials. Thus, it is possible that the novelty of the hand touching and lifting the object for the first time on the test trials of the static condition masked the differentiation of the two outcomes for 10-month-olds. There is some support for this possibility – in both Experiments 1 and 3, infants looked overall longer in the test trials of the static condition than in the movement condition. However, another result from these studies makes this interpretation less likely: 12-month-old infants in the static condition saw the same habituation and test events and they were able to successfully parse the array into two objects. Furthermore, two other series of studies (Xu and Carey, 1996; Van de Walle et al., submitted) using different methodologies, provide convergent evidence for the 10 to 12 months shift, again making the alternative interpretation less likely.

Table 2
Mean looking times for 10- and 12-month-olds by number of habituation trials

	Ten-month-olds		Twelve-month-olds	
	Six habituation trials (n = 21)	More than six habituation trials (n = 31)	Six habituation trials (n = 7)	More than six habituation trials (n = 13)
Together (s)	6.6	7.1	9.9	11.2
Apart (s)	7.2	8.4	8.7	8.7

It is, of course, possible that idiosyncratic details of our procedure contributed to the failure of the 10-month-old infants in the static condition and to their success in the movement condition. This is why it is important to seek converging measures. Recently, Van de Walle et al. (submitted) found evidence for a change between ages 10 and 12 months, in the ability to draw on kind information for object individuation using an entirely different paradigm. Instead of a looking time measure, Van de Walle et al. (submitted) used a reaching measure, which placed greater information processing demands on the infant than either the present studies or the studies in Xu and Carey (1996). Infants were shown a box into which they could reach but could not see what was inside. Objects were removed from the box; either one object was removed and replaced twice, or two objects were removed and replaced one at a time. In the kind condition, infants never saw both objects, whereas in the spatio-temporal condition they did. The dependent measures reflected the persistence of reaching for the second object on the two-object trials, in which the infant should expect a second object, as opposed to on the one-object trials, in which the infant should not expect a second object. The reaching measure requires a robust representation of the hidden object (Munakata et al., 1997), robust enough to generate a reach in the absence of any current visual evidence concerning the number of objects in the box. Van de Walle et al. (submitted) found that both 10- and 12-month-old infants reached more persistently for the second object on two object trials in the spatiotemporal condition, but only the 12-month-old infants did so in the kind condition.

This third series of studies by Van de Walle et al. (submitted) provides direct, unambiguous evidence concerning how many objects the child has represented as being in the box. Although reaching measures often reveal competence later than looking time measures, the data from this method converge on the 10–12 months developmental change found in Xu and Carey (1996) and the present studies.

Across these three series of studies we found converging evidence for the developmental change between 10 and 12 months in the infant's success in object individuation tasks. These data are in apparent conflict with data from Needham (Needham et al., 1997; Needham, 1998) and Wilcox and Baillargeon (1998, 1999), which revealed some competence in much younger infants ability to use object property information for object individuation. How might we reconcile the discrepancy? We present three possibilities.

First, the information processing demands in studies by Needham (Needham et al., 1997; Needham, 1998) and Wilcox and Baillargeon (1998, 1999) may be less than those in our studies. For example, Wilcox and Baillargeon (1998) have argued that an event-monitoring paradigm may be less demanding than an event-mapping

[2]Some of the tasks by Wilcox and Baillargeon might not be reflecting object individuation per se, but rather be reflecting conditions under which the trajectory information specifies one single object, and the infant's longer looking may be interpreted as detecting a surprising change of properties in a single object. Some preliminary results provide some support for this possibility. Carey and Bassin (1998) showed adults the narrow screen events in Wilcox and Baillargeon's studies and asked them to describe what they saw. Adults had a strong impression that a single object with ball-properties went behind the screen and came out as an object with box-properties.

paradigm[2] and Needham (1998) used fewer familiarization trials than the present studies. Perhaps 12-month-olds are better able to cope with a more complex task. However, the three series of studies (the present studies; Xu and Carey, 1996; Van de Walle et al., submitted) vary a great deal in information-processing demands and yet we found converging evidence for the developmental change between 10 and 12 months. This suggests that some development in representational capacities in the infant is taking place, orthogonal to particular information-processing demands of these tasks.

Second, the stimuli in all of the studies of Xu, Carey, and their colleagues are exemplars of real or miniature artifact kinds such as cup, shoe, ball, bottle, book, telephone, duck or elephant. These stimuli differ in two respects from those used by Needham, Wilcox, Baillargeon, Leslie, and their colleagues in other studies of object individuation. First, the stimuli in Needham, Wilcox, Baillargeon and Leslie's studies tend to be simple objects which support a single perceptual parse using gestalt properties of good form and good continuity (in most cases the color, texture and shape changes all converge). In contrast, the stimuli in the present studies, the duck on the car, or the cup on the shoe, do not support a single parse – the stimuli are irregularly shaped, with multiple parts, multiple colors, and multiple textures which may have multiple parses. We suggest that this perceptual complexity may be the reason for why infants need to categorize the stimuli as members of distinct kinds in order to succeed at the present task. Second, our stimuli are all members of the functional, namable kinds that infants first learn words for. Thus 10-month-old infants' capacity to draw on kind information for object individuation may differ from older children along either of these two dimensions. That is, they may be more limited in their capacity to process more complex stimuli, or they may be in the process of developing their first genuine kind representations. In favor of the complexity hypothesis, Needham and Baillargeon (1998) have documented the effects of object complexity on object individuation tasks.

The third possibility, which we favor, is that the developmental change observed in our studies reflects the emergence and consolidation of kind representations. Several sources of data provide converging evidence that kind representations, representations of functionally relevant, inductively rich, namable categories, are being constructed during the last few months of the infant's first year of life.

The first line of evidence is a series of studies we have completed recently addressing whether success on the Xu and Carey (1996) task reflects individuation on the basis of kind or individuation on the basis of properties. After all, a toy duck differs from a toy car on the basis of many properties (color, shape, texture) as well as kind membership (Xu et al., 1997, and unpublished data) explored 12-month-olds' use of property distinctions for object individuation within a single namable kind. Using the Xu and Carey (1996) paradigm, infants were shown in different studies successive emergence of a red ball and a green ball, or a small cup and a big cup, or a big, red, semi-transparent cup and a small, green, opaque cup. Although infants were sensitive to the property changes, they failed to use any of these property differences as the basis for object individuation. Moreover, infants failed to use shape differences within a kind (e.g. a sippy cup vs. a regular cup) for object individuation but they succeeded in doing so when the shape differences crossed kind boundaries (e.g. a cup and a bottle). These findings are consistent with our tentative conclusion that these tasks reflect the infant's capacity to draw on kind representations for object individuation, and that the period from 10 to 12 months witnesses the emergence and consolidation of genuine kind representations. Note that these data speak to issues of task demand and stimuli complexity as well. Infants at 12 months are clearly able to follow the procedure of Xu and Carey (1996), with multiple occlusions of objects, and they are able to encode more complex stimuli which belong to distinct kinds, e.g. a cup and a bottle. Still, they failed at the simpler stimuli, e.g. a red ball vs. a green ball, which suggests that information processing demand and stimuli complexity are not the only factors which effect success (see also Leslie et al., 1998 for related results).

The second line of evidence that kind representations are emerging during these months is from early word learning. Parental report of comprehension vocabulary converges on these ages as the time of first reliable word comprehension (Fenson et al., 1991). Arriaga et al. (1996) found that parental report of 10-month-olds' word comprehension was accurate when assessed in the laboratory with a preferential looking procedure. Further, Xu and Carey (1996) found a correlation, at 10 months, between parental report of comprehension of words for the highly familiar object kinds used in two of their experiments (bottle, book, cup and ball) and success at their task. Moreover, Balaban and Waxman (1996) and Xu (1997a) found evidence that labeling promotes both kind based categorization and kind based individuation in 9-month-old infants. In Balaban and Waxman's studies, when 9-month-olds heard a word (e.g. 'rabbit') during familiarizations, they showed stronger categorization behavior than if they had not heard a word. Similarly, Xu (1997a) reported success among 9-month-old infants in the Xu and Carey (1996) paradigm if the objects were labeled (e.g. 'Look, a ball' and 'Look, a duck') as they emerge from behind the occluder, but not if the two objects were labeled with the same word (e.g. 'Look, a toy'). These results suggest that the process of early word learning may be part of the process of constructing genuine kind representations. The presence of two words may be in itself evidence for the infant that two kinds of objects are present.

The third line of evidence that kind representations are emerging during these months is from tasks probing infants' understanding of the function of the various kinds of objects. For example, Baldwin et al. (1993) found that infants' ability to use perceptual similarity to predict non-obvious property of the objects (e.g. if turned over, the object goes 'moo') emerges between 9 and 12 months of age. Similarly, Mandler and McDonough (1993) found that inductive inference on the basis of categorization of objects as animals or vehicles is quite weak at around 7 months and it becomes much stronger between 9 and 11 months of age.

Still, other studies in the literature challenge the hypothesis that genuine kind representations develop between 10 and 12 months of the first year. In particular, how do we reconcile with evidence from visual and manual habituation studies suggesting that much younger infants represent categories such as cat, dog, horse and zebra?

Several studies have shown that infants as young as 3 or 4 months can establish categories such as horse, cat or table (Cohen and Caputo, 1978; Cohen and Younger, 1983; Quinn et al., 1993; Eimas and Quinn, 1994; Behl-Chadha, 1996). In one experimental paradigm, young infants are familiarized with pairs of exemplars from a given category, e.g. cat, they then devote more time looking at an exemplar from a different category, e.g. dog or bird, than a new exemplar from the familiar category. Similar results have also been obtained in manual habituation paradigms (Mandler et al., 1991; Oakes et al., 1991). These results are sometimes interpreted as evidence that infants represent the concepts that underpin count nouns (e.g. basic-level kinds: cf. Roberts and Horowitz, 1986; Macnamara, 1987; global kinds: cf. Mandler et al., 1991). The present studies, along with Xu and Carey (1996), suggest rather that these habituation studies may reflect infants' sensitivity to cat- and dog-shape, or cat- and dog-properties. The results from our object individuation studies suggest that below 10–12 months, infants do not encode the habituation stimuli as a series of distinct individuals (e.g. a cat, another cat, a third cat which is numerically distinct from the first two) then dishabituate to an object that is numerically distinct from the cats (e.g. a dog). Instead, the infants may have extracted the commonalities among the habituation stimuli as cat-shape or cat-properties and dishabituated to dog-shape or dog-properties. For adults, shape similarity is not the same as kind representations, e.g. an orange and a ball are very similar in shape but they belong to different kinds, and our category labels pick out distinct kinds not distinct shapes. It is only when infants represent distinct individuals such as cats and dogs are we warranted to conclude that they represent the kind concepts that underpin natural language count nouns.

In conclusion, it is clear that the task demands and the stimulus variables which determine success and failure in a given study are not yet fully understood. Most certainly, much further research is required before the conflicting results from all the paradigms are reconciled. A full account of the development of object perception during infancy will require us to integrate research on object individuation with research on kind representation.

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