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Infants' Metaphysics: The Case of Numerical Identity

FEI XU AND SUSAN CAREY

Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

Adults conceptualize the world in terms of enduring physical objects. *Sortal concepts* provide conditions of individuation (establishing the boundaries of objects) and numerical identity (establishing whether an object is the *same one* as one encountered at some other time). In the adult conceptual system, there are two roughly hierarchical levels of object sortals. Most general is the sortal *bounded physical object* itself, for which spatiotemporal properties provide the criteria for individuation and identity. More specific sortals, such as *dog* or *car*, rely on additional types of properties to provide criteria for individuation and identity. We conjecture that young infants might represent only the general sortal, *object,* and construct more specific sortals later (the *Object*-first Hypothesis). This is closely related to Bower's (1974) conjecture that infants use spatiotemporal information to trace identity before they use property information. Five studies using the visual habituation paradigm were conducted to address the *Object*-first Hypothesis. In these studies, 10-month-old infants were able to use spatiotemporal information but failed to use property/kind information to set up representations of numerically distinct individuals, thus providing empirical evidence for the *Object*-first Hypothesis. Finally, infants succeed at object individuation in terms of more specific sortals by 12 months. The relation between success at our task and early noun comprehension is discussed.

Adults conceptualize the world in terms of enduring physical objects. We have criteria for individuation of objects (telling where one ends and another begins) and for numerical identity (telling whether an object is the *same one* as one that we encountered earlier). As philosophers are at pains to point out, these criteria are part of our conceptual system; we *could* individuate and trace identity on the basis of different criteria, or we *could* have a conceptual system that contained no criteria for individuation or identity at all (see Hirsch, 1982, for a lucid discussion of logically possible conceptual systems that

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differ from ours in these respects). That this construction is far from inevitable raises the question of its origin; which aspects are innate, which constructed through interaction with various kinds of objects, and which constructed through language learning?

The philosophical literature has introduced the term ''sortal'' to denote a concept that provides criteria for individuation and identity (Wiggins, 1967, 1980; Gupta, 1980; Hirsch, 1982; Macnamara, 1987). In languages with the count/mass distinction, sortal concepts are lexicalized as count nouns. We cannot count without specifying what individuals to count. ''How many are there in a pack of cards?'', while syntactically well formed, cannot receive a definite answer. The answer could be ''fifty-two cards,'' ''four suits of cards,'' or ''billions of molecules.'' If we specify a sortal, ''how many *cards* are there in a pack of cards?'', the answer becomes definite, ''fifty-two.'' Similarly, we can only question numerical identity under a sortal. For example, a caterpillar turns into a butterfly. The answer to the question ''is it the same *animal*?'' is ''yes,'' but the answer to the question ''is it the same *caterpillar?*'' or ''is it the same bunch of molecules?'' is ''no.''

There are a variety of criteria for individuation and tracing identity over time. In the case of ordinary physical objects, the most fundamental criteria are spatiotemporal. A single object cannot be in two places at the same time; and two objects cannot occupy the same space at the same time. Moreover, objects move on spatiotemporally continuous paths; if no continuous path exists between two appearances of what might be a single object or two distinct objects, we infer there must be two. Thus, *object,* in Spelke's (1988, 1990) sense of *bounded physical object,* is a sortal with spatiotemporal criteria for individuation and numerical identity.[1] For our everyday concepts such as *car, table,* or *person,* spatiotemporal continuity is not sufficient and additional criteria are called into play. To use an example from Hirsch (1982), imagine a junk car, consigned to the crusher. The process of crushing is spatiotemporally continuous. Yet we say that at a certain point the car goes out of existence, and is replaced by a lump of metal and plastic. When a person, Joe Shmoe, dies, Joe ceases to exist, even though Joe's body still exists. In both of these examples, a spatiotemporal continuous path could be traced throughout the process of crushing or death, but tracing identity under a sortal such as *car* or *person* leads us to override the spatiotemporal continuity and judge that the car or person ceases to exist at some point.

There is considerable evidence that infants as young as four months also represent the general sortal *object.* They use spatiotemporal information to establish representations of the individual objects in their immediate environ-

[1] Many philosophers claim that ''object'' is not a sortal term (Wiggins, 1980; Hirsch, 1982; Macnamara, 1987). We do not here claim that the sortal concept *bounded physical object* is expressed by the English word ''object.'' We do claim, however, that *bounded physical object* functions as a sortal in the adult's conceptual system (see Xu, 1995, for a defense of this claim).

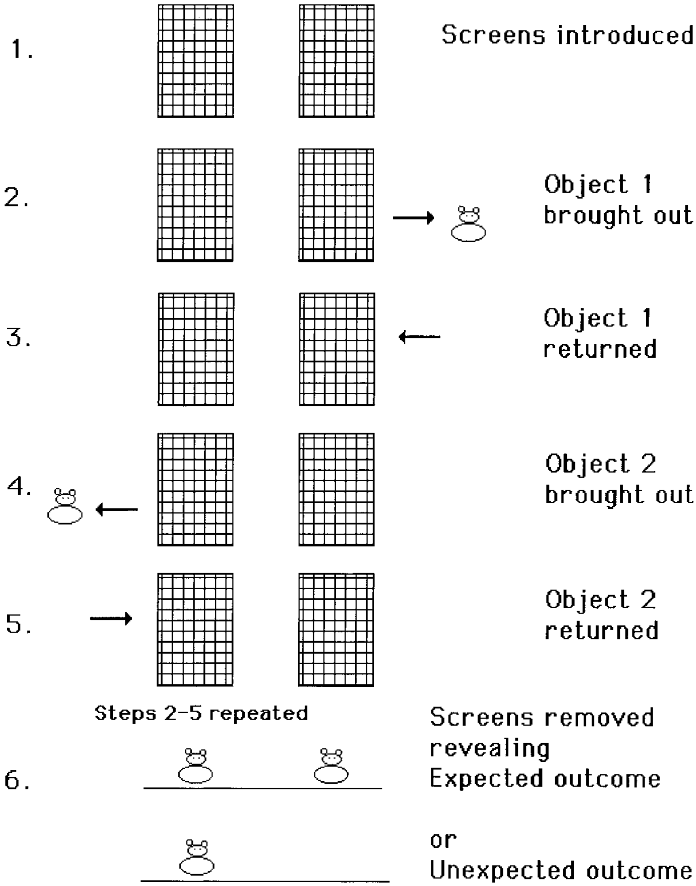

FIG. 1. Schematic representation of the Discontinuous movement event and the expected and unexpected outcomes in Experiment 1.

ment, and to trace identity through time (Spelke & Kestenbaum, 1986; Baillargeon & Graber, 1987; Spelke, 1988). To see how adults use such information, and to see what types of evidence show young infants to be like us in this regard, consider an experiment by Spelke and Kestenbaum (1986). Four-month-old infants were introduced to two screens, separated in space (see Fig. 1 for a very similar design). They were shown an object emerging from the left hand edge of the left screen and then reemerging behind it. No object appeared in the space between the two screens. Then a physically identical object emerged from the right hand edge of the right screen, and then re-emerged behind it. This sequence of events was repeated until the baby reached a habituation criterion, at which point the screens were removed revealing either two objects (expected outcome) or one object (unexpected outcome). Babies looked longer at the unexpected outcome, overcoming a baseline preference to look longer at two objects. Adults viewing the display also express surprise at the unexpected outcome of one object. Spelke and Kestenbaum conclude that babies (and adults) analyze the possible paths connecting the appearances of the objects, and infer from the spatiotemporal discontinuity that there must be two numerically distinct objects involved in the event.

At least two psychological theories of how sortals are learned have been proposed. Some have argued that the child's first sortal concepts are at the level of basic level kinds and establishing the gestalts for basic level kinds is the process of learning sortal concepts, i.e., once the child establishes a gestalt for dogs to the exclusion of cats and other categories, the child represents the sortal *dog* (Macnamara, 1987). Others, most notably Bower (1974), conjecture that babies use spatiotemporal criteria for individuating and tracing identity of objects well before they can use other property information. Although Bower was not concerned with what sortal concepts infants represent, his conjecture can be captured in our framework: Infants may have the sortal *object* before they have other sortals more specific than *object,* e.g., *ball.* We will dub this ''the *Object*-first Hypothesis.''

Reflecting upon Bower's hypothesis, one may find it intuitive why *object* should have a privileged status: The spatiotemporal principles apply in the same way to all physical objects, but tracing identity under more specific sortals requires kind-relative information about types of objects and which of their properties change over time and which do not. For example, a size difference between observations at times 1 and 2 does not warrant an inference of two numerically distinct plants, but would warrant an inference of two numerically distinct chairs; a radical shape difference does not warrant an inference of two numerically distinct hands, but would warrant an inference of two numerically distinct toasters, and so on. Similarly, if we see a plant on the window sill and later a toy car at the same location, we infer two numerically distinct objects, for we know that plants do not turn into cars. It might serve the human baby well to use spatiotemporal information to individuate objects, and then slowly learn about the more specific kinds of individuals, and for each which properties change over time and which do not.

Although the hypothesis is plausible, Bower's attempts to address his conjecture were inconclusive. He examined infants' tracking of objects that disappeared behind screens. Of most relevance here are his studies in which the baby is habituated to one object (say a large, yellow, fuzzy rabbit) disappearing behind a screen (or into a tunnel) and then reemerging out the other side. After habituation, the baby is shown an event in which the object (the rabbit) goes behind the screen, but a different object (say a small, shiny, red ball) emerges from the other side. Bower claimed that 5-month-olds were surprised and that their looking behavior was disrupted, and he inferred that this was due to their realization that the object that emerged from behind the screen was a different one from the one that entered.

Others have failed to replicate this finding (Gratch, 1982; Meicler & Gratch, 1980; Muller & Aslin, 1978). These researchers found no disruption of tracking due to property differences between the objects at 5 months, 9 months, or even 18 months! However, failure to find a disruption of looking under these circumstances may simply reflect the power of a moving object to capture eye tracking. The baby may know that it is a new object, and that the original object must be somewhere else, but track it nonetheless. This is the reason for monitoring surprise as well as tracking behavior. Gratch (1982) found that 5-month-olds show no codable surprise when the object that emerged from the screen differed from the one that entered, but that 9-month-olds and 16-month-olds were surprised in this situation. Unfortunately, surprise does not establish that the child knows two numerically distinct objects are involved. The baby simply may be registering the differences in properties between the new entity and the entity they had been habituated to without inferring that there must be two entities. Baillargeon and Graber (1987) has established that babies expect objects to maintain their properties when out of sight. So the babies in Gratch's study may be evincing surprise that the rabbit-shaped object turned into a ball-shaped object, without inferring that there must be two distinct objects.[2]

What is needed is a sensitive methodology that can evaluate *how many* objects the infant represents in a certain event when given only property/kind information. In the present series of studies, we adapt Spelke and Kestenbaum's (1986) procedure and devise a variant of their procedure to address the hypothesis that infants may have the sortal *object* before other sortals more specific than *object*. We show babies events in which one object (say a rabbit) emerges from one side of a screen alternating with a different object (say a cup) emerging from the other side of the same screen. Adults infer from this display that there must be at least two objects behind the screen, since adults individuate and trace identity relative to sortals such as *rabbit*

[2] Another source of data potentially relevant to the question at hand derives from object permanence studies, in which on some trials the object hidden is surreptitiously replaced by a different object, so that when the baby retrieves it, it is not the one expected (e.g., LeCompte & Gratch, 1972). Two dependent measures—surprise and whether the baby looks around for the other object—were used. LeCompte and Gratch found that most 18-month-olds showed surprise, and they searched around the box. The 9-month-olds, on the other hand, showed mild puzzlement but did not search for the missing toy. The 12-month-olds' performance was intermediate in level: some acted like 18-month-olds and some like 9-month-olds. These results are inconclusive for the same reasons as Bower's studies: Showing surprise may just mean that the babies noticed the property differences but did not infer that it was a *different* toy; looking for the missing toy, on the other hand, may be too much to ask—the babies might have realized that it was a different toy, but somehow decided not to look for the missing one, possibly because the new toy is of interest to them as a novel stimulus or maybe because they do not know where to look.

and *cup.* At issue is whether babies would make the same inference. The way to find out is to remove the screen, revealing either the two objects (expected outcome) or one (the rabbit *or* the cup; unexpected outcome). By the logic of the Spelke and Kestenbaum's study, if babies are able to use specific sortal membership or property information to establish representations of numerically distinct objects under these circumstances, they should look longer at the unexpected outcome.

Given Gratch's (1982) findings, we begin with 10-month-old babies. Our first task is to replicate Spelke and Kestenbaum's (1986) demonstration that babies use spatiotemporal information to trace the identity of objects under conditions similar to those we will use in our probes for the baby's use of property/kind information. Experiment 1 is a modified replication of Spelke and Kestenbaum's split screen procedure; Experiments 2–5 address the *Object*-first Hypothesis with the methodology sketched above.

EXPERIMENT 1

Experiment 1 seeks to confirm that 10-month-olds use spatiotemporal continuity to individuate and trace identity of objects over time. Spelke and Kestenbaum's (1986) split screen procedure was modified in two major ways. First, instead of a full habituation paradigm, babies were shown the critical events a fixed number of times. Second, Spelke and Kestenbaum's experiments used constantly moving objects; that is, after habituation, when the screens were removed, the objects (or object) revealed were in motion (i.e., oscillating). Spelke (personal communication) found this to be necessary for her results to obtain, perhaps because after extensive habituation, stationary objects would not hold very young infants' interest. Again, if the baby's understanding is robust, the results should hold whether the revealed objects are stationary or in motion.

Spelke and Kestenbaum's (1986) experiment contrasted the condition already described, where no object ever appeared in the space between the screens, with a condition in which an object traced a path continuously back and forth behind the screens, appearing in the middle. This controlled for any tendency to expect two objects for reasons unrelated to the path of the object(s) in the array (e.g., perhaps babies expect two objects because there are two screens). In Spelke and Kestenbaum's findings, babies differentiated the continuous condition from the discontinuous ones, by treating the continuous events as indeterminate. That is, when the object appeared between the two screens, they did not reliably expect either one or two objects to be behind the screens. The babies are, strictly speaking, right—the continuous events are consistent with any number of objects behind the screens. Experiment 1 includes a continuous condition for two reasons. First, it will serve as a control that will help establish the basis of the infant's preference in the discontinuous condition, and second, we will be able to see whether 10-month-olds make the simplest assumption that the continuous condition involves only one object.

Method

Subjects

Twenty-four full-term infants participated in the study (12 female and 12 male), age range from 9 months, 13 days to 10 months, 18 days (mean age 10 months, 3 days). Equal numbers of infants were in each of the two conditions (mean ages 10 months, 1 day, and 10 months, 5 days). Thirteen additional infants were excluded from the sample due to fussiness (7), experimenter error (1), or equipment failure (5). All infants were recruited by obtaining their birth records from town halls in the Greater Boston area and contacting their parents by mail.

Materials

One pair of identical yellow plastic cups was used in the baseline trials. Two pairs of toys were used in the test trials: two identical bright yellow toy ducks and two identical white foam balls. The toy ducks were about 8 × 6 × 4 cm in size; the foam balls were about 6 cm in diameter. Four pairs of screens (11 × 25 cm each) of different colors, green, mauve, yellow, and lavender, were used.

Apparatus

The occlusion events were presented on a three-sided, 76 × 31 × 13 cm, puppet stage with a light blue top surface and a false bottom. A 70 cm track along which objects traveled was dug out in the middle of the stage; a slit in the back of the stage connected to the track was the route by which objects were taken out when necessary. A black curtain was hung at the back of the stage to make the object and background contrast prominent and to conceal the movement of the experimenter. Black curtains also concealed the observers, who sat on both sides of the stage and monitored when the babies were looking at the stage. The observers could not see what was presented on the stage and were blind to the condition the baby was in. Two push buttons were connected to an IBM-486 computer which recorded the amount of time an infant looked at each display. White noise masked any sounds produced by the movement of the experimenter throughout the experiment.

The stage was lit from above and from one side of the baby; otherwise the room was darkened. The baby sat in a high chair, 66 cm from the stage, facing the stage, with eye level slightly above (about 5 cm) the floor of the stage. The parent sat next to the baby with her/his back toward the stage. She or he was instructed not to look at the displays, so as not to influence the baby's response, and not to attempt to draw the baby's attention either toward or away from the stage. Her/his hand was on the edge of the high chair, and she/he was instructed to smile whenever the baby looked at her/him.

Design and Procedure

Equal numbers of infants participated in two conditions: continuous movement condition and discontinuous movement condition (See Fig. 1 for schematic representations of the discontinuous condition).

Baseline/introductory trials. Both conditions had identical baseline/introductory trials. In these trials the experimenter tapped on the center and both ends of the stage to draw the baby's attention to the empty stage; only the experimenter's hand was visible to the infant. The experimenter then lowered two identical screens onto the center of the stage, 12 cm apart; the objects were lowered along with the screens but hidden behind them and invisible to the infant. When there were two objects involved, one object was placed behind each screen. The baby's attention was drawn (by tapping and hand waving) to each end of the stage, and to the empty space between the screens. No objects emerged from behind the screen. The experimenter then grasped the screens with both hands and turned them to the sides of the stage, revealing one cup or two cups standing still on the stage, about 15 cm apart. The screens stood next to the objects but not against the side walls of the stage. As the screens were being moved, the baby's attention was drawn, ''Look at this, [baby's name,]''; the experimenter's hands were visible while removing the screens but her body was hidden behind the back curtain. The experimenter could not see the infant's face; if the infant did not look at the objects on stage, the primary observer would indicate that to the experimenter and the experimenter repeated ''Look here, look, [baby's name].'' The baby's looking at the cup(s) was monitored. One of the observers was designated the primary observer; a trial ended when the baby looked away for two consecutive seconds, as determined by the primary observer's button. At the end of the trial, the experimenter placed the screens back to their original position and removed the screens along with the objects hidden behind them. The baby's attention was then drawn to the empty stage, and the next trial began. Each baby saw one of two orders of outcomes: 2, 1, 1, 2 or 1, 2, 2, 1.

These baseline trials served two purposes. First, they showed the baby that in this event, there could be either one or two objects behind the two screens that were lowered onto an empty stage. Second, they provided a baseline for each baby's preference for looking at displays consisting of one vs two objects. Of course, they provided the baby with no way of predicting which outcome would occur in the test trials.

Test trials: discontinuous movement condition. Two pairs of test trials followed the baseline/introductory trials. Each test trial contained two phases, a familiarization and a test phase.

Every test trial began by drawing the baby's attention to the empty stage, lowering two screens onto the stage, and drawing the baby's attention to the empty space between them. The manner in which these steps were carried out was identical to that of the baseline trials. During the familiarization event, objects emerged from behind the screen, traveling on the track. All object movement was controlled by the experimenter holding a stick on the bottom of each object that protruded through the track. About .5 cm of the stick was visible to the infant as the object moved; no noise was associated with the movement. One object started from behind one of the screens, moved to one end of the stage, tapped for three or four times to draw the infant's attention, ''Look here, [baby's name],'' and then back to its original position. After roughly a 2 s pause (the same amount of time for an object to travel through the intervening space), a second object, emerged from behind the second screen, moved along the track to the opposite end of the stage, tapped for three or four times to draw the infant's attention, and then back to its original position. From the infant's point of view, no object ever appeared between the two screens. In all events, the objects moved at a constant speed of about 8 cm/s.

The baby observed two emergences to one side and two to the other, alternating between the two sides and then on the fourth emergence the object was left in full view and the baby's looking monitored. This ensured that infants realized that sometimes these objects could be stationary. After the baby looked away (as determined by the primary observer's push button), the object was returned behind the screen, and a total of four more emergences and returns were presented. Thus, the baby saw the object emerge from the left screen a total of four times and from the right screen a total of four times and never saw any object move from the left to the right screen through the middle space or vice versa. After this familiarization event, the experimenter grasped the screens and turned them to the sides of the stage, revealing one object (unexpected outcome) or two objects (expected outcome). During the whole experiment, only the experimenter's hands were visible to the infant; her body was hidden behind the back curtain. In case of the unexpected outcome trials, the experimenter swiftly and quietly removed one of the objects right before the removal of the screens; the timing was such that the pause in between the last emergence and the removal of the screens for both expected and unexpected outcomes was identical. Looking time was monitored after the screens were removed, and when the baby had looked away for two consecutive seconds, the trial ended and all screens and objects were removed. A second trial ensued with the opposite outcome using a different pair of screens but the same toys. It was exactly the same as the above, except that the infant had only four exposures to the objects before the screens were removed, instead of eight. Pilot testing suggested that eight more emergences were too boring and babies became fussy. This second set of four familiarization emergences from the screen did not include one in which the object was left stationary.

A second pair of trials using the second pair of toys followed. The procedure was identical to that of the first pair (i.e., eight emergences for first trial, including one in which the object was left stationary; four emergences for second trial).

The order of pairs of toys (ducks first, foam balls first), order of outcomes (expected, unexpected, unexpected, expected or unexpected, expected, expected, unexpected), and side on which the single object appeared (left, right) were counterbalanced across subjects.

Test trials: continuous movement condition. The continuous condition was identical to the discontinuous condition except that only one object was used in the familiarization emergences and it moved back and forth along the whole track, appearing in the space between the screens.

Different color screens were used for all baseline and test trials; the order of the screens was determined in a quasi-random manner. No two consecutive trials used the same screens; the different colors were used to attract the baby's attention. One might worry that the observers could tell from the infant's eye movement whether there were one or two objects on the stage. However pilot testing revealed that observers simply could not tell, because infants move their eyes back and forth in both one- and two-object trials. This may be due to the fact that infants were searching for the second object or because screens were left on both sides of the stage so the infant does have something to look at on both sides of the stage. One may also query whether the observer could tell which condition (discontinuous vs continuous) the infant was in. Pilot testing showed that infants turned their heads to track objects in both the discontinuous and continuous conditions and it was impossible to tell whether an object appeared in the middle.

Nine of the twenty-four babies were observed by two observers. Inter-observer reliability was modest (83%) because many of these sessions were training sessions for the second observer. The primary observers had been trained in other studies; an observer is considered trained when he or she attains interscorer reliability with a trained primary observer for an average of 95% on three consecutive babies.[3]

Results

Figure 2 presents the mean looking times for each condition.[4]

Consider first the baseline/introductory trials, which were identical in both

[3] In Experiments 3–5, we introduced videotaping of babies' looking so that subjects can be off-line observed completely blindly. For all of these experiments, interscorer reliability was over 90%. Sometimes the observers could tell which experiment or condition the baby was in because of the procedure, but they were completely blind to the order of outcomes. In all experiments, observers reported that they could not guess whether the babies were looking at one object or two object outcomes. For Experiments 4 and 5, the videotape observers were asked to guess which order of outcome (1, 2 or 2, 1) each baby was in. For all 49 babies videotaped, the observers guessed correctly 26 of them, which was chance performance.

[4] Within each condition in this experiment and all subsequent experiments, initial ANOVAs examined the effects of gender, order of outcomes (1,2,2,1 or 2,1,1,2), order of object (duck first, ball first), and side of single outcome (left, right). Except for one case, there were no statistical effects of gender, order of object, order of outcomes, or side of single outcome. However, given the small number of subjects, these non-effects are not particularly meaningful.

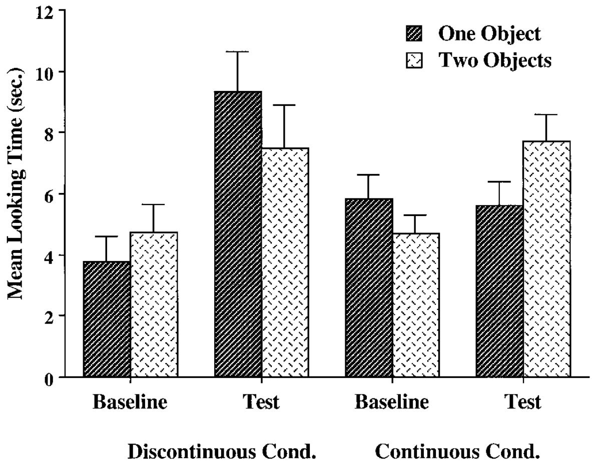

FIG. 2. Mean looking times of subjects in the discontinuous and continuous conditions to the baseline and test trials in Experiment 1.

conditions. Recall that these trials involved lowering two screens onto the stage and then turning them to the side revealing either one object behind one of them or two objects (one behind each). Babies did not differentiate outcomes of one vs two objects on the baseline trials of either condition, nor did looking times in the baseline trials differ in the two conditions. In the discontinuous condition, 8 out of 12 babies looked longer at 2 objects in the baseline trials; in the continuous condition, 6 out of 12 babies looked longer at 2 objects in the baseline trials.

Separate ANOVAs for each condition compared the pattern of looking on baseline and test trials. In the Discontinuous Condition, there was a main effect of trial type ($F(1,11) = 35.33$, $p < .001$). Babies looked reliably longer on the test trials (8.4 s) than on the baseline trials (4.3 s). Most importantly, the interaction between trial type (baseline vs test) and outcome (one vs two objects) was significant, $F(1,11) = 8.58$, $p < .02$. Babies looked longer at outcomes of one object on the test trials ($M_{\text{one-obj.}} = 9.3$ s, $SD = 4.5$; $M_{\text{two-obj.}} = 7.5$ s, $SD = 4.9$), but not the baseline trials ($M_{\text{one-obj.}} = 3.8$ s, $SD = 2.6$; $M_{\text{two-obj.}} = 4.7$ s, $SD = 3.2$; see Fig. 2). That is, babies looked longer at what for adults would be the unexpected outcome. The looking preference for one object on the test trials was itself significant ($F(1,11) = 4.97$, $p < .05$). Non-parametric analyses revealed the same pattern. Nine of twelve babies differentiated the outcomes on the test trials (i.e., looking longer at one-object displays) more than on the baseline trials (Wilcoxin $T = 12$, $p < .03$, one-tailed). On the test trials only, 9 of 12 babies showed a preference for one-object outcomes (Wilcoxin $T = 10$, $p < .03$, one-tailed). Infants looked longer at the one-object outcomes for both pairs of test trials: first pair: $M_{\text{one-obj.}} = 9.1$ s, $M_{\text{two-obj.}} = 7.7$ s; second pair: $M_{\text{one-obj.}} = 9.3$ s, $M_{\text{two-obj.}} = 7.2$ s.

An ANOVA of looking times in the Continuous Condition with trial type (baseline vs test) and outcome (one vs two objects) as factors revealed no main effect of trial type or outcome. The interaction between trial type and outcome on looking times for the test trials was significant ($F(1,11) = 6.74$, $p < .03$). This interaction was due to the babies differentiating the outcomes on the test trials, but not on the baseline trials. In this condition, babies looked longer at outcomes of *two* objects on the test trials, again, looking longer at what for adults would be the unexpected outcome. The looking preference for two objects on the test trials was itself marginally significant ($F(1,11) = 4.42$, $p < .06$). Non-parametric analyses revealed the following pattern: On the test trials alone, 9 of 12 babies preferred two-object outcomes (Wilcoxin $T = 14$, $p < .05$, one-tailed). Seven of 12 babies showed more differentiation on the test trials than on the baseline trials (Wilcoxin $T = 22$, $p > .1$, one-tailed). Infants looked longer at the two-object outcomes for both pairs of test trials: first pair: $M_{\text{one-obj.}} = 5.9$ s, $M_{\text{two-obj.}} = 8.4$ s; second pair: $M_{\text{one-obj.}} = 5.3$ s, $M_{\text{two-obj.}} = 6.9$ s.

Finally, an analysis of variance examined the effects of condition (discontinuous vs continuous) and outcome (one vs two objects) on the test trials. The interaction between condition and outcome was significant ($F(1,22) = 9.25$, $p < .006$). This further confirms that the infants were influenced by whether the familiarization events they saw involved continuous or discontinuous motion.

Discussion

Infants interpreted the discontinuous event as involving two objects, and looked longer at the unexpected outcome of one object. Just like adults, 10-month-old infants use spatiotemporal information to establish how many individuals are involved in an event, and to track identity of those individuals over time. They understand that objects travel on continuous paths; no object can jump from one point in space to another without passing through the intervening space. These data replicate the pattern of results Spelke and Kestenbaum (1986) obtained with younger infants. At 10 months, a relatively brief familiarization exposure to the discontinuous motion suffices, and at 10 months, babies differentiate the expected and unexpected outcomes even when the objects are stationary.

Spelke and Kestenbaum's (1986) younger infants interpreted the continuous event as indeterminate with respect to whether one or two objects were involved, and the 10-month-olds in Experiment 1 seem to have done the same. Although the interaction between the baseline and test trials was significant, only 7 of the 12 babies showed a stronger preference for two objects on the test trials than on the baseline trials. Furthermore, the longer looking at two objects may reflect a familiarity effect as opposed to an expectancy of one object: The babies have been shown one object over and over again, they may simply find the two-object outcome novel and more interesting to look at. Of course, the continuous event *is* actually indeterminate; it is compatible with there being one or more than one object behind the screen.

Experiment 1 confirms that 10-month-olds have the sortal concept *object.* Their capability of analyzing spatiotemporal information for evidence of how many objects are involved in events such as these is quite robust, and can be demonstrated in the familiarization version of Spelke & Kestenbaum's (1986) procedure. This sets the stage for the studies that are our main focus, those concerning the infants' ability to trace identity under sortals more specific than *object.*

EXPERIMENT 2

Experiment 2 was closely modeled on Experiment 1, with two critical differences. First, a single screen was involved in each trial. Second, the baby was familiarized with two very different objects (e.g., a toy duck and a foam ball) emerging alternately from each side of the screen. The objects in each pair differed in texture, shape, and color, as well as in kind. Adults draw the inference from the property/kind differences that there must be at least two objects behind the screen. The question is whether 10-month-old babies will similarly conclude that there must be two numerically distinct objects behind the screen.

Experiment 2 also included a condition in which babies were provided spatiotemporal information that two distinct objects were involved in the test event. At the beginning of each set of familiarization emergences, both objects were moved to each side of the screen, simultaneously visible, and the babies' attention was drawn to them. In this condition babies had both spatiotemporal and property/kind information available in their interpretation of the familiarization events.

A third condition in Experiment 2 was a baseline condition in which babies saw the same introductory trials followed by the outcomes of the test trials without any familiarization emergences. This condition provided us with an estimation of whether there was any intrinsic preference for looking at one- or two-object displays.

Method

Subjects

Forty-eight full-term infants participated in the study (24 male and 24 female) with a mean age of 10 months, 2 days (ranged from 9 months, 12 days to 10 months, 18 days). Equal numbers of infants (16) participated in each condition (mean ages 9 months 28 days, 10 months 3 days, and 10 months 2 days). The infants were recruited from the Greater Boston area as in Experiment 1. Eight additional infants were eliminated from the experiment due to fussiness (5) or equipment failure (3).

Materials and Apparatus

The same puppet stage as in Experiment 1 was used in Experiment 2. Four foam board screens (34×25 cm each) of different colors (green, yellow, lavender, and mauve) were used. The single screen was the same width as the two screens plus the gap between them in Experiment 1.

Six different toys were used in this experiment. A yellow plastic cup and a brown toy camel were used in the introductory trials. Two pairs of toys, a white foam ball and a yellow rubber toy duck, and a bright red toy truck and a light blue rubber toy elephant, were used for the test trials. The toy duck and ball were the same ones that were used in Experiment 1. The toy truck was about $12 \times 4 \times 4$ cm in size; the toy elephant was about $8 \times 6 \times 4$ cm in size.

Design and Procedure

Introductory trials. As in Experiment 1, babies in all three conditions began with four introductory trials where they were introduced to the experiment: Babies learned that there were objects behind the lowered screens, sometimes one and sometimes two. Again, these introductory trials provided no information as to how many objects would be present when the screen was removed in the test trials.

In each introductory trial, an experimenter hiding behind the black backdrop lowered a screen onto the empty stage, and then she turned the screen to the side revealing either one object (a cup or a camel) or two objects (the cup and the camel). In this and other parts of the experiment, only the experimenter's hands were visible to the infant. The experimenter had a top view of the stage such that she could not see the infant's face. Two orders of outcomes (1, 2, 2, 1 and 2, 1, 1, 2), and the order of the single object (cup, camel; camel, cup) were counterbalanced across subjects.

The same recording procedure was used as in Experiment 1. Only one very experienced observer observed each baby in this experiment (but see Experiments 3–5 for replications). The observer did not know which order of outcome (expected first or unexpected first) the baby was shown.

Property/kind condition. Experiment 2 was closely modeled on Experiment 1 (Fig. 3a). An experimenter tapped on both ends of the stage to draw the baby's attention to the empty stage, and a screen with two toys concealed behind it was lowered onto the stage. The screen was lowered at exactly the same position on the stage as were the two screens in Experiment 1. One toy was moved from behind the screen to its left and returned behind the screen; the other toy was then moved from behind the screen to its right and then returned behind the screen. The number, structure, and timing of the familiarization emergences were exactly as in Experiment 1. The first set involved four emergences of each toy, one toy being left stationary in view on the fourth emergence. After the familiarization emergences, the screen was removed

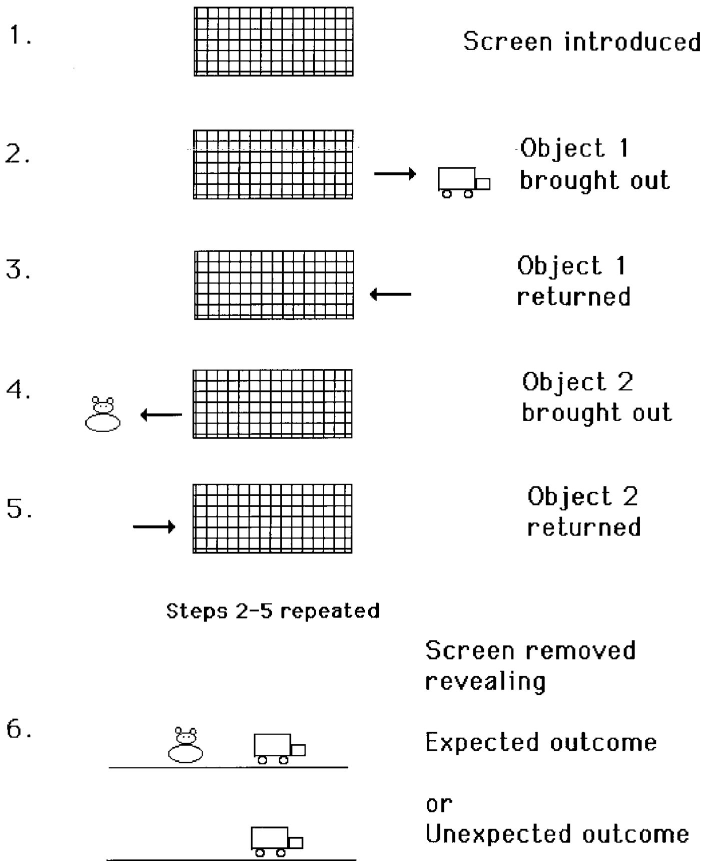

FIG. 3a. Schematic representation of the Property/Kind condition: familiarization event and the expected and unexpected outcomes in Experiment 2.

to the side, revealing either two objects (expected outcome) or one object (unexpected outcome). After the first trial, the stage was cleared, and a new screen concealing the same two toys was lowered. The second trial with this set of toys involved two familiarization emergences to each side before the screen was removed to reveal the opposite outcome of the first trial. The whole procedure was then repeated with the second pair of toys. The order of toy pairs (duck/ball vs elephant/truck), the order of outcomes (1,2,2,1 or 2,1,1,2), and which toy was the single outcome were counterbalanced across subjects.

Spatiotemporal condition. The spatiotemporal condition was identical to the property/kind condition except for one difference. The infants saw the same introductory trials involving the cup and the camel. But before each set

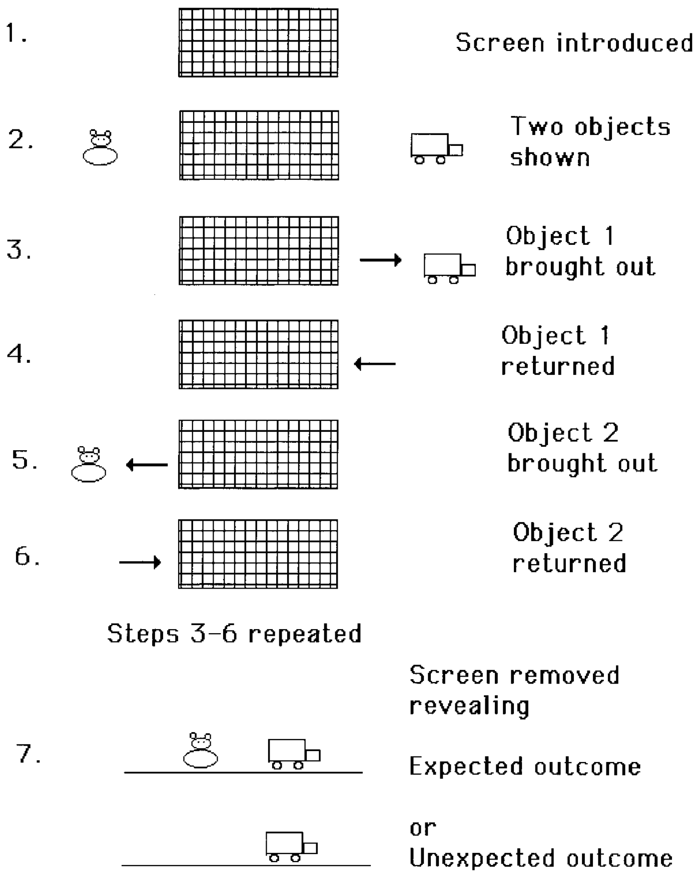

FIG. 3b. Schematic representation of the Spatiotemporal condition: familiarization event and the expected and unexpected outcomes in Experiment 2.

of familiarization emergences for the test trials, with the screen standing on stage, the experimenter brought out the two objects from behind the screen simultaneously, one to each side of the screen, tapped them on the stage for about 3 s, the baby's attention drawn to them, and then returned the objects behind the screen. The procedure then unfolded exactly as on the test trials of the property/kind condition.

Baseline condition. The baseline condition also had the same introductory trials. Following these, the infants were simply shown the outcomes of the test trials of the other two conditions without any familiarization emergences, e.g., a screen was lowered then turned to the side, showing either one or two objects behind it. The baseline condition provides a measure of the infants' intrinsic preference for looking at one-object vs two-object displays with the same objects used in the test trials.

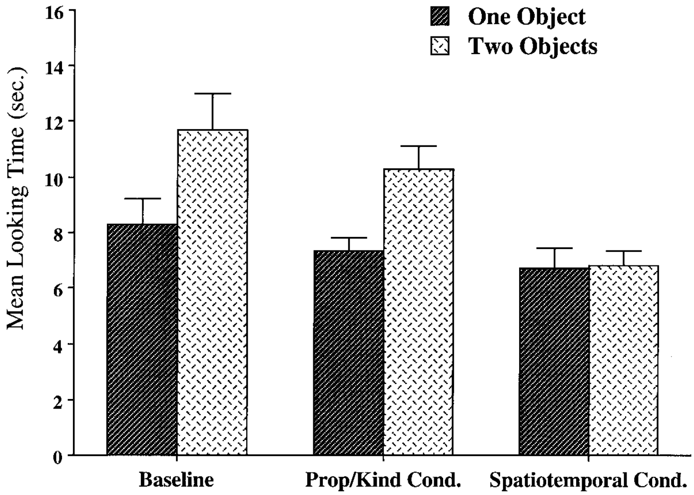

FIG. 4. Mean looking times in baseline, property/kind and spatiotemporal conditions of Experiment 2.

Results

Introductory trials. The introductory trials were identical in all three conditions. An ANOVA examined the effects of number of objects (one vs two) and condition (baseline, property/kind, spatiotemporal) on looking times. There was no main effect of number of objects, nor an interaction between number of objects and condition. In the introductory trials, infants showed no preference for looking at the outcome of one (M = 5.4 s) or two objects (M = 6.2 s). There was, however, a main effect of condition ($F(2,45)$ = 3.955, $p < .03$). Posthoc ANOVAs employing the Bonferroni procedure revealed that this was due to the infants in the spatiotemporal condition (M = 4.4 s) looking less than those in the baseline condition (M = 6.7 s) and the property/kind condition (M = 6.2 s). Since these trials were identical in all conditions, this effect must reflect random sampling differences among the groups.

Test trials. The principal findings are shown in Fig. 4, where the baseline trials were compared with the test trials of the property/kind condition and the spatiotemporal condition.

As Fig. 4 shows, the main result of this study is that the infants had a strong preference for two objects in the baseline, and they *failed* to overcome this preference in the property/kind condition but *succeeded* in the spatiotemporal condition.

Property/kind condition. Looking times in the property/kind condition were compared with that of the baseline in an ANOVA with condition (baseline vs property/kind) and outcome (one vs two objects) as variables. There was a main effect of number; overall infants looked longer at two-object displays ($F(1,30) = 14.55$, $p < .001$). More importantly, the looking time pattern for the property/kind condition did *not* differ from that of the baseline ($F(1,30) = .098$, $p = .756$; Baseline: $M_{\text{one-obj.}} = 8.3$ s, $SD = 3.8$; $M_{\text{two-obj.}} = 11.7$ s, $SD = 5.4$; Prop/Kind: $M_{\text{one-obj.}} = 7.3$ s, $SD = 2.2$; $M_{\text{two-obj.}} = 10.3$ s, $SD = 3.1$). That is, the infants did not look longer at the unexpected outcome of one object in the property/kind condition. Remember that there were two sets of test trials, first with one pair of objects and then a second pair of objects. There was no effect of trial pair; the looking preference for two object outcomes was equally strong on the second pair of objects as on the first pair of objects (Trial pair 1: $M_{\text{one-obj.}} = 7.7$ s, $M_{\text{two-obj.}} = 10.9$ s; Trial pair 2: $M_{\text{one-obj.}} = 7.0$ s, $M_{\text{two-obj.}} = 9.6$ s). Planned *t*-tests on each condition alone showed main effects of number in both conditions (Baseline: $F(1,15) = 4.708$, $p < .05$; Property/kind Condition: $F(1,15) = 32.204$, $p < .0001$). The strong baseline preference for two objects showed that the infants had to overcome this strong bias in order to succeed in any version of this task. There was not even a hint in the data that their preference was reduced in the test trials of the property/kind condition.

Individual data confirmed the above results. Twelve of the sixteen infants in the baseline condition looked longer at outcomes of two objects and 15 of the 16 infants in the property/kind condition showed the same preference on the test trials.

Spatiotemporal condition. A very different pattern of results emerged when we compared the spatiotemporal test trials and the baseline (see Fig. 4); looking preferences for outcomes of one or two objects were clearly influenced by whether or not both objects were seen simultaneously before the familiarization emergences began. An ANOVA examining the effects of condition (baseline vs spatiotemporal) and outcome (one vs two objects) on looking times revealed a main effect of condition ($F(1,30) = 10.90$, $p < .002$); infants looked overall longer in the baseline condition ($M = 10.0$ s) than in the spatiotemporal condition ($M = 6.7$ s). Recall that the same difference was seen on the introductory trials. There was also a marginally significant effect of number ($F(1,30) = 4.08$, $p = .053$). More importantly, there was an interaction between condition and number of objects ($F(1,30) = 4.71$, $p < .05$; Spatiotemporal: $M_{\text{one-obj.}} = 6.7$ s, $SD = 2.8$; $M_{\text{two-obj.}} = 6.8$ s, $SD = 2.2$). That is, although there was no overall looking preference for one object on the test trials (the unexpected outcome), the interaction between the two conditions showed that the looking time pattern in the spatiotemporal condition was significantly different from that of the baseline. The looking preference for each test trial pair was as follows: Trial pair 1: $M_{\text{one-obj.}} = 7.2$ s, $M_{\text{two-obj.}} = 7.5$ s; Trial pair 2: $M_{\text{one-obj.}} = 6.1$ s, $M_{\text{two-obj.}} = 5.9$ s.

Non-parametric analyses confirmed that infants in the spatiotemporal condition were able to overcome a baseline preference for two objects. Twelve out of sixteen infants looked longer at two-object outcomes in the baseline condition; in contrast, only 5 of the 16 infants in the spatiotemporal condition looked longer at outcomes of two objects (χ^2 (1) = 4.52, $p < .04$).

A third ANOVA compared patterns of looking times on the test trials of the property/kind condition and the spatiotemporal condition with condition and outcome (one vs two objects) as variables. There was a main effect of condition; babies looked longer at the test trials in the property/kind condition (M = 8.8 s) than in the spatiotemporal condition (M = 6.7 s; $F(1,30) = 6.87$, $p < .02$). Recall that this difference was also seen on the introductory trials. Overall there was a main effect of number ($F(1,30) = 10.98$, $p < .002$); babies looked longer at two objects. Most importantly, there was an interaction between condition and outcome ($F(1,30) = 9.53$, $p < .004$). Only the babies in the property/kind condition looked longer at outcomes of two objects. The difference between the two conditions was further revealed by non-parametric analyses; 15 of the 16 babies in the property/kind condition looked longer at outcomes of two objects whereas only 5 of the 16 babies in the spatiotemporal condition looked longer at outcomes of two objects ($\chi^2(1) = 10.80$, $p < .001$).

All of the babies in this study were observed by a single, highly trained observer. There are three reasons to be confident in these results, in spite of the fact that there was only one observer. First, the observer was blind to the order of the outcomes, and reported that she did not know which order the infant was in. Second, the results were the opposite of what we expected (we expected babies to succeed at this task), so it is unlikely that unconscious experimenter or observer bias could have influenced the results. Finally, in Experiments 3–5, we replicate these results in a new setup in which we videotape the baby’s looking and report interscorer reliability between the primary observer and the videotapes that are scored blind.

Discussion

Given that the babies had a strong preference for two-object displays, success at this task is not looking longer at the unexpected outcome of one object, but rather overcoming the baseline preference. The major result of this experiment is the failure of 10-month-old infants in the property/kind condition to do so. Rather, they did not show a different looking pattern compared to the baseline preference of looking longer at two objects. In this experiment, babies failed to demonstrate that they could use the differences between a yellow rubber toy duck emerging from one side of the screen and a white Styrofoam ball emerging from the other side of the screen to infer that there must be at least two objects behind the screen. And they equally failed to demonstrate the ability to use the differences between a bright red metal toy truck and a light blue rubber toy elephant to infer that there must be two objects behind the screen. As we try to interpret this result, we must remember that babies of this age succeeded at using two types of spatiotemporal information, i.e., the spatiotemporal information provided by discontinuous path in Experiment 1 and the spatiotemporal information provided by seeing the two objects simultaneously in Experiment 2, when provided the *same* number of familiarization emergences, and where success was measured by the *same* outcome variable. Thus, these data are consistent with the *Object*-first Hypothesis: 10-month-old infants represent one sortal concept, *object,* but not the more specific sortal concepts probed in this study (*duck, ball, truck,* and *elephant*). These data are also consistent with Bower's conjecture: Babies use spatiotemporal information to individuate and trace identity of objects over time before they use property/kind information. However, these data do not support Bower's contention that property/kind information can be exploited for object individuation and identity tracing by 5 months of age; under the conditions of this experiment, at least, even 10-month-olds failed to do so.

The infants showed a strong intrinsic preference for two objects in the baseline of Experiment 2. In contrast, the infants in Experiment 1 did not show particular preference for outcomes of one cup or two cups in the baseline trials. The difference between the two experiments lies in the fact that in Experiment 2, single object displays (e.g., a ball) are contrasted with double object displays of two very different objects (e.g., a ball and a duck). Apparently, infants found a duck and a ball much more interesting to look at than just a ball or a duck.[5]

One might argue that the strong intrinsic preference for looking longer at two objects, as shown by the baseline data, may have swamped the effect of infant's expectation for two objects. This possibility is unlikely because despite the intrinsic preference for two objects, infants in the spatiotemporal condition nonetheless showed success. That is, when given spatiotemporal information, 10-month-old infants were able to overcome their preference for two objects and exhibited a different pattern of looking compared to their baseline.

Although the looking preferences of the babies in the spatiotemporal condition differed from the baseline, these babies in the spatiotemporal condition did not look overall longer at the unexpected outcome (see Fig. 4); rather they looked about equally at outcomes of one and two objects. It seems plausible that given the strong intrinsic preference to two-object displays shown in the baseline, infants may not be able to completely override the tendency. It is also possible, however, that the infants construed the back and forth pattern of emergences as providing positive spatiotemporal evidence for a single object, much in the same manner of the continuous trajectory of

[5] Readers may wonder why there was no preference for two-object displays (a camel and a cup) over one-object displays (just a camel, or just a cup) on the introductory trials of Experiment 2. We think that the properties of these two objects were not as distinct as the other objects we used. Since they were different objects from the ones used in the test trials, they did not provide a proper baseline. Hence a baseline condition was needed.

Experiment 1. Thus the spatiotemporal condition of Experiment 2 may pit two sources of spatiotemporal information against each other and these two sources of information canceled each other. We think that the first possibility (strong baseline preference for two) is more likely, but in Experiment 3 we attempt to break the illusion of a single oscillating motion by leaving the objects in view for the baby to habituate to during the familiarization emergences.

Readers may recall that overall the infants in the spatiotemporal condition looked less than infants in the other two conditions. This is worrisome because it is possible that the reason infants succeeded in the spatiotemporal condition is not because they had the spatiotemporal information but rather it was because this particular group of babies were fast encoders (Columbo, Mitchell, & Horowitz, 1988). And the fact that we did not use a full habituation paradigm raises the possibility that 10-month-olds may be able to use property/kind information to infer identity change but just not as efficiently as using the spatiotemporal information. These questions will be taken up in Experiments 3 and 4, respectively.

One last concern is that babies apparently failed to use property/kind differences to infer there must be two objects, but perhaps they did not *notice* the property differences. Babies' performance in the property/kind condition was consistent with the following representation of the familiarization events: An object emerges from left and returns behind the screen; an object emerges from right and returns behind the screen, etc. In this representation, there is no further specification of object properties or kind. We find this an unlikely possibility, given evidence that babies even much younger than these habituate to objects that share salient properties, and dishabituate when presented an object that differs with respect to these properties (e.g., Cohen & Younger, 1983). However, it is important for us to show that under the circumstances of our experiments, infants encode the properties of the objects. This question is addressed directly in Experiment 3.

EXPERIMENT 3

Experiment 3 addresses several questions raised by Experiment 2. First, given the amount of exposure during familiarization, perhaps babies did not even notice the property/kind differences between the two objects, in which case they certainly could not infer from these differences that there were two objects behind the screen. In Experiment 3, objects were left stationary in full view for a total of four times during familiarization emergences, providing ample opportunities for the infants to encode their properties. The infants were allowed to look at these objects for as long as they desired. This manipulation will also bear on the possibility that infants in Experiment 2 may have taken the oscillating motion as *positive* evidence that there was only one object, for leaving the objects stationary breaks the regular oscillation. Finally, the possibility that the property differences between the objects might be having at least *some* effect on object individuation will be addressed through a comparison with a condition where a single object emerged from both sides of the screen.

Method

Subjects

Thirty-two full-term 10-month-old infants (14 male and 18 female) were randomly assigned to the Different Condition (mean age of 10 months, 1 day; range from 9 months, 15 days to 10 months, 13 days) or to the Same Condition (mean age of 9 months, 29 days; range from 9 months, 13 days to 10 months, 16 days). The baseline from Experiment 2 served as the baseline for the Different Condition. A group of 16 infants (7 male and 9 female) was assigned to the baseline condition for the Same Condition (mean age 10 months, 7 days; range from 9 months, 23 days to 10 months, 17 days). All infants were recruited from the Greater Boston area as in previous experiments.

Materials and Apparatus

The toys used were exactly the same as in Experiment 2. The stage was the same one as in Experiment 2. Additionally, a video camera was set up under the stage, focusing on the baby's face. 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.

Design and Procedure

Equal numbers of infants participated in four conditions: the Different Condition (or the ''duck-ball'' condition) and its baseline (the ''duck-ball'' baseline), and the Same Condition (or the ''duck-duck'' condition) and its baseline (the ''duck-duck'' baseline). Four introductory trials preceded test trials in all four conditions. In the Different Condition and its baseline condition, the introductory trials were the same as in Experiment 2 using a cup and a toy camel; in the Same Condition and its baseline condition, one or two identical cups were shown in the order of 1, 2, 2, 1 or 2, 1, 1, 2.

Different (or ''duck-ball'') condition. The procedure for the Different Condition was the same as in the Property/Kind condition in Experiment 2 with one important modification. During the familiarization emergences (preceding the first removal of the screen on the test trials), the infants saw a total of 10 emergences of the pair of toys alternating on two sides of the screen. On the third and fourth, and seventh and eighth emergences, the object was left stationary on the side of the stage and looking time was monitored. That is, the infants saw each object twice standing stationary. This modification serves several purposes. One is that the looking times we record during the familiarization event, when compared with the counterpart in the Same Condition, will tell us whether the infants have noticed the perceptual differences between the duck and the ball. A second is that leaving the objects out for the babies to look at until they are bored will, to a certain extent, break the illusion of a single oscillating trajectory. Finally, this modification provides the infant more time to encode the properties of the two different objects.

Different (or ''duck-ball'') baseline. The baseline for the Different Condition was taken from Experiment 2. After the four introductory trials, the baby was shown the outcomes of the test trials without any familiarization emergences, e.g., a screen was lowered with the objects concealed behind it, then removed to the side to reveal the objects, say a duck and a ball.

Same (or ''duck-duck'') condition. The procedure for the Same Condition was the same as that in the Different Condition with one major difference: Instead of using two very different objects for each pair of toys, two identical objects were used, i.e., two identical toy ducks, two identical balls, two identical toy elephants, and two identical toy trucks. Half of the babies saw a pair of ducks and a pair of balls; half of the babies saw a pair of elephants and a pair of trucks.

Same (or ''duck-duck'') baseline. The infants in this condition were shown the same introductory trials as in the Same Condition, followed by just the outcomes of the test trials of the Same Condition without any familiarization emergences, e.g., a screen was lowered with the objects concealed behind it, then removed to the side to reveal the objects, say two identical ducks.

Results

Introductory trials. An ANOVA examined the introductory trials of the Different Condition and its baseline with condition (different vs baseline) and outcome (one vs two objects) as variables. There were neither main effects of condition or outcome nor an interaction between the two factors. That is, infants did not look longer at either one object or two objects and the baseline infants did not differ from the infants in the Different condition. A similar ANOVA examined the introductory trials of the Same Condition and its baseline with condition and outcome as variables. Again, there were no main effects or interactions between these variables.

Habituation trials. During the familiarization emergences, each object was left stationary twice for the baby to look at until she/he turned away, yielding four habituation trials. An ANOVA examined the effects of trial (1 vs 2 vs 3 vs 4) and condition (Different vs Same) on these looking time measures (Fig. 5). There was an interaction between the two factors, $F(3,90) = 2.886$, $p < .04$. This interaction was due to there being no effect of trial number in the Different Condition, contrasted with a significant decrease in looking times between trial 1 and trial 2 in the Same

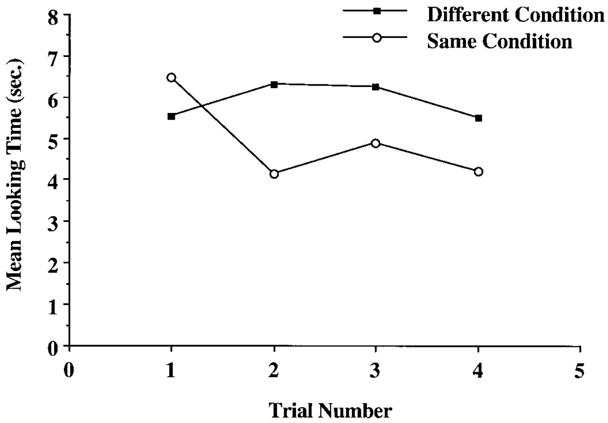

FIG. 5. Mean looking times for the habituation trials of Experiment 3.

Condition. In sum, babies who saw the sequence duck, duck, duck, duck showed significant habituation over the familiarization emergences, whereas babies who saw the sequence duck, ball, duck, ball did not. We conclude that babies in the Different Condition noticed the differences between the two objects of each pair.

Even though the infants noticed the property differences, the question of interest is whether these property differences had any impact at all on infants' inference of how many objects were behind the screen. This was analyzed by a comparison of the test trials with the baseline condition (Fig. 6).

Different (or ''duck-ball'') condition test trials and its baseline. Baseline: An ANOVA examined the effect of number, and found a strong preference for looking longer at two-object displays ($F(1,15) = 4.708$, $p < .05$). Twelve of the sixteen infants exhibited this preference.

Different Condition: An ANOVA was performed with type of trial (baseline vs test) and outcome (one vs two) as variables. There was a main effect of number ($F(1,30) = 11.111$, $p < .002$). Infants looked longer at two-object displays ($M = 10.5$ s) than one-object displays ($M = 7.3$ s). There was no interaction between the two factors ($F(1,30) = .066$, $p = .80$; Test: $M_{\text{one-obj.}} = 6.4$ s, $SD = 2.7$; $M_{\text{two-obj.}} = 9.4$ s, $SD = 5.4$). Thirteen of the sixteen infants looked longer at two-object outcomes on the test trials. In sum, the infants did not exhibit a pattern of data on the test trials that was different from the baseline preference for two objects.

Same (''duck-duck'') condition test trials and its baseline. Baseline: An ANOVA examined the effect of number. There was no main effect of number. Nine of the sixteen infants looked longer at two-object outcomes.

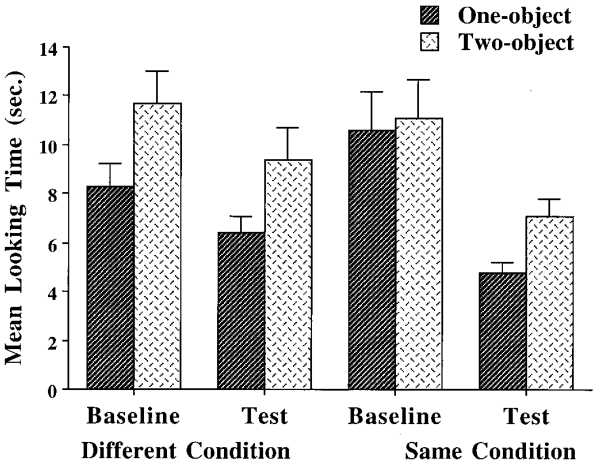

FIG. 6. Mean looking times for the Different and Same conditions and their respective baseline in Experiment 3.

Same Condition: An ANOVA was carried out with type of trial (baseline vs test) and outcome (one vs two) as variables. There was a main effect of type ($F(1,30) = 9.222$, $p < .005$) as well as a main effect of number ($F(1,30) = 4.522$, $p < .05$). Infants looked longer on the baseline trials ($M = 10.8$ s) than the test trials ($M = 6.0$ s); they also looked longer at two-object displays ($M = 9.1$ s) than one-object displays ($M = 7.7$ s). There was no interaction between type of trial and outcome ($F(1,30) = 1.816$, $p = .188$; Baseline: $M_{\text{one-obj.}} = 10.6$ s, $SD = 6.5$; $M_{\text{two-obj.}} = 11.1$ s, $SD = 6.5$; Test: $M_{\text{one-obj.}} = 4.8$ s, $SD = 1.8$; $M_{\text{two-obj.}} = 7.1$ s, $SD = 2.8$). That is, the infants' preference for two-object outcomes on the test trials did not differ significantly from the baseline preference. However, since there was no reliable difference on the baseline trials, an ANOVA with outcome (one vs two) as factor was carried out with the test trials alone. There was a main effect of outcome, $F(1,15) = 9.372$, $p < .01$. Thirteen of the sixteen infants preferred two-object outcomes on the test trials.

Finally a three-way ANOVA was performed with condition (different vs same), type of trial (baseline vs test) and outcome (one vs two objects) as variables. There was a main effect of number ($F(1,60) = 15.617$, $p < .001$); infants looked longer at two-object displays ($M = 9.8$ s) than one-object displays ($M = 7.5$ s). There were no interactions among these variables. For our purpose, it was especially important that there was no three-way interaction ($F(1,60) = .944$, $p = .335$). This shows that the pattern of results for the Different Condition was not statistically different from that of the Same Condition.

All babies in Experiment 3 were videotaped. Off-line observers, who were completely blind to which condition the baby was in or in which order the stimuli were presented, scored the videotapes. Interscorer reliability averaged 90%.

Discussion

Experiment 3 replicated and extended our findings from Experiment 2. In Experiment 3, we tried to break the illusion of an oscillating single trajectory by leaving the toys out for the baby to habituate to. That this manipulation did not change the results suggests that it was unlikely that in Experiment 2 the oscillating motion provided positive evidence for the babies that there was only one object. In Experiment 3, we have shown that the babies' failure is not due to not noticing the property differences between the two objects. Rather, the babies noticed the perceptual differences between each pair of objects, but they failed to use that information to infer that there were two objects behind the screen. Experiment 3 makes the important conceptual point that setting up representations of two numerically distinct individuals is different from noticing the property differences between two presentations of what might be one or two objects.

The data from Experiment 3 are consistent with the strong claim that the property differences between the two objects had no effect at all on the baby's looking time patterns, since there was no three-way interaction between condition (Same vs Different), trial type (baseline vs test) and number of objects in the outcome (one vs two). However, it is likely that the babies' looking preference for two objects in the test trials of the Same Condition had a different source from superficially the same preference in the test trials of the Different Condition. First, babies had habituated in the Same Condition, but not in the Different Condition (see Fig. 5). Thus, while infants had noticed the property differences between the two objects, perhaps they had not fully encoded them, and that is why they had not concluded that there were two distinct objects. Perhaps they did expect two objects, but since they were in the midst of habituation, they had a preference for the expected outcome. Experiment 4 addresses these possibilities with a full habituation paradigm.

A second reason to suspect that the babies' preference for two objects in the Same Condition has a different source from that in the Different Condition is that in the Different Condition, the preference for two objects was the baseline preference and in the Same Condition it was not.[6] The significant preference for two objects in the test trials of the Same Condition is closely analogous to the preference for two objects in the Continuous Condition of Experiment 1. In both cases, it may simply reflect familiarity with ''oneness'' and novelty with ''twoness.'' (This factor could be playing a role in the

[6] Note, however, that there was no baseline by test interaction in either the Same or the Different Condition.

preference for two objects in the Different Condition as well.) Alternatively, it is possible that the infants' analysis of the properties of the objects contributed to an expectation of one. However, the fact remains that the infant was not able to use the *differences* of properties in the Different Condition to establish representations of two distinct objects.

EXPERIMENT 4

The results so far still leave open the possibility that 10-month-olds can use property/kind information to trace identity, but they simply cannot do so as efficiently as they can use spatiotemporal information. First, we have not so far used a full habituation paradigm, so we have not given babies the greatest possible opportunity to set up representations of two objects in the property/kind condition. Second, recall that in Experiment 2, the infants in the spatiotemporal condition showed a significantly shorter looking time on the introductory as well as the test trials than did the infants in the property/kind condition. This fact may be important, since it raises the possibility that the success of the babies in the spatiotemporal condition was due to their being fast habituators. The lack of habituation in the Different Condition in Experiment 3 also points to the possibility that the infants might not have had sufficient time to set up representations of two distinct objects in the experiment. And finally, the relatively unfamiliar objects used in Experiments 2 and 3 might have contributed to their failure.

Experiment 4 compared two conditions, Property/kind and Spatiotemporal, in a full habituation procedure. Since babies were randomly assigned to these conditions, we expected no sampling differences between the two groups in Experiment 4. Experiment 4 introduces three changes to Experiment 2. First, new objects were used, ones judged to be highly familiar by parents (bottle, ball, cup, and book). Second, only one pair of objects was used in the test trials (due to full habituation). Third, the introductory trials used two pairs of dissimilar and distinct objects, therefore providing a within-subject baseline.

Method

Subjects

Twenty-four full-term infants participated in the study (11 female and 13 male). Half of the infants were randomly assigned to the property/kind condition; their mean age was 10 months 6 days (ranged from 9 months, 20 days to 10 months, 20 days). Half of the infants were randomly assigned to the spatiotemporal condition; their mean age was 10 months 1 day (ranged from 9 months 16 days to 10 months 13 days). All infants were recruited from the Greater Boston area as in previous experiments. One additional infant was eliminated from the study due to fussiness.

Materials and Apparatus

Six toys were used as stimuli: a red metal toy truck, a gold wire basket, a tennis ball with green and pink stripes, a bottle with small light blue bear pattern, a sippy cup with a red top, and a yellow baby book. The apparatus was the same as in Experiment 3. All sessions were videotaped for off-line observing; the videotapes provided no information about what was shown on the stage or in what order objects were shown.

Design and Procedure

Before the experiment, parents were asked to fill out a questionnaire to indicate whether their infants were familiar with the objects in the stimulus set (ball, bottle, cup, and book) on a 1 to 5 rating scale and whether they thought their infants understood the words for these objects (yes or no).

Baseline/introductory trials. Experiment 4 used a within subject baseline. In order to maximize the reliability of the baseline as an accurate measure of the infants' intrinsic preference, the following design was adopted: For half of the infants who had bottle and ball as their test stimuli, the other two pairs of objects, namely truck and basket, and cup and book, were used as baseline stimuli; for the other half of the infants who had cup and book as their test stimuli, truck and basket, and bottle and ball were used in the baseline. The baseline/introductory trials were carried out exactly the same way as in previous experiments with order of objects and order of outcome (1, 2, 2, 1 or 2, 1, 1, 2) counterbalanced across subjects.

Property/kind condition. After the four baseline/introductory trials, habituation began. The experimenter lowered a screen with two objects concealed behind it. To minimize the difference between this condition and the spatiotemporal condition (see below), she first showed the infant the objects briefly one at a time: One object was brought out to one end of the stage, tapped for three or four times, the infant's attention was drawn to it, ''Look, [baby's name],'' and returned behind the screen. The second object was then brought out briefly to the other end of the stage in the same manner. Then the habituation phase began. The experimenter brought out the first object, say a bottle, to one end of the stage, tapped the object on the stage three or four times while saying ''Look at this, [baby's name],'' then left the object there for the infant to look at until the infant turned away for two consecutive seconds. The experimenter then brought the first object back behind the screen. After a brief pause, she brought out the second object, say a ball, to the other end of the stage. She tapped the object on stage, drew the infant's attention, and left it in full view for the infant to look at until the infant turned away. This sequence was repeated until either the habituation criterion was met, i.e., the average looking time for the last 3 trials was half of the average for the first 3 trials, or when the baby had looked for 14 trials. To remind the baby that there were two objects behind the screen, objects were then brought out briefly one at a time without being left stationery for the infants to look at. After habituation and the two brief emergences of the objects, the experimenter removed the screen to the side revealing one or two objects. After the baby looked away, the stage was cleared. A different color screen was then lowered with the same two objects concealed behind it. The experimenter showed the infant each object briefly one at a time then removed the screen to the side to reveal the objects. This sequence was repeated until 6 test trials were completed. The test trials were in the order of 1, 2, 1, 2, 1, 2 or 2, 1, 2, 1, 2, 1, counterbalanced across subjects.

Spatiotemporal condition. As in the Property/Kind condition, habituation began after the four baseline/introductory trials. The experimenter lowered a screen with two objects concealed behind it. She brought out the first object, say a bottle, to one end of the stage, tapped it on the stage for three or four times, and drew the baby's attention to it ''Look, [baby's name]''; she then brought out the second object, say a ball, to the other end of the stage when the first object was in full view, tapped the second object for three or four times, and drew the baby's attention to it ''Look, [baby's name].'' The experimenter then tapped both objects on the stage simultaneously for three or four times while saying ''Look, [baby's name]'' and brought them behind the screen together. The timing of this event was matched with the timing of the Property/Kind condition's brief emergences of the two objects. Then the habituation phase began; it was carried out in exactly the same way as in the Property/Kind condition, i.e., each infant looked at the two objects alternately (not simultaneously) until she/he met the habituation criterion. When the baby reached habituation criterion or looked for 14 trials, the two objects were again brought out for a brief period simultaneously and returned behind the screen. The experimenter then removed the screen to the side revealing either one or two objects. After the baby looked away, the stage was cleared. A different screen was then lowered with the same two objects concealed behind it. The experimenter showed the two objects simultaneously for a brief few seconds, returned them behind the screen, then removed the screen to the side to reveal the objects. This sequence was repeated until 6 test trials were completed. The test trials were in the same orders as in the Property/Kind Condition, counterbalanced across subjects.

Results

Twenty-two of the twenty-four infants' parents filled out the questionnaires. Parental reports indicated that the objects we used in the study were indeed very familiar to the infants of this age. With 1 being very familiar and 5 being very unfamiliar, the mean ratings for the objects were as follows: ball-1.5; bottle-1.9; book-1.5; and cup-1.4. In addition, babies were judged to understand the words that label these objects more than half of the time. The rates of parentally judged comprehension were comparable to those gathered on the MacArthur Communicative Development Inventory (Fenson *et al.*, 1991): ball-59.1% (MacArthur, 59.7%); bottle-63.6% (MacArthur, 68.7%); book-63.6% (MacArthur, 50.7%); and cup-54.5% (MacArthur, 41.8%). Since parents were instructed to give us their best guess as to whether the child understood the words, we don't know how reliable these figures are.

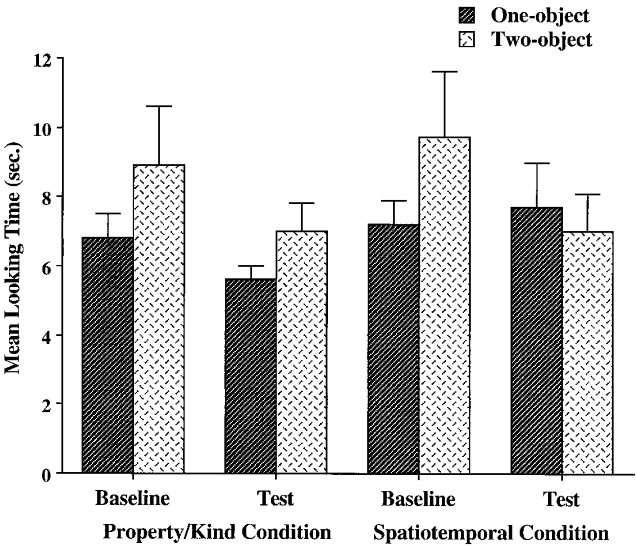

FIG. 7. Mean looking times for property/kind and spatiotemporal conditions of Experiment 4.

The mean numbers of trials taken to reach habituation criterion were 9.3 trials for the property/kind condition and 10.3 trials for the spatiotemporal condition. A *t*-test revealed that they did not differ from each other ($t(22) = .887$, $p = .39$).

The main findings of Experiment 4 are shown in Fig. 7. Baseline/introductory trials, which were identical in both conditions, were examined for effects of condition (property/kind vs spatiotemporal) and number (one vs two). An ANOVA revealed a main effect of number, $F(1,22) = 4.904$, $p < .04$, and no interaction between the two variables. The main effect for number reflects the baseline preference for displays of two objects, also seen in the baseline trials of Experiments 2 and 3. There was a fairly strong preference for looking longer at two-object displays in both conditions (Property/Kind condition: $M_{\text{one-obj.}} = 6.8$ s, $SD = 2.5$; $M_{\text{two-obj.}} = 8.9$ s, $SD = 5.7$; Spatiotemporal condition: $M_{\text{one-obj.}} = 7.2$ s, $SD = 2.3$; $M_{\text{two-obj.}} = 9.7$ s, $SD = 6.6$). As expected, there was no main effect of condition; the sampling difference between the two conditions of Experiment 2 was not found here.

Separate ANOVAs compared baseline and test trials within each condition. The ANOVA examining the effects of trial type (baseline vs test) and outcome (one vs two objects) on looking times in the property/kind condition revealed no main effects or interactions (Prop/Kind: $M_{\text{one-obj.}} = 5.6$ s, $SD = 1.6$; $M_{\text{two-obj.}} = 7.0$ s, $SD = 2.8$). The ANOVA examining the effects of trial type (baseline vs test) and outcome (one vs two objects) in the spatiotemporal condition revealed an interaction between these two variables ($F(1,11) =$

6.091, $p < .04$; $M_{\text{one-obj.}} = 7.7$ s, $SD = 4.4$; $M_{\text{two-obj.}} = 7.0$ s, $SD = 3.7$). Finally, an ANOVA with condition (property/kind vs spatiotemporal) and number of objects in outcome (one vs two) revealed an interaction between the two variables ($F(1,22) = 4.324$, $p < .05$).

Nonparametric tests corroborated on the above results. In the property/kind condition, 8 out of 12 babies looked longer at two-object displays on the baseline trials and 9 babies showed the same preference on the test trials; in the spatiotemporal condition, 8 out of 12 babies looked longer at two-object displays on the baseline trials whereas only 4 babies showed the same preference on the test trials. A chi-square test revealed that the patterns on the test trials of the two conditions were different, $\chi^2(1) = 4.17$, $p < .05$.

All infants in this study were videotaped and scored off-line by an observer. The average interscorer reliability was 91%.

We will defer discussion of the possible relations between word comprehension and performance on the task until after presenting Experiment 5.

Discussion

Despite all the changes between Experiments 2 and 4—new highly familiar objects, full habituation procedure—Experiment 4 provides a complete replication of the results of Experiment 2. The full habituation paradigm gives the infant massive exposure to the objects, yet those in the property/kind condition still failed to overcome their baseline preference for two object displays. And again, those in the spatiotemporal condition succeeded in overcoming their baseline preference for outcomes of two objects.

In Experiment 4, the babies in the spatiotemporal condition did not differ from those in the property/kind condition in overall looking time, suggesting that the different pattern of results between the two conditions in Experiment 2 was not due to the sampling difference between the two groups. Rather, these data support the conclusion that the difference between the groups in Experiments 2 and 4 is due to the fact that 10-month-olds use spatiotemporal information to individuate objects but fail to use property/kind information to do so, at least under the circumstances of our experimental manipulations.

The data from Experiment 4 provide further evidence that setting up a representation of the properties of objects is psychologically separable from establishing representations of distinct individuals. Babies in the spatiotemporal condition established representations of two different individuals; babies in the property/kind condition did not. Yet both groups habituated to the familiarization emergences at exactly the same rate.

Together, Experiments 1–4 provide support for the *Object*-first hypothesis. These studies raise the question of when babies come to represent sortals more specific than *object,* such as *ball, bottle, book,* and *cup.*

EXPERIMENT 5

Experiment 5 addressed the question of at what age infants will use property/kind information to individuate objects under these conditions. In a pilot study, we tested a group of 11-month-olds under exactly the same conditions as the 10-month-olds of Experiment 2. Their preference for two-object outcomes was less than that of the 10-month-olds, but not significantly so. Therefore, we decided to test a group of 12-month-olds with the more familiar objects of Experiment 4. A new group of 10-month-olds were tested under the exact same conditions to provide a comparison and to provide still further possibility of disconfirmation of our basic findings in Experiments 2–4.

Method

Subjects

Thirty-two full-term infants participated in the study, including 16 10-month-olds (9 boys and 7 girls) with a mean age of 10 months, 1 day (ranged from 9 months 17 days to 10 months, 20 days) and 16 12-month-olds (10 boys and 6 girls) with a mean age of 12 months, 10 days (ranged from 11 months, 29 days to 12 months, 23 days). The infants were recruited from the Greater Boston area as in previous experiments. An additional four 10-month-olds were eliminated from the experiment due to fussiness; an additional three 12-month-olds were eliminated from the experiment due to fussiness (2) or experimenter error (1).

Materials and Apparatus

Two pairs of toys were used in baseline/introductory trials: a bunny and a basket; a toy truck and a camel. The same two sets of toys from Experiment 4 were used as stimuli for the test trials: ball, bottle, cup, and book. The stage was the same as in previous experiments. A video camera recorded the sessions for off-line observing; the videotapes provide no information about what was presented on the stage.

Design and Procedure

Before the experiment, parents were asked to fill out a questionnaire to indicate whether their infants were familiar with the objects in the stimulus set (ball, bottle, cup, and book) on a 1 to 5 rating scale and whether they thought their infants understood the words for these objects (yes or no).

The procedure was exactly the same as in the property/kind condition of Experiment 2 with both groups of infants. The only modification was that this experiment used a within-subject baseline; two pairs of objects were used during four baseline/introductory trials which preceded the test trials. Two orders of outcome on these baseline/introductory trials were 1, 2, 2, 1 or 2, 1, 1, 2. The order of objects and which object was in the single-object outcome were counterbalanced across subjects.

Results

Parental reports collected before the experiment showed that both groups of infants were very familiar with the stimuli. For each group, 13 of the 16

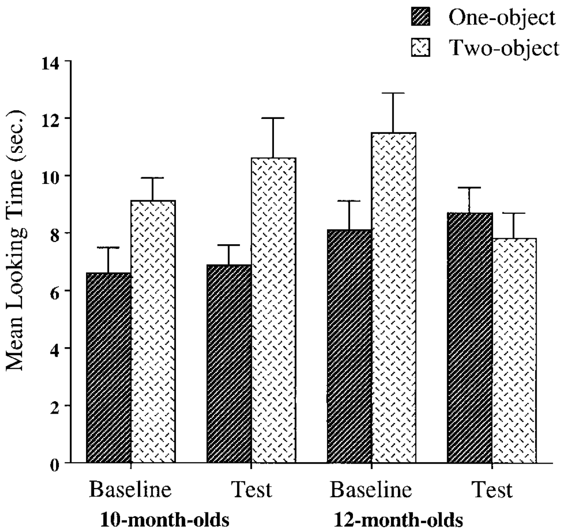

FIG. 8. Mean looking times for 10- and 12-month-olds in Experiment 5.

parents filled out the questionnaire. With 1 being very familiar and 5 being not familiar at all, the mean ratings for 10-month-olds were ball-2, bottle-1.7, cup-1.4, and book-1.7; the mean ratings for 12-month-olds were ball-1.2, bottle-1.6, cup-1.2, and book-1.4. The ratings between the two age groups are not substantially different. For word comprehension, the proportion of infants who were reported to understand these works were: 10-month-olds: ball-7.7% (MacArthur: 59.7%); bottle-30.8% (MacArthur: 68.7%); book-15.4% (MacArthur: 50.7%); cup-7.7% (MacArthur: 41.8%); 12-month-olds: ball-84.6% (MacArthur: 79.5%); bottle-84.6% (MacArthur: 77.3%); book-53.8% (MacArthur: 68.2%); and cup-46.2% (MacArthur: 55.7%). As can be seen, the 10-month-olds in this study were rated as less likely to comprehend these words than were those in Experiment 4 and the MacArthur norms. The 12-month-olds were rated more likely to know these words than the 10-month-olds, and more or less in line with the MacArthur inventory norms.

The main results of the experiment, comparing 10- and 12-month-olds, are shown in Fig. 8.

First consider the baseline/introductory trials. An ANOVA examined the baseline trials for both groups with age (10- vs 12-month-olds) and number (one vs two) as variables. There was no effect of age, a significant effect of number ($F(1,30) = 16.599$, $p < .0001$), and no interaction between these two variables. Infants looked longer at two-object displays ($M = 10.3$ s) than one-object displays ($M = 7.3$ s). Twelve of the sixteen 10-month-olds showed longer looking at two-object displays and 12 of the 16 12-month-olds showed the same preference. In sum, both age groups had an equally strong intrinsic preference for looking at two-object displays in the baseline/introductory trials.

Looking times for each group were analyzed in an ANOVA with trial type (baseline vs test) and outcome (one vs two) as within-subject variables. For the 10-month-olds, there was no main effect of trial type but there was a significant main effect of number ($F(1,15) = 10.692$, $p = .005$). Babies looked longer at two-object displays ($M = 9.8$ s) than one-object displays ($M = 6.7$ s). There was no interaction between trial type and outcome ($F(1,15) = .718$, $p = .410$; Baseline: $M_{\text{one-obj.}} = 6.6$ s, $SD = 3.1$; $M_{\text{two-obj.}} = 9.1$ s, $SD = 3.7$; Test: $M_{\text{one-obj.}} = 6.9$ s, $SD = 2.8$; $M_{\text{two-obj.}} = 10.7$ s, $SD = 5.6$). Recall that there were two pairs of test trials, and the same pattern held for both of them (Trial pair 1: $\mathrm{M}_{\text{one-obj.}} = 7.1$ s, $M_{\text{two-obj.}} = 10.7$ s; Trial pair 2: $M_{\text{one-obj.}} = 6.7$ s, $M_{\text{two-obj.}} = 10.5$ s). For the 12-month-olds, there was no main effect of trial type and a marginally significant effect of number ($F(1,15) = 3.96$, $p = .065$). Again, babies looked longer at two-object displays ($M = 9.6$ s) than one-object displays ($M = 8.4$ s). More importantly, there was a significant interaction between trial type and outcome ($F(1,15) = 4.824$, $p < .05$; Baseline: $M_{\text{one-obj.}} = 8.1$ s, $SD = 4.0$; $M_{\text{two-obj.}} = 11.5$ s, $SD = 5.5$; Test: $M_{\text{one-obj.}} = 8.7$ s, $SD = 3.7$; $M_{\text{two-obj.}} = 7.7$ s, $SD = 3.8$). Again, there were two pairs of test trials and the trial pair data were as follows: Trial pair 1: $\mathrm{M}_{\text{one-obj.}} = 8.2$ s, $M_{\text{two-obj.}} = 8.5$ s; Trial pair 2: $M_{\text{one-obj.}} = 9.2$ s, $M_{\text{two-obj.}} = 7.1$ s.

An ANOVA analyzing the test trials only with age group as a between subject variable and outcome (one vs two) as a within-subject variable showed no main effect of either age or outcome. Most importantly, there was an interaction between age group (10- vs 12-months) and outcome (one vs two), $F(1,30) = 6.275$, $p < .02$. This interaction confirms that the two groups of infants differed in their capacity to use property/kind information to establish representations of two distinct objects.

Nonparametric tests confirmed the above results. For the 10-month-olds, 12 of the 16 infants looked longer at the two-object displays on the baseline trials and 13 of them showed the same preference on the test trials. In contrast, 12 of the 16 12-month-olds looked longer at two-object displays during baseline trials whereas only 4 12-month-olds showed the same preference on the test trials (Wilcoxin $T = 29$, $p < .05$, one-tailed). A chi-square test showed that difference between the two age groups on the test trials was significant, $\chi^2(1) = 8.03$, $p < .01$.

Twelve of the sixteen 10-month-olds and 13 of the 16 12-month-olds were videotaped and observed off-line by observers who were blind to the order of the outcomes. The mean interscorer reliability was 94 and 91%, respectively.

Discussion

The 10-month-olds in Experiment 5 showed the same failure as those in Experiments 2–4. By 12 months of age, infants succeed at the task quite robustly. By this age, they are able to overcome a strong baseline preference

TABLE 1
Number of Infants in Each Age Group Comprehending 0, 1, 2, 3, or 4 Words

Number of words understood	0	1	2	3	4
10-month-olds	9	4	6	4	0
12-month-olds	0	2	4	5	2

for two-object displays, showing a very different pattern of looking on the test trials than on the baseline trials.

These data are consistent with the possibility that by 12 months of age, babies have constructed at least some sortals more specific than *object* (namely, *ball, book, cup,* and *bottle*). That is, babies can use membership in two of these kinds to individuate objects. However, these data do not allow us to decide whether 12-month-olds are using *property* information (e.g., the distinction between a bottle shape and a ball shape) or *kind* information (e.g., the distinction between a bottle and a ball) in individuating these entities.

In sum, these data are consistent with the hypothesis that 10-month-old infants have *not* constructed sortals corresponding to the kinds of objects used in these studies, even for highly familiar objects such as bottles and cups. By 12 months of age, babies may have done so.

Exploratory Analyses of the Noun Comprehension Data

There is a change between 10- and 12-month-olds' ability to use property/kind information to individuate objects, at least under the conditions of this study. The age at which this transition is made is significant, for these are the ages during which babies begin to comprehend words (Huttenlocher, 1974; Oviatt, 1980). Collapsing over Experiments 4 and 5, we have parental reports on infants' comprehension of the nouns for the four highly familiar objects in the test trials for 23 10-month-olds and 13 12-month-olds.

Table 1 shows the distribution of number of words known by the infants. A Chi-square test shows that the distributions are different ($\chi^2(4) = 10.2$, $p < .05$). Over half of the 10-month-olds were judged by their parents to know none or at most one of the four words. In contrast, the majority (85%) of the 12-month-olds were reported to understand two or more of the words, and most of them were credited with knowledge of three or four words. No 10-month-olds were judged to comprehend all four words whereas two of the 12-month-olds were. No 12-month-olds were reported to understand zero words whereas nine 10-month-olds were. The correspondence in time of the two developments—the ability to use the differences between a ball and a bottle to individuate objects and the ability to comprehend nouns such as ''ball'' and ''bottle''—raises the question of the relation between the two achievements. As a preliminary exploration of this relation, we analyzed 10-

TABLE 2
10-Month-Olds' Looking Time Patterns (in seconds) as a Function of Comprehension Scores

	Experiment 4		Experiment 5		Collapsing Experiments 4 and 5	
Comprehension score	0 or 1	2 or 3	0 or 1	2 or 3	0 or 1	2 or 3
Number of subjects	$n = 3$	$n = 7$	$n = 10$	$n = 3$	$n = 13$	$n = 10$
2-object outcomes	8.2	5.5	10.3	7.2	10.1	6.0
1-object outcomes	5.1	5.6	6.7	6.9	6.3	6.0

month-olds' performance on our object individuation task as a function of the number of words comprehended (see Table 2). Although there were not enough data to draw any strong conclusions, a very consistent pattern emerged. In both studies, the babies who knew 0 or 1 word failed at the task, exhibiting the baseline preference for two objects on the test trials. In both studies, the 10-month-olds who understood two or more words were able to overcome their baseline preference on the test trials and look about equally at the two outcomes. Note this latter pattern also characterizes the performance of the 12-month-olds.

In order to get enough data to do statistical analyses, we pooled the data from Experiments 4 and 5. An ANOVA examined the effect of comprehension group (0 or 1 vs 2 or 3 words) and number of objects in the outcome (one vs two) on looking times in the test trials. There was a main effect of number ($F(1,21) = 14.564$, $p < .001$). As always, the infants looked longer at two-object outcomes. There was also a main effect of group ($F(1,21) = 4.683$, $p < .05$). The infants who knew fewer words looked longer ($M = 8.1$ s) than the ones who knew more words ($M = 6.0$ s). Most importantly, the interaction between these two variables was significant ($F(1,21) = 10.254$, $p < .004$). Those babies who understood more words overcame the baseline preference for two objects, performing like 12-month-olds or like 10-month-olds who have been provided spatiotemporal information. In sum, the number of nouns comprehended by 10-month-olds predicts their success at individuating objects under the condition of Experiments 4 and 5.

These studies were not designed to test the relationship between using property/kind information to individuate objects and noun comprehension, so we must emphasize the preliminary status of these findings. Still, the association appears strong in these data. Of course we cannot draw any conclusions about possible causal relations between the two abilities. It may be the case that word learning plays a role in establishing sortal concepts; it may be the case that infants do not begin to comprehend words for objects until they have constructed object kind sortals. However, given that these object words are among the first that infants acquire as established by the MacArthur Communicative Inventory (Fenson, Dale, Reznick, Thal, Bates, Reilly, & Hartung, 1991), the data are suggestive: The very first object words that infants acquire refer to object kind sortals.

GENERAL DISCUSSION

The major result of these studies is the consistent failure of 10-month-old infants to use property/kind information to establish representations of two numerically distinct objects. The conditions under which they failed were quite varied—full habituation to the two objects shown alternately (Experiment 4), partial habituation to the two objects (Experiment 3), and brief familiarization to the two objects (Experiments 2 and 5). Ten-month-olds failed with relatively unfamiliar objects (e.g., trucks, elephants; Experiments 2 and 3) and highly familiar objects (e.g., bottles, cups; Experiments 4 and 5).

The failures in Experiments 2–5 are consistent with the claim that 10-month-olds are unable to use property/kind information to support object individuation and numerical identity. However, two considerations mandate caution in reaching this conclusion. First, the strong baseline preference for two object outcomes in Experiments 2–5 raises the possibility that perhaps babies of this age *do* use property/kind information in object individuation, but cannot demonstrate this ability in these experiments. Of course, it is possible that some more sensitive method could be brought to bear on this question, but we are doubtful that the picture presented by these data will be radically revised. This is because our method was sensitive to variables that might, on theoretical grounds, be expected to influence performance. Most importantly, 10-month-old infants, when given spatiotemporal information, succeeded in overcoming the baseline preference for two objects (Experiments 2 and 4) and 12-month-olds succeeded in doing so given only property/kind information (Experiment 5). And most telling, in Experiments 4 and 5, 10-month-old infants whose parents judged them to understand the nouns for the familiar objects used as stimuli also succeeded in overcoming the baseline preference for two objects. These *successes* show that the baseline preference does not totally swamp any indication that the babies are expecting two objects behind the screen. Thus, the failures of the 10-month-olds in the property/kind condition probably indicate that they had not established representations of two objects in these events.

Indeed, our method is more sensitive than others that have been brought to bear on the question. LeCompte and Gratch (1972) assessed whether babies searched for the original toy when it had been mysteriously replaced by a second one after being hidden. Only at 18 months did babies do so, consistent with the conclusion that younger babies did not know that there were two objects involved in the event. Similarly, Gratch (1982) did not find babies looking back when one toy disappeared behind a screen and a different toy emerged until 16 months of age. Our data suggest that these earlier studies overestimated the age at which babies begin to use property/kind information to establish representations of numerically distinct objects.

The second reason we should be cautious in drawing conclusions from the results presented is that we only sampled a few cases of property/kind contrasts (yellow rubber duck/white foam ball; red metal truck/light blue elephant; bottle/ball; cup/book). However, there are at least three reasons to believe that these results would generalize beyond the particular pairs of objects probed here. First, the habituation data from Experiment 3 showed that infants *noticed the differences* within each pair of objects, so the failure cannot be due to our choice of property distinctions the baby is not sensitive to. Second, the objects used in Experiments 4 and 5 were extremely familiar to 10-month-old infants, so the failure cannot be explained by unfamiliarity with the stimuli. Third, the contrasts used in these studies span the global contrasts (animal/artifact; vehicle/animal) that Mandler and her colleagues (Mandler & Bauer, 1988; Mandler, Bauer, & McDonough, 1991) posit to be the first kind distinctions infants make. However, it is very much an open question whether other contrasts (e.g., extreme size differences; kind changes between a living, moving entity and an inanimate entity) would lead 10-month-old infants, or even younger infants, to infer that two distinct objects were involved in these events.

Thus, although these data are consistent with the *Object*-first hypothesis, they do not establish that it is true. Nonetheless, the finding that sortals such as *duck, truck, cup, bottle, ball,* and *book* do not provide criteria for individuation and identity for 10-month-olds has implications for the many habituation studies which have shown that even much younger infants are sensitive to such categories of objects. That is, much younger infants can habituate to a series of objects (e.g., stuffed animals) that they can discriminate, then dishabituate to an object from a different category (e.g., a cup; Cohen & Younger, 1983; Quinn & Eimas, 1993). Such results were obtained in both manual and visual habituation paradigms (Oakes, Madole, & Cohen, 1991). They are often interpreted as bearing on what kind concepts the infant represents (e.g., basic level kinds; cf. Macnamara, 1987; Roberts & Horowitz, 1986; global kinds, Mandler, Bauer, & McDonough, 1991). The present studies indicate that the categories revealed by these visual/manual habituation studies probably reflect perceptual distinctions that infants are sensitive to, not sortals or kinds that can support the learning of count nouns. Infants may be able to habituate to animal-shape, or animal-ness, without encoding these habituation exemplars as ‘‘an animal, another animal . . .’’ The studies reported here show that sensitivity to property differences between two entities is not tantamount to representing them as two distinct individuals. The fact that infants distinguish cups from balls in their action has no direct implications for how babies individuate entities with cup-like and ball-like properties. Similarly, even though infants react differently to their mothers and fathers, experiments such as the ones reported here would be required to establish when infants represent their mothers and fathers as distinct individuals. Indeed, Meltzoff and Moore (1992) presented some preliminary evidence suggesting that very young infants do not use properties to individuate people but rather rely on spatiotemporal information.

If infants are not representing the familiarization emergences in the property/kind conditions of Experiments 2–5 as involving two distinct objects, how might they be representing them? The results suggest that 10-month-old infants were agnostic about whether there were one or two objects behind the screen. In all four versions of the property/kind condition in Experiments 2–5, we found no statistical difference between the test trials and the baseline, as if the infants had not seen any of the emergences and when the screens were taken away, they simply exhibited their baseline preference for two objects. The baby seems to be representing the event as OBJECT emerging from the left of the screen, followed by OBJECT emerging from the right of the screen, and she represents these neither as a single object ($OBJECT_i$) nor as distinct objects ($OBJECT_i$, $OBJECT_j$). Adults encounter such situations sometimes. Suppose you see a leaf on the sidewalk as you walk to class, and you see a leaf at roughly the same place on the sidewalk as you return from class. That may be the same leaf or it may not; your conceptual system is capable of drawing that distinction, but you leave the question open due to insufficient evidence.

An alternative interpretation of the results is that the infants may actually establish a representation of a single object ($OBJECT_i$) moving back and forth behind the screen, attributing to this object the properties of being yellow and duck shaped at times and white and ball shaped at other times. If this were the case, the infants should have been surprised at two-object outcomes. The lack of difference between the test and the baseline trials may be due to the strong intrinsic preference for two objects masking the hypothesized surprise at two on the test trials. That is, the looking time measure may not be sensitive enough to reveal a surprise reaction on top of a strong intrinsic preference. This is, of course, speculative. The data at hand do not allow any conclusions to be drawn.

We do not know how exactly the infants may be representing the events. What is important is that both possibilities differ from adult representations of these events. Precisely because adults use property/kind information to establish numerically distinct objects, they are not agnostic when shown a toy duck at time 1 and a ball at time 2 emerging from behind the same screen. The adult's inference is clear and determinate: There are *two* objects in these events, a duck and a ball, and they will be surprised if shown only one object behind the screen.

By 12 months of age, infants succeed quite robustly in our task; that is, they succeed under conditions of four brief familiarization emergences of each object (Experiment 5). We have recently found convergent evidence of 12-month-olds' success (Xu, Carey, Raphaelidis, & Ginzbursky, 1994). Babies were trained to reach through a small hole on the top of a box to retrieve objects. Then they were shown objects being pulled out of the box one at a time, say, a toy duck being pulled out and put back in the box, then a ball being pulled out and put back in the box. The measure of how many objects they think are in the box is how many times they reach into it. We found that 12-month-olds reached roughly twice when shown two distinct objects and that they reach roughly once when shown a single object twice.

It is not the case that 10-month-old infants do not have any conceptual categories in the sense of sortal concepts. As demonstrated by Spelke and Kenstenbaum (1986) as well as Experiments 1, 2, and 4, in the present studies, infants as young as 4 months and 10 months represent at least one sortal concept, *physical object.* The criteria for individuation and identity for *physical objects* are spatiotemporal. Even though 10-month-old infants may not represent *ball, truck, duck, elephant, bottle, cup,* and *book* as kind, or sortal, concepts, the very existence of the sortal *physical object* shows that their conceptual system is capable of representing sortal concepts that provide conditions of individuation and identity. The concept *physical object* does more conceptual work for the infant than just this. A wealth of evidence gathered in the last 10 years shows that infants' representations of objects are embedded in a system of intuitive physics that supports inferences about object motion and causal interactions (Leslie & Keeble, 1987; Spelke, 1988; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Baillargeon, 1993, 1994).

What causes the changes observed in these studies between 10- and 12-month-olds? The fact that the change seems to be taking place during a rather short time window suggests that there may be maturational changes underlying the developmental accomplishment. It is also possible that the construction of specific sortals is the result of a learning process. We can imagine three different learning mechanisms.

The first draws on the *Object*-first hypothesis. Note that which properties of objects remain constant through time and which do not vary from object kind to object kind. For example, we expect the shape of a cup to remain constant over time, but are not surprised when the shape of a dog undergoes constrained transformations. The infant must learn which properties stay constant for various categories of objects. In order to learn this, however, the infant must have some way of individuating objects and tracing them through time. The spatiotemporal criteria for object fulfill this need. Perhaps the infant establishes individuals by spatiotemporal means, and learn how properties covary within individuals, and how some property clusters predict some property changes and other property clusters predict others. For example, babies may observe that a human hand traversing a spatiotemporally continuous path (evidence that it is one and the same hand) can change shape quite drastically therefore conclude that shape change is not a good indicator of change of identity in the case of a human hand. It is possible that kinds are then abstracted from this correlational analysis.

A second possibility grants the infants the concept of more specific kinds/sortals all along, in the absence of any examples. Perhaps also the infant knows innately that nouns refer to kinds (Pinker, 1984; Macnamara, 1987). If the infant picks out the referentially used words, and if the infant has learned through experience about what properties are likely to change for individual objects, the infant might then be in a position to use adult word usage as evidence for kind distinctions. This would predict the association between word comprehension and success on our tasks in Experiments 4 and 5. (Of course, as noted above, there are alternative interpretations of this association.) The limiting factor, in this scenario, comes from language learning—at least the child must isolate some words before this form of evidence would be available.

A third possibility also grants the infant an antecedent notion of specific kind in the absence of any example. Infants may also expect kind distinctions to predict functional distinctions between objects. Baldwin, Markman, and Melartin (1993) showed that 9- to 16-month-olds were able to predict that if one horn honked, a perceptually similar horn would honk.[7] Perhaps learning the functions of objects helps the infant construct kinds because they may expect objects with the same function to be in the same kind and objects with different functions to be in distinct kinds.

These three sorts of input to a learning procedure (correlational analyses, referential word usage, functional analyses) are not mutually exclusive. All could play a role in the construction of sortals more specific than *object.*[8]

[7] Examining the data from their study suggests that this ability was fragile in the 9- to 10-month group. That is, in spite of the absence of significant age effects, it is clear that the 9- and 10-month-olds did not have as strong expectancies about the second toy, perhaps because they have not yet constructed the kind concepts (as specific sortals).

[8] The finding that babies use spatiotemporal information to individuate objects before they use property/kind information bears a formal similarity to findings in the apparent motion literature (Ternus, 1926/1938; Kahneman and Treisman, 1984; Kahneman, Treisman, & Gibbs, 1992). If the temporal parameters are those that give rise to apparent motion, a display consisting of two objects (Xi and Xj), followed by a display containing two objects (X? and X?) in new locations, followed by the original, and so forth, will be perceived as two objects each moving back and forth between two locations. The question is which of the second objects (X? and X?) is seen as Xi in a second location and which as Xj? Spatiotemporal information, rather than property/kind information, is the determining factor. That is, subjects will see two cases of red squares turning into green circles rather than a red square moving back and forth and a green circle moving back and forth, if the former solution to establishing the individuals in the display minimizes the total amount of motion. At least in two cases then, spatiotemporal information dominates property/kind information in individuating entities and tracking identity over time: over very short term perceptual processing (as tapped by the apparent motion studies, where milliseconds make a difference) and over much longer conceptual processing in infants (as tapped by the present studies). Further studies will explore the relations between the two phenomena.

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