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Object permanence and knowledge of number in 5.5- and 10-month-old infants.

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OBJECT PERMANENCE AND KNOWLEDGE OF NUMBER IN 5.5- AND 10-
MONTH-OLD INFANTS

A Thesis Presented

by

JEANNE L. SHINSKEY

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

February 1996

Psychology

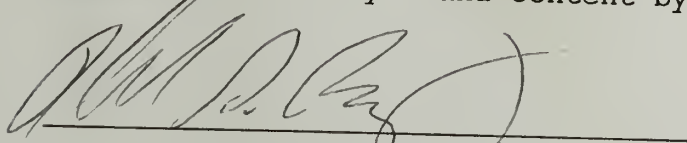
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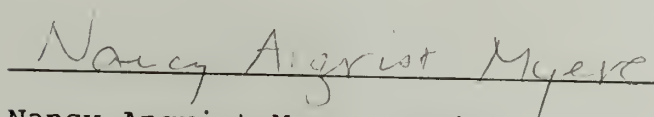
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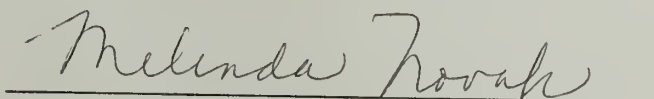
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ABSTRACT

OBJECT PERMANENCE AND KNOWLEDGE OF NUMBER IN 5.5- AND 10- MONTH-OLD INFANTS

FEBRUARY 1996

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The study attempts to replicate and extend the findings of Xu and Carey's (in press) Experiment 1, which concluded that 10-month-old infants use spatiotemporal information to infer the number of objects involved in an occlusion event. Two groups of eight infants each (four 5.5 and four 10 months old) saw Xu and Carey's events involving either one (continuous-screen condition) or two (discontinuous-screen condition) inferred objects. Looking times to one and two objects on subsequent test trials were recorded. The remaining two groups of infants saw events that were perceptually similar to Xu and Carey's (continuous-periphery and discontinuous-periphery conditions), with the exception that the outcome of either one or two objects on the test trials was impossible. The cognitive processing hypothesis predicts replication of Xu and Carey's results for the first two groups of infants: infants should look longer at one object following familiarization to the event with two inferred objects, and longer at two objects following familiarization to the event with one inferred object. The

cognitive hypothesis further predicts that infants in the second two groups should look equally long at the unlikely outcomes of either one or two objects. However, the perceptual processing hypothesis predicts that infants should show the same pattern of looking at one and two objects in all four groups: Infants should look longer at two objects in the continuous-screen and continuous-periphery groups, and longer at one object in the discontinuous-screen and discontinuous-periphery groups. Xu and Carey's results were not replicated: infants did not look longer at the unlikely outcomes following familiarization events. Thus the cognitive hypothesis is not supported by this study. The perceptual processing hypothesis fared somewhat better in that more of its predictions were confirmed, although not all were. In addition, lack of replication of the two original conditions has made interpretation of the results somewhat difficult. Further studies, using a different design, may better differentiate between the two hypotheses, but for now, we do not believe the available evidence strongly supports cognitive processing of occluded objects in young infants.

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CHAPTER I

INTRODUCTION

Object Permanence According to Piaget

Because this study investigates object permanence in infants, and because Piaget was one of the first researchers to empirically investigate object permanence in infancy, a brief summary of the Piagetian view of object permanence is necessary. According to Piaget (1952, 1954), attainment of the object concept is one of the most important achievements of the sensorimotor period of development. An infant who has the object concept knows that objects continue to exist even when they are not in view. The object concept is important because it is evidence that infants can mentally represent events, and mental representations subserve most, if not all, aspects of cognitive development.

In the Piagetian model (1952, 1954), knowledge of the permanence of objects is acquired gradually. The young infant has no conception that objects exist separately and independently from the infant's actions upon them. Objects are the extensions of the infant's specific actions, and the infant engages in action to produce the object. When the object disappears, the infant briefly continues to perform the same action in expectation of reproducing the object. If

this behavior fails to produce the desired outcome, the infant ceases to repeat it, and does not try to engage in alternative behaviors. For the infant, it is as if the object is created and destroyed with each appearance and occlusion. From 4 to 8 months of age, the infant will search for objects that are partially occluded or that have dropped out of sight. It is not until about 8 months of age that the infant will engage in new behaviors, search behaviors, to try to recover an object. According to Piaget, the infant begins to conceive of the object as existing apart from the infant's own specific actions between 8 and 12 months of age. The object has a separate and independent existence that, when hidden, can be uncovered by many different behaviors. Infants' acquisition of the object concept also extends beyond the search for completely hidden objects at 8 to 12 months of age. Between 12 and 18 months of age, infants acquire the ability to successfully perform visible displacement tasks, in which the object is moved, in view of the infant, from one location to another. Between 18 and 24 months of age, infants can perform invisible displacement tasks, in which the object is moved out of sight of the infant from one location to another.

Recent Evidence for Object Permanence

Piaget's conclusions were based on tasks in which infants manually searched for hidden objects. Other researchers have suggested that younger infants may fail to search for hidden objects because they have difficulty performing coordinated actions, not because they lack knowledge of object permanence (e.g., Baillargeon, Spelke, & Wasserman, 1985). Manual search tasks are not well-suited for exploring object permanence knowledge in younger infants. More recent methodologies have been used to investigate object permanence knowledge in young infants. For example, Baillargeon, Spelke, and their colleagues have undertaken several studies using a visual habituation-dishabituation paradigm to determine whether knowledge of object permanence exists in younger infants (e.g., Baillargeon, Spelke & Wasserman, 1985; Baillargeon & DeVos, 1991; Baillargeon & Graber, 1987; Baillargeon, 1987b). In these studies, infants are visually habituated to an event, using a standard looking-time criterion. Dishabituation to a test event occurs when infants perceive the event as novel, or according to some researchers, impossible.

The following studies are discussed here because they all conclude that object permanence knowledge is present in infants younger than 8 to 12 months, contrary to what Piaget concluded. These studies provide an important foundation upon which the present experiment is based. Collectively,

they conclude that young infants engage in cognitive processing of occluded objects. Not only are we unconvinced that these conclusions are true, we also have found that many subsequent studies, particularly those investigating infants' knowledge of number, use methodologies based on the assumption of object permanence knowledge in young infants. It is therefore important to detail how these studies are carried out, as well as to point out how pervasive these conclusions are in the recent literature on infants' processing of occluded objects.

Many of these studies were carried out by Spelke, Baillargeon and their colleagues. For example, Baillargeon and Graber (1987) presented 5.5-month-old infants with possible and impossible test events following habituation to a toy rabbit moving across a stage and behind a screen. In the impossible event, a tall rabbit traveled behind a screen with a window in it and did not show up in the window. In the possible event, a short rabbit traveled behind the screen and did not appear in the window, as it was not tall enough to do so. Infants looked longer at the impossible than at the possible event. Baillargeon and Graber concluded that the infants believed that the hidden rabbit continued to exist, and maintained its height and trajectory while hidden. The infants expected the tall rabbit to show up in the window, and were surprised when it did not. Baillargeon and DeVos (1991) found similar results in a study with 3.5-month-old infants, and concluded that young infants know that

objects cannot exist at two points in time without existing in between, cannot appear in two places without traveling a continuous path in between, and cannot move through the space occupied by other objects. However, Bogartz, Shinskey, and Speaker (1995) found different results using the same stimuli and similar possible and impossible events as Baillargeon and Graber, but in a mixed-model design. Infants were familiarized on one of the three types of events (original familiarization, impossible event, and possible event), and then tested with all three events. A multiple regression analysis revealed that impossibility and possibility were not factors affecting looking time. Infants looked longer at test trial events because they had features that were different from the familiarization event, regardless of the possibility factor.

In a now classic study of object permanence in young infants, Baillargeon, Spelke, and Wasserman (1985) habituated 5-month-old infants to a rotating screen moving in a 180-degree arc. After infants reached habituation, a box was placed behind the screen. Infants were then presented with either a possible event, in which the screen stopped moving when it reached the hidden box, or an impossible event, in which the screen continued to rotate through 180 degrees, as if the box had disappeared. Infants looked longer at the impossible event than at the possible event. Baillargeon et al. concluded that the infants knew the box continued to exist behind the screen, expected the screen to stop moving

when it reached the hidden box, and were surprised when this expectation was violated. In variations of this study, Baillargeon found similar results with 7-month-old infants (1987a) and with 3.5- to 4.5-month-old infants (1987b). However, an alternative view predicts that a mixed-model design using the same stimuli and events will show that looking time is dependent not on the possibility or impossibility of the events, but on the featural differences between habituation and test events (Bogartz et al., 1995).

Many more studies of this type have been carried out in the last decade (see, for example, Spelke, Breinlinger, Macomber & Jacobson, 1992). These studies almost unanimously conclude that young infants represent and reason about occluded objects in much the same way as adults. As will be seen in the following section, many recent studies of infants' knowledge of number also assume cognitive processing of occluded objects in infancy.

Object Permanence and Knowledge of Number

The assumption that young infants have acquired the object concept is a crucial one for the paradigms used by Wynn (1992a), Uller (1993) and Spelke and Kestenbaum (as cited in Xu & Carey, in press) in their investigations of infants' knowledge of number. Wynn (1992a) used a looking-time procedure with occluded objects in her study of addition

and subtraction in 5-month-old infants. Wynn's procedure was as follows. Infants were shown an empty stage. An object was introduced onto the stage, and a screen was raised to occlude the object. A second object was placed on the stage behind the raised screen. Infants saw the object briefly before it was occluded. In the impossible test event, the screen was removed and one object was revealed. In the possible test event, two objects were revealed. Infants looked longer at the impossible than at the possible event. Corresponding results were found with infants in the subtraction group. Two objects on a stage were occluded by a screen. One object was removed from behind the screen, in view of the infant. The screen was lowered to reveal two objects in the impossible event and one object in the possible event. Infants looked longer at the impossible event. Wynn concluded that infants have true numerical concepts, and further suggested that these abilities are innate.

Uller (1993) used 7- to 8-month-old infants to replicate Wynn's (1992a) results in the addition event. She also added another condition that was a variation on Wynn's experiment. Wynn showed infants the first object on the stage before raising the screen and adding the second object. Uller first raised the screen on the empty stage, then placed the first object behind it, followed by the second object. However, Uller's 7- to 8-month-old infants did not look differentially to one versus two objects. When Uller used 9-

to 10-month-old infants in the screen-first condition, she found that the infants looked longer at one than two objects. This finding suggests that knowledge of object permanence and number are still undergoing significant development between 7 and 10 months of age. Uller and her colleagues are presently investigating whether using two screens instead of one will provide infants with spatiotemporal information that may aid them in this task (C. Uller and S. Carey, personal communication, October 7, 1994).

Spelke and Kestenbaum (as cited in Xu & Carey, in press) conducted an experiment using occluded objects to determine whether 4- to 5-month-old infants could use spatiotemporal information to infer the number of objects involved in an event. Infants were shown two screens on a stage (see Figure 1 on the next page for a similar design). Infants were habituated to an event in which one object emerged from behind the left screen, traveled to the left, and then returned to its position behind the left screen, followed by an object that emerged from behind the right screen, traveled to the right, and then returned to its position behind the right screen again. No object appeared in the space between the two screens. Following habituation, infants were presented with what the authors refer to as an expected or unexpected outcome. In the expected outcome test trial, the screens were removed to reveal two objects. In the unexpected outcome test trial, only one object was revealed. Adults express surprise at the unexpected outcome, and Spelke

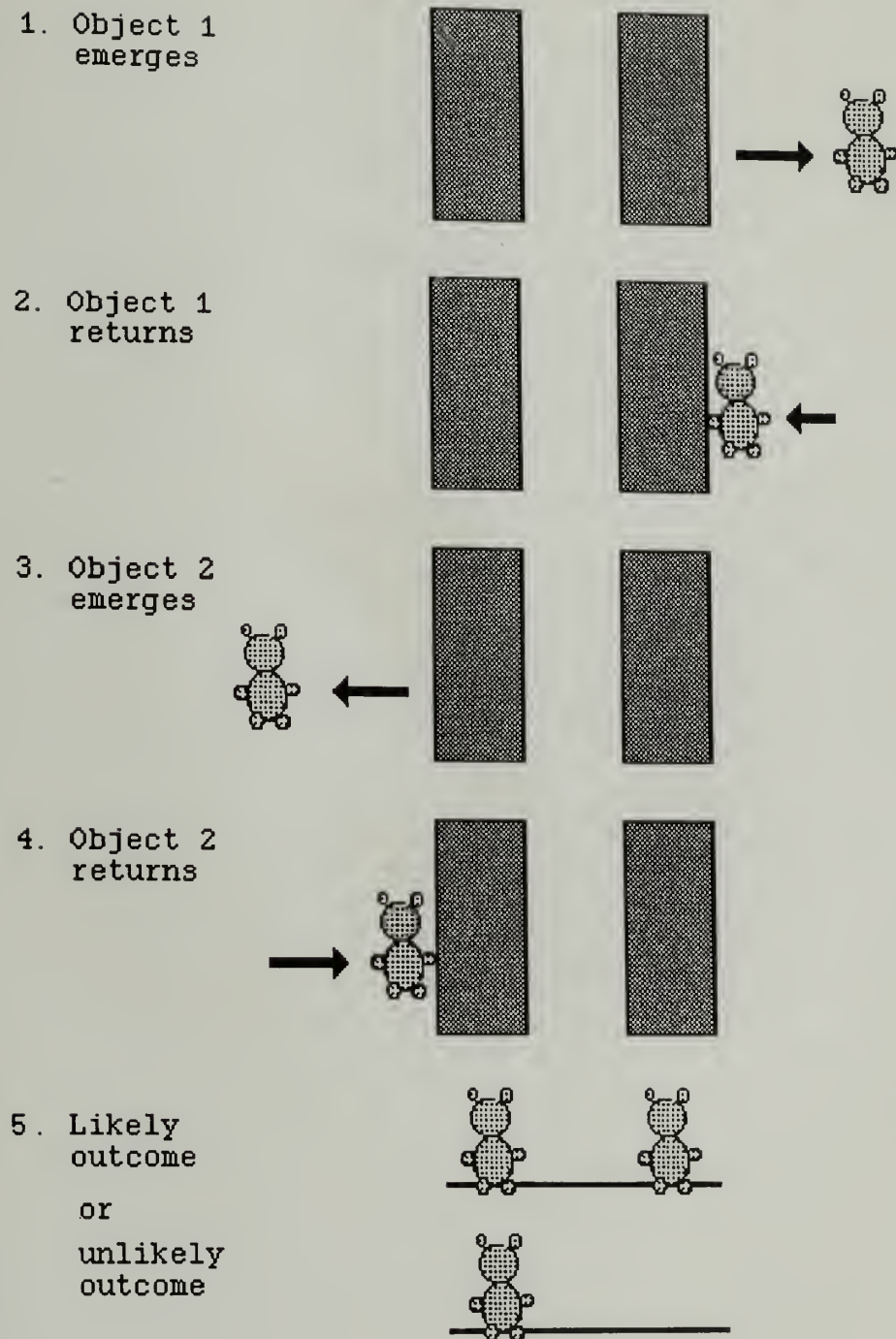
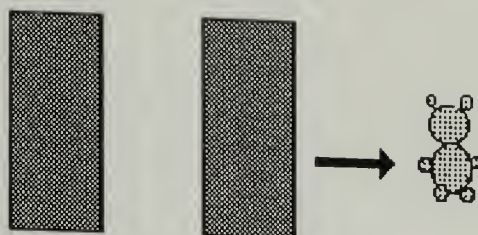


Figure 1. Schematic representation of the discontinuous-screen condition.

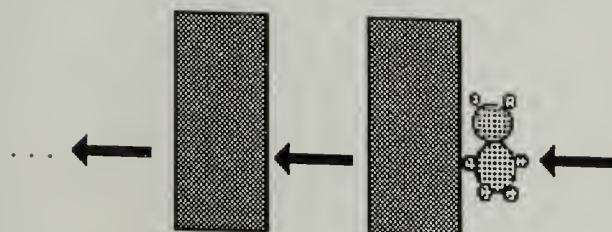
and Kestenbaum found that infants looked longer at the unexpected outcome than at the expected outcome. Spelke and Kestenbaum concluded that the infants analyzed the possible paths between the objects and, failing to see any object travel between the two locations, inferred that there must be two objects. According to the authors, the presence of only one object in the test trial violated the infants' expectations and was manifested by longer looking.

In addition to the discontinuous condition described above, which will be called the discontinuous-screen condition from here on, Spelke and Kestenbaum's experiment (as cited in Xu & Carey, in press) also included a continuous-screen condition, in which one object traveled back and forth across the stage, appearing in the space between the two screens (see Figure 2 on the next page for a similar design). Infants in this condition were given the same test trials as in the discontinuous-screen condition, displaying either one or two objects. Infants did not look significantly longer at one outcome than the other. While it is possible that more than one object could be involved in the continuous-screen condition, most adults interpret the event as involving only one object. Two objects are unexpected. If infants have the same object-concept knowledge as adults, they should look longer at two objects than one.

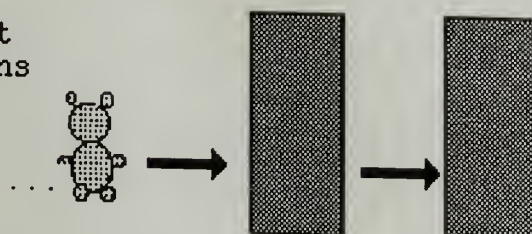
1. Object emerges



2. Object crosses stage 4 times



3. Object returns



4. Likely outcome



or

unlikely outcome

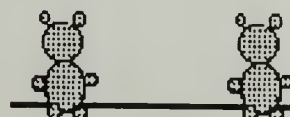


Figure 2. Schematic representation of the continuous-screen condition.

Xu and Carey (in press) conducted an experiment similar to that of Spelke and Kestenbaum (as cited in Xu & Carey, in press), with some modifications. Participants were 10-month-old infants, with whom Xu and Carey did not find it necessary to use a full habituation paradigm. Xu and Carey reasoned that if infants can use spatiotemporal information in an adult-like manner, they should be able to infer the number of objects involved in the event without full habituation. Xu and Carey fixed the number of familiarization trials at four. They also did not find it necessary to use objects that were continuously in motion, although Spelke and Kestenbaum did. Ten-month-old infants were able to sustain attention even when the objects were stationary part of the time.

Xu and Carey found that 10-month-old infants looked longer at one object in the discontinuous-screen condition. Infants also looked longer at two objects in the continuous-screen condition, but this effect was only marginally significant. Xu and Carey's conclusions were that the infants interpreted the discontinuous-screen event as involving two objects. The infants used the spatiotemporal information to establish the number of objects and to track the objects over time. The authors also conclude that most of the infants assumed that only one object was involved in the continuous-screen event, in accord with adults' interpretations. Finally, Xu and Carey conclude that 10-month-old infants' ability to use spatiotemporal information to establish the number of objects in an event is robust.

These studies are all based on the assumption that the infants have object permanence knowledge. The studies are important here because the present experiment also investigates infants' knowledge of object permanence and number. Specifically, the goal of the present experiment is to replicate the results of Xu and Carey's study, and to test the hypothesis that the results may be better explained by lower-level perceptual processing rather than by cognitive processing such as reasoning.

CHAPTER II

THE EXPERIMENT AND ITS PREDICTIONS

The present experiment was designed with several goals in mind. The first goal was to replicate the findings of Xu and Carey (in press) with 10-month-old infants. A second goal was to determine whether the same pattern of results would be found with younger infants, at 5.5 months of age. The findings of Spelke and Kestenbaum (as cited in Xu & Carey, in press) suggested that differential looking might be found for the discontinuous-screen condition, but not for the continuous-screen condition. However, since the full habituation paradigm used by Spelke and Kestenbaum was not used here, it was worth investigating whether 5.5-month-old infants would perform as well as 10-month-old infants with a fixed number of trials. If the understanding is adult-like, or even perhaps innate, there should be little difference between 5.5- and 10-month-old infants. Results which do not replicate with 5.5-month-old infants may suggest that, if infants do have a robust understanding of number at 10 months of age, it is an understanding that undergoes significant development between 5.5 and 10 months of age. Such results would suggest that knowledge of object permanence and of number is not innate, but develops rapidly in the first year

of life, or else cannot be measured at 5.5 months in the same way as at 10 months of age.

Another goal was investigated by presenting infants with a variation of the conditions used by Spelke and Kestenbaum (as cited in Xu & Carey, in press) and by Xu and Carey (in press). It is possible that infants may look longer at "unexpected" outcomes for reasons other than that they have inferred the correct number of objects. One alternative and more parsimonious interpretation is that the results may be due to lower-level perceptual processing rather than to higher-level cognitive functioning. It may not be necessary for infants to draw inferences about objects and their properties in order for them to look longer at what an adult would consider an unexpected outcome. Longer looking times may not reveal anything about inferences on the part of the infant.

The perceptual processing perspective maintains that young infants do not have innate or acquired knowledge of object permanence or of number, and that young infants do not use higher-level cognitive processes such as inferring or reasoning about the properties of objects. The assumption is that the young infant has no representation of an object while it is occluded, since the infant cannot see and has not seen the object while it is occluded, and does not yet have the ability to infer the object's possible location.

Consider the discontinuous-screen condition used by Spelke and Kestenbaum (as cited in Xu & Carey, in press) and

by Xu and Carey (in press), with this interpretation in mind. The discontinuous condition involves attending back and forth to two separate bundles of activity. It is possible that the infant's representation of this event does not include the information that there is a space between the screens through which objects could travel, since during the actual familiarization trials the infant's attention is not attracted to the center of the stage. It is also possible that the motor behavior of turning the head and looking back and forth is establishing a sense of "twoness", such that the presentation of one object in the test trials is contrasting enough to hold the infant's attention longer. This interpretation does not require the infant to infer that it is logically impossible for there to have been only one object on the stage. The same interpretation can be applied to the findings for the continuous condition. The smoother visual tracking of the object in this condition can lead to a perception of "oneness", such that the presentation of two objects in the test trials is novel and more interesting, without requiring expectation or knowledge of number. Infants may also look longer at two objects in the continuous condition because they do not expect to see an object in the left location when they last saw an object on the right side of the stage and vice versa.

The remaining two conditions of the present experiment were designed with the perceptual processing perspective in mind. The apparatus was the same as for the first two

conditions, and the infants were presented with continuous and discontinuous conditions. The only difference is that the objects did not start and finish behind the screens, but off the stage. For each familiarization trial, the objects were occluded by being off the stage. They came in towards the center of the stage and were occluded temporarily by the screens, and they exited again off to the sides of the stage (see Figures 3 and 4 on the following pages). These two conditions are referred to as the continuous-periphery and discontinuous-periphery conditions.

Since no object ever ended up behind the screens at the end of a familiarization trial, no object should be behind the screens when they are removed. However, when the screens were removed, either one or two objects were revealed. Adults would express surprise at either outcome. Infants with object permanence knowledge should look longer on the average in the periphery conditions, since the presence of either one or two objects should be unexpected. If infants do have an understanding of object properties and of number, it might be expected that the looking times to one and two objects in the periphery conditions would not differ significantly. (The experiment included a test for a baseline tendency to look differentially at one versus two objects.) If infants do not have a full understanding of object properties and number, the same results could be obtained as were obtained by Xu and Carey (in press). Infants could look longer at one object in the discontinuous-

periphery condition and at two objects in the continuous-periphery condition, because of some lower-level, perceptual processing explanation or novelty effect. Another possibility is that the results may indicate that 10-month-old infants have a fuller understanding of objects than 5.5-month-old infants. Such results would lend support to the hypothesis that knowledge of objects and physical laws may not be present at birth, but develops rapidly early in life.

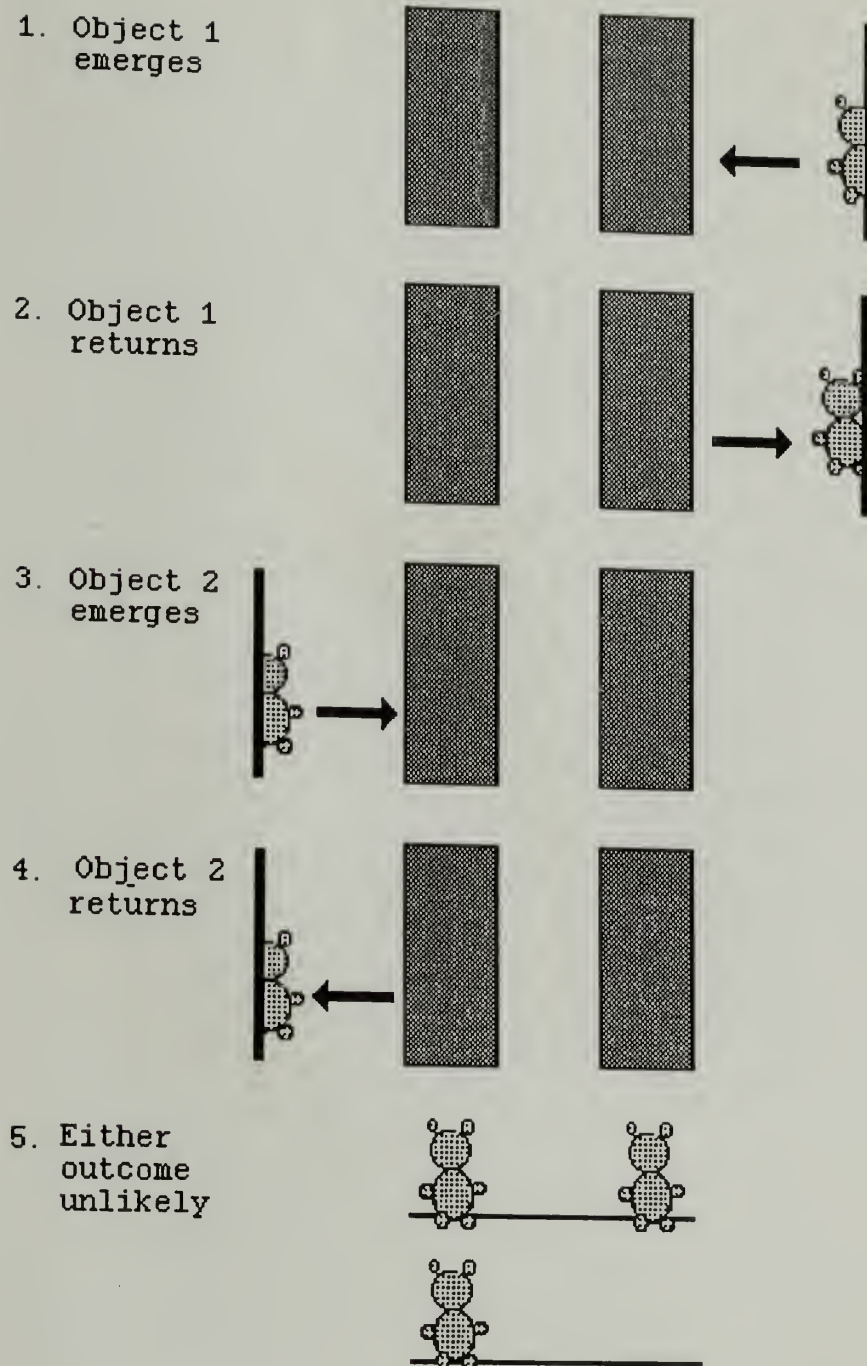
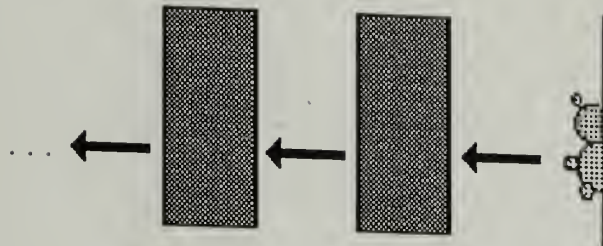
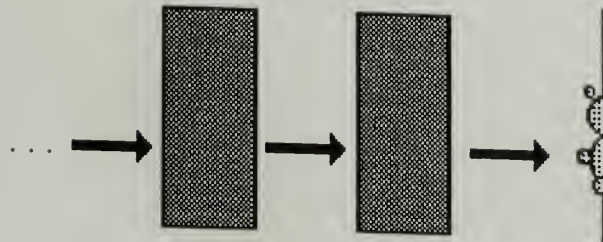


Figure 3. Schematic representation of the discontinuous-periphery condition.

1. Object emerges; crosses stage 4 times



2. Object returns



3. Either outcome unlikely

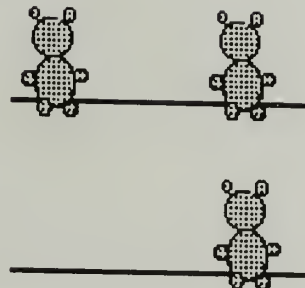


Figure 4. Schematic representation of the continuous-periphery condition.

CHAPTER III

METHOD

Participants

Forty full-term infants participated in the study. Twenty infants (13 female, 7 male) ranged in age from 5 months 5 days to 6 months 9 days, with a mean of 5 months 21 days, and 20 infants (13 female, 7 male) ranged in age from 9 months 24 days to 10 months 20 days, with a mean of 10 months 4 days. Eight infants participated in a baseline condition, and eight participated in each of the four experimental conditions. In each condition, half of the infants were 5.5 months old and half were 10 months old. Six additional infants were excluded from the sample because of fussiness, and one because of experimenter error. Participants were recruited from published birth announcements through a letter and subsequent telephone call to parents. Participants received a toy and a certificate of appreciation for participating.

Materials

Four identical pink toy pigs were used in the familiarization and test trials. The objects were about 8 x 7.5 x 6.5 cm in size. Yellow posterboard was attached to two masonite screens which were about 11.5 x 25.5 cm in size.

Apparatus

Testing took place in a brightly lit experimental room (300 x 225 cm). A wooden stage (203 x 141 x 70 cm) was located in the center of the room. Two black curtains (180 x 95 cm) hung from the sides of the stage to the wall behind the infant in order to isolate the infant and parent from the rest of the experimental room. A black cloth hung parallel to the back of the stage, making the depth of the stage 39 cm. A shorter black cloth divider (100 x 21 cm) hung between the black cloth wall and the front of the stage, making the portion of the stage floor visible to the infant 25 cm in depth. Infants viewed the events through an opening (37 x 63 cm) in the front of the stage.

All parts of the stage visible to the infant were covered with black cloth in order to minimize distraction. A narrow groove (86.5 x 1 cm) running parallel to the back wall of the stage was located in the floor of the stage. Four additional grooves (19 x 1 cm) ran perpendicular to the main

groove, one behind each screen and one at each end of the stage. The objects traveled along these grooves. The objects were attached to wooden dowels (57 x 1 cm) that were operated from under the floor of the stage by the experimenter. The screens were two vertical masonite boards (11.5 x 25.5 cm), covered with yellow posterboard and positioned 11 cm apart from each other in the center of the stage. The masonite boards were glued at the top and bottom to horizontal black masonite boards (36 x 11.5 cm) to stabilize the movement of the two screens as they were raised and lowered by a pulley system operated by the experimenter from behind the stage.

Two video cameras were mounted in the room in order to record the infant's face and the events on the stage. The camera focusing on the infant's face was positioned centered behind the black cloth wall of the back of the stage (36 cm above the floor), so that only the lens was visible to the infant. The camera focusing on the stage was positioned above and behind the infant. The video monitor for the camera focusing on the infant's face was used by the observer from a separate room. Looking times were recorded online using a keyboard interface to a Macintosh SE/30 computer operated by the observer.

Procedure

For all five groups (four experimental plus baseline), the infant was seated in an infant car seat secured to a chair. The infant's face was about 45 cm from the stage, and eye level was about 18 cm above the floor of the stage. The parent was seated next to the infant, but with his or her back to the stage. The parent was instructed not to look at the displays, so as not to influence the infant's behavior, and not to interact with the infant unless the infant became too fussy to continue the experiment.

Experimental Groups

For each of the four experimental conditions, the familiarization trials began with the stage empty. The experimenter drew the infant's attention to the empty stage by tapping the stage with her hand until the infant looked. The infant was briefly presented with the object both stationary and moving across the stage. The object was removed from the stage, and the screens were lowered. The experimenter drew the infant's attention to the spaces between and on either side of the screens by tapping her hand until the infant looked.

The objects moved at a rate of about 10 cm/sec, so that it took about 6 sec to travel the length of the stage once. The objects were in continuous motion, as in Spelke and

Kestenbaum's experiment (as cited in Xu & Carey, in press), rather than being stationary for part of the time, as in Xu and Carey's (in press) study. For each of the four conditions, half the infants saw the object start moving from the left side, and half saw the object start moving from the right side. Each infant was presented with four familiarization trials, each followed by a test trial. Two test trials revealed one object behind the screens, and two test trials revealed two objects. The order of object presentations was counterbalanced: 1,2,2,1; 2,1,1,2; 1,2,1,2; 2,1,2,1. The side on which the single object was also counterbalanced between subjects. Each test trial ended when the infant looked away from the object(s) for 2 consecutive sec after having looked for at least .5 cumulative sec. The stage was cleared of objects and screens after each test trial and before each subsequent familiarization trial.

Continuous-screen Condition

For half the infants in the continuous-screen condition, the object came out from behind the left screen, moved to the left end of the stage, then to the right end of the stage, and back to the left end of the stage. The object traversed the stage in this manner a total of four times, and its final position was occluded by the left screen. For the other half of the infants, the object emerged from and returned to the right screen. The screens were raised to reveal one or two

objects. When only one object was revealed, it was behind the screen where it was last seen. For half the infants, this was on the left and for half it was on the right.

Discontinuous-screen Condition

For half the infants, the left object moved first. The object emerged from behind the left screen, traveled to the left end of the stage, and traveled back to its position behind the left screen. There was a pause of about 3 sec when no objects were visible (the time it would take the object to travel from the left edge of the left screen to the right edge of the right screen), followed by the emergence of the right object from the right screen. This event was repeated four times, and the last visual contact with an object was as it was being occluded by the right screen. When there was only one object displayed in the test trials, it was on the right. The other half of the infants first saw the object emerge from the right screen and last saw the object being occluded by the left screen. When one object was displayed in the test trials, it was on the left.

Continuous-periphery Condition

For half the infants, the object entered the stage from the left, traveled across the stage to the right end of the stage, and back to the left end. This event was repeated

four times. Except for the beginning and end of each familiarization trial, in which the object was occluded because it was off the stage, the object was only occluded by the screens. At the end of the familiarization trial, the infant last saw the object leaving the left side of the stage. When only one object was presented in the test trials, it was on the left. The other half of the infants first saw the object enter from the right and last saw it exit on the right. When only one object was presented in the test trials, it was on the right.

Discontinuous-periphery Condition

For half the infants, the object entered the stage from the left, was occluded by the left screen, and then exited to the left side of the stage again. After a 3-sec pause, an object entered the stage on the right, was occluded by the right screen, and exited the stage to the right. This event was repeated four times. Since the object was last seen on the right side of the stage, the presentation of one object in the test trials was on the right. For the other half of the infants, the object was first seen on the right and last on the left. When one object was presented in the test trial, it was on the left.

Baseline Group

Eight infants (four 5.5- and four 10-month-old infants) were presented with four baseline trials to determine whether they had an initial preference for looking at either one or two objects. All baseline trials began with the stage empty. The experimenter drew the infant's attention to the empty stage by tapping the stage with her hand until the infant looked. The infant was briefly presented with the moving object on the stage. The object was removed from the stage, and the screens were lowered. The experimenter drew the infant's attention to the spaces between and on either side of the screens by tapping her hand until the infant looked.

The screens were then raised to reveal the object(s). Two trials revealed one object and two trials revealed two objects. The order of object presentations was counterbalanced as in the experimental group. The side of the presentation of the single object (left or right) was also counterbalanced. Baseline trials were ended using the same criteria for trials in the experimental group. The stage was cleared of screens and objects between each baseline trial.

CHAPTER IV

RESULTS

The first observer (RSB) used a video monitor to score looking times during the experiment. The scores of the first observer were used in the data analyses. Since the first and second observers have previously achieved reliability measures above .98 (see Bogartz, Shinskey & Speaker, 1995), only 6 of the 40 subjects were rescored by the second observer (JLS). Interobserver reliability was .977.

Baseline Group

An analysis of variance conducted on the data from the baseline group included four factors with two levels each. The variables were age (5.5 or 10 months), number of objects (one or two), sequence of objects (1,2,2,1; 2,1,1,2; 1,2,1,2; 2,1,2,1), and trial (first or second pair of object presentations). No main effects or interactions were found. Infants did not show a significant preference for looking at two objects over one object.

Experimental Groups

For the experimental groups, the variables included in the analysis of variance were age (5.5 or 10 months), movement (continuous or discontinuous), location of occlusion (screen or periphery), side of single object (left or right), number of objects (one or two), sequence of objects (1,2,2,1; 2,1,1,2; 1,2,1,2; 2,1,2,1), and trial pair (first or second pair of object presentations). Sequence of objects was completely confounded with the Movement x Location x Side interaction. The mean looking times for the four experimental groups are listed in Table 1 at the end of the chapter and the analysis of variance is listed in Table 2. Since the first analysis indicated that the sequence factor was not involved in any significant effects, the subsequent analyses excluded sequence as a factor in order to increase power.

The Cognitive Processing Hypothesis

Test Trials

The specific predictions and outcomes of the cognitive processing hypothesis were as follows. First, we expected to replicate the results of Xu and Carey's two original conditions. If infants have object permanence knowledge that can be manifested in this task, they should look longer at

two objects in the continuous-screen condition and one object in the discontinuous-screen condition. This looking pattern would have been reflected in a significant Movement x Location x Number interaction effect. However, no such effect was found.

Second, according to the cognitive processing hypothesis, infants should generally look longer during test trials of periphery events than screen events, since both periphery outcomes are unlikely, whereas only one screen outcome is unlikely. This pattern would be revealed by a significant main effect of location of occlusion. However, no main effect of location was found.

Third, if 10-month-old infants have more object permanence knowledge than 5.5-month-old infants, it is possible that only the older infants would look longer at periphery test trials than screen test trials. This pattern would be manifested by a significant Age x Location interaction. No Age x Location interaction occurred; however, a marginally significant Age x Location x Trial interaction occurred [$F(1,16) = 4.207$, $p < .057$], as may be seen in Figure 5 at the end of the chapter. Ten-month-old infants did look longer following the periphery events than the screen events on the first trial pair, although they looked about equally on the second trial pair. Five-and-a-half-month-old infants looked about equally to the periphery and screen events on both trial pairs, although they looked longer at the first trial pair than at the second trial pair.

The fourth prediction of the cognitive processing hypothesis was that infants would look equally at one and two objects in the periphery conditions. This pattern would have been reflected in a significant Movement x Location x Number interaction, but no interaction occurred.

A fifth, related prediction was that 10-month-old infants would look equally at one and two objects, although 5.5-month-old infants may not. In this case, a significant Age x Movement x Location x Number interaction would occur. An Age x Movement x Location x Number interaction did occur [$F(1,16) = 6.054, p < .026$]; however, it does not support the pattern that was expected, as seen in Figure 6 at the end of the chapter. Ten-month-old infants looked longer at test trials following continuous events than discontinuous events, and they looked longer at two objects than one, regardless of the location of occlusion (screen or periphery events). However, 5.5-month-old infants looked about equally at one and two objects in the discontinuous-screen condition, looked longer at two objects in the continuous-screen and discontinuous-periphery conditions, and looked longer at one object in the continuous-periphery condition.

The only pattern predicted by the cognitive processing hypothesis that was partially, but not significantly, revealed was for 5.5-month-old infants for the screen condition on the first trial pair only, as shown in the Age x Movement x Location x Trial x Number interaction (Figure 7). However, the pattern is reversed on the second trial pair for

these infants. Furthermore, the pattern of looking for the 5.5-month-old infants in the periphery events, as well as the pattern for 10-month-old infants in both screen and periphery events, does not conform to cognitive processing predictions.

Familiarization Trials

The sixth prediction involves looking time during familiarization trials. Both the continuous-screen and discontinuous-screen events are actually impossible events. Infants saw the screens being lowered onto an empty stage, and immediately following, an object emerged from behind a screen. Since no object was on the stage before the screens were lowered, this was an impossible event. If infants have object permanence knowledge, the impossible screen events should violate their expectations. Infants with object permanence knowledge should therefore look longer at the screen events than at the periphery events during the familiarization trials. An analysis of variance showed a main effect of location of occlusion. However, the effect reflected a pattern in the opposite direction: infants actually looked longer during familiarization to the periphery events than to the screen events [$F(1,16) = 23.386$, $p < .000$]. One problem with this analysis is that the periphery events took longer for the experimenter to enact than the screen events, so that infants had more time to look. However, infants in the screen events were found to

spend about 76% of the time looking, whereas infants in the periphery events spent about 84% of the time looking.

The Perceptual Processing Hypothesis

Test Trials

The perceptual processing hypothesis shared the same first prediction as the cognitive processing hypothesis - to replicate the results of the two original conditions of Xu and Carey. However, as discussed above, replication did not occur. No significant Movement x Location x Number interaction occurred.

The second prediction was that infants would look equally at screen and periphery events, since infants are not assumed to know that any object in periphery events is unlikely. This prediction was confirmed: no main effect of location of occlusion occurred.

The third prediction was that infants in the continuous conditions should look longer at two objects, and infants in the discontinuous conditions should look longer at one object, as would be reflected by a Movement x Number interaction. No Movement x Number interaction was found. However, a Movement x Side x Number interaction was found [$F(1,16) = 4.808, p < .043$], as seen in Figure 8 at the end of the chapter. When the single object was shown on the right side, infants looked longer at two objects following

the continuous events. However, when the single object was shown on the left side, infants looked longer at two objects following the discontinuous events. The meaning of this interaction is unclear, and interactions involving the side factor are discussed later in the paper.

Fourth, it was possible that 10-month-old infants might look longer at two objects in the continuous-screen condition and one object in the discontinuous-screen condition, but look equally at one and two objects in the two periphery conditions, if they have object permanence knowledge. This prediction, mentioned in a previous section, would have been reflected in an Age x Movement x Location x Number interaction with a specific looking pattern. Although an interaction occurred, the predicted looking pattern was not reflected in it.

Familiarization Trials

The fifth prediction for the perceptual processing hypothesis involved looking time on familiarization trials. Infants without object permanence knowledge would not be expected to look any longer at screen events during familiarization than at periphery events, since they are not expected to realize that the screen familiarization events are actually impossible. This prediction was confirmed, since the main effect of location of occlusion for familiarization trials did not show infants to look longer at

screen events than periphery events. As mentioned earlier, infants actually looked significantly longer at periphery events [$F(1,16) = 23.386, p < .000$].

Unpredicted Significant Results

Test Trials

Many significant results occurred that were not predicted. Since the pattern of these results cannot be determined by looking at the analysis of variance in Table 2, they are briefly described here.

Infants looked longer on the first pair of test trials than on the second pair of test trials, as shown by the main effect of trial [$F(1,16) = 35.047, p < .000$]. Infants also looked longer at two objects than at one object [main effect of number: $F(1,16) = 6.105, p < .025$]. This was not expected, given the finding that the baseline group did not have a significant preference for two objects over one. In addition, 5.5-month-old infants looked longer at test trials following discontinuous than continuous events, whereas 10-month-old infants showed the reverse pattern [Age x Movement interaction: $F(1,16) = 7.171, p < .016$]. A marginally significant Age x Movement x Trial interaction [$F(1,16) = 4.121, p < .059$] supported the same pattern for the first trial pair. Finally, infants looked longer at test trials

following the discontinuous than continuous events on the first pair of object presentations, but looked longer following continuous than discontinuous events on the second pair of object presentations [Movement x Trial interaction: $F(1,16) = 7.984, p < .012$].

In addition, many unexpected interactions involving the side factor were found. The side factor indicates whether the infant saw the single object in the left or right location. Five-and-a-half-month-old infants looked longer on test trials following the screen events when the single object was shown on the right side, but looked longer following the periphery events when the single object was shown on the left side. Ten-month-old infants, however, looked longer following the screen events when the single object was shown on the right, and looked longer following the periphery events when the single object was shown on the left [marginally significant Age x Location x Side interaction: $F(1,16) = 4.039, p < .062$]. In addition, five-and-a-half-month-old infants in the screen events and 10-month-old infants in the periphery events looked longer at the first trial pair when the single object was shown on the left, but did not prefer left or right on the second trial pair. However, 5.5-month-old infants in the periphery events and 10-month-old infants in the screen events looked longer at the first trial pair when the single object was shown on the right, but did not show a preference on the second trial pair [Age x Location x Side x Trial interaction: $F(1,16) =$

8.942, $p < .009$]. In addition, the Age x Side x Number interaction [$F(1,16) = 4.808$, $p < .043$] was significant: 5.5-month-old infants looked longer at one object when it was on the right, and longer at two objects when the single object was on the left. Ten-month-old infants, however, looked longer at both one and two objects when the single object was on the right, and generally looked longer at two objects than one. Finally, the Age x Movement x Side x Number interaction [$F(1,16) = 6.054$, $p < .026$] was also significant: both 5.5- and 10-month-old infants looked longer at two objects than one when the single object was shown on the right following the continuous conditions. However, 5.5-month-old infants in the discontinuous conditions looked longer at one object than two when the single object was on the right, and looked longer at two objects than one when the single object was on the left. Ten-month-old infants in the discontinuous conditions looked longer at both one and two objects when the single object was shown on the left than when it was shown on the right.

Familiarization Trials

Several unpredicted findings also occurred in the familiarization trial analysis. Ten-month-old infants spent more time looking away when the object started from the right, but 5.5-month-old infants looked away more when the object started from the left [Age x Side interaction: $F(1,16)$

= 6.241, $p < .024$]. In addition, infants looked longer when the single object started moving from the left side in the periphery event, whereas in the screen event, they looked longer when it started moving from the right side [marginally significant Location x Side interaction: $F(1,16) = 4.049$, $p < .061$]. Similarly, infants looked about equally during the continuous-screen and continuous-periphery conditions whether the single object started from the left or the right, but looked longer in the discontinuous-periphery condition when the object started from the left, and looked longer in the discontinuous-screen condition when the object started from the right [Movement x Location x Side interaction: $F(1,16) = 12.382$, $p < .003$].

Additional Analyses

All of the analyses above were performed on infants' total looking time for each trial, as well as on both the first and second trial pairs. Additional analyses were performed on the infants' first look during each trial, as well as for the first trial pair only. Fewer significant results were found overall when only the first look and/or first trial pair were analyzed.

When total looking time was analyzed for the first trial pair only, the results revealed the same looking patterns as when both trial pairs were analyzed. However, significance

level increased or decreased for some of these results. For example, the marginally significant Age x Location x Side interaction ($p < .062$) became significant when only the first trial pair was analyzed [$F(1,16) = 7.310$, $p < .016$].

However, the effect of number (longer looking at two objects than one, with a $p < .025$) was no longer significant when only the first trial pair was analyzed [$F(1,16) = 2.664$, $p < .122$].

When only the infants' first looking time (first gaze) on each trial was analyzed for both trial pairs, some of the significant results mirrored those found for total looking time, but some new results occurred. Three of these effects, one of which was marginally significant, involved the side factor. Since interpretation of the meaning of the results involving the side factor is unclear, they will not be discussed further. The fourth, marginally significant effect (Location x Trial x Number [$F(1,16) = 3.992$, $p < .063$]) supported the finding that infants looked longer at two objects than one for both trial pairs of the periphery events, but in the screen events, infants looked longer at two objects on the first trial pair and one object on the second trial pair. This finding does not support either of the hypotheses investigated here.

Infants' first looking times were also analyzed for the first trial pair only. Fewer significant results were found overall. One result mirrored the previous pattern of the Age x Movement interaction. The second significant finding was a

new result, but involved the side factor and so cannot be meaningfully interpreted here.

Table 1

Mean looking times to one and two objects as a function of age, movement, location and side

Group	Trial 1		Trial 2	
	No 1	No 2	No 1	No 2
5.5 month olds ($\underline{n} = 16$)				
Continuous-periphery				
L	13.950	8.400	6.700	4.817
R	4.633	4.608	9.833	8.158
Continuous-screen				
L	8.650	4.558	4.267	3.225
R	3.833	29.958	10.892	3.933
Discontinuous-periphery				
L	8.967	43.200	6.583	9.908
R	21.692	20.308	9.317	5.175
Discontinuous-screen				
L	9.308	28.808	5.000	7.817
R	41.092	10.200	3.825	9.383

Continued, next page

Table 1 continued

		10 month olds ($\underline{n} = 16$)			
Continuous-periphery					
	L	9.542	15.083	10.425	12.892
	R	24.508	31.217	5.425	17.808
Continuous-screen					
	L	18.542	14.283	14.500	14.958
	R	10.600	10.650	5.808	15.775
Discontinuous-periphery					
	L	8.100	13.967	5.717	9.433
	R	27.242	23.425	7.625	7.992
Discontinuous-screen					
	L	8.375	9.925	3.125	6.508
	R	6.375	14.100	4.600	13.325

Note. Looking times are in sec.

Table 2

Analysis of variance of looking times

Source	<u>df</u>	MS	F
Between subjects			
Age (A)	1	29.471	0.230
Movement (M)	1	71.950	0.556
Location of occlusion (L)	1	114.194	0.882
Side of single object(S)	1	170.124	1.314
A x M	1	928.266	**7.171
A x L	1	103.141	0.797
A x S	1	25.235	0.195
M x L	1	34.688	0.268
M x S	1	2.042	0.016
L x S	1	2.411	0.019
A x M x L	1	0.203	0.002
A x M x S	1	71.551	0.553
A x L x S	1	522.857	*4.039
M x L x S	1	16.603	0.128
A x M x L x S	1	51.723	0.400
<u>S</u> within-group error	16	129.438	

Table 2 continued

Within subjects			
Trial pair (T)	1	1850.601	****35.047
T x A	1	125.281	2.373
T x M	1	421.588	**7.984
T x L	1	46.843	0.887
T x S	1	71.351	1.351
T x A x M	1	217.622	*4.121
T x A x L	1	222.166	*4.207
T x A x S	1	81.973	1.552
T x M x L	1	15.657	0.297
T x M x S	1	.940	0.018
T x L x S	1	7.363	0.139
T x A x M x L	1	15.703	0.297
T x A x M x S	1	8.422	0.159
T x A x L x S	1	472.141	***8.942
T x M x L x S	1	3.955	0.075
T x A x M x L x S	1	4.896	0.093
T x <u>S</u> within-group error	16	52.803	

Table 2 continued

Number of objects (N)	1	280.549	**6.105
N x A	1	22.641	0.493
N x M	1	10.484	0.228
N x L	1	9.589	0.209
N x S	1	43.517	0.947
N x A x M	1	27.969	0.609
N x A x L	1	1.221	0.027
N x A x S	1	220.938	**4.808
N x M x L	1	15.240	0.332
N x M x S	1	676.967	****14.732
N x L x S	1	53.260	1.159
N x A x M x L	1	278.185	**6.054
N x A x M x S	1	278.185	**6.054
N x A x L x S	1	5.514	0.120
N x M x L x S	1	0.054	0.001
N x A x M x L x S	1	63.141	1.374
N x <u>S</u> within-group error	16	45.941	

Table 2 continued

T x N	1	12.272	0.236
T x N x A	1	128.067	2.461
T x N x M	1	0.096	0.002
T x N x L	1	36.587	0.703
T x N x S	1	109.829	2.111
T x N x A x M	1	21.918	0.421
T x N x A x L	1	2.284	0.044
T x N x A x S	1	12.984	0.250
T x N x M x L	1	172.283	3.311
T x N x M x S	1	408.146	**7.845
T x N x L x S	1	8.559	0.165
T x N x A x M x L	1	292.316	**5.618
T x N x A x M x S	1	537.783	**10.336
T x N x A x L x S	1	0.745	0.014
T x N x M x L x S	1	85.097	1.636
T x N x A x M x L x S	1	110.323	2.120
T x N x <u>S</u> within-group	16	52.028	
error			

Note. Looking times are in sec. S = subjects. * $p < 0.10$.

** $p < 0.05$. *** $p < 0.01$. **** $p < .001$.

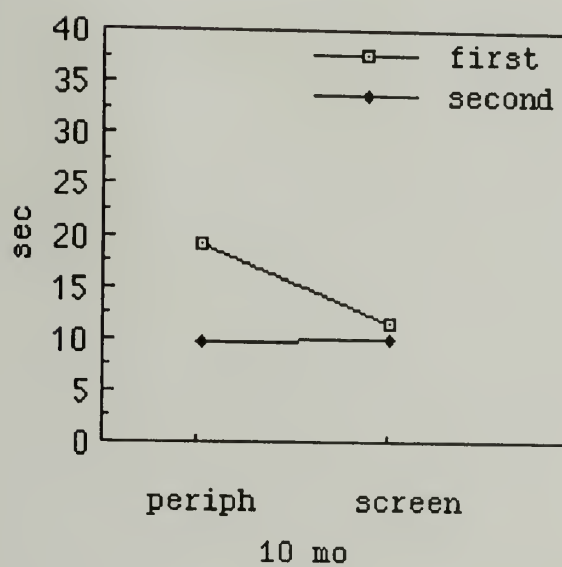
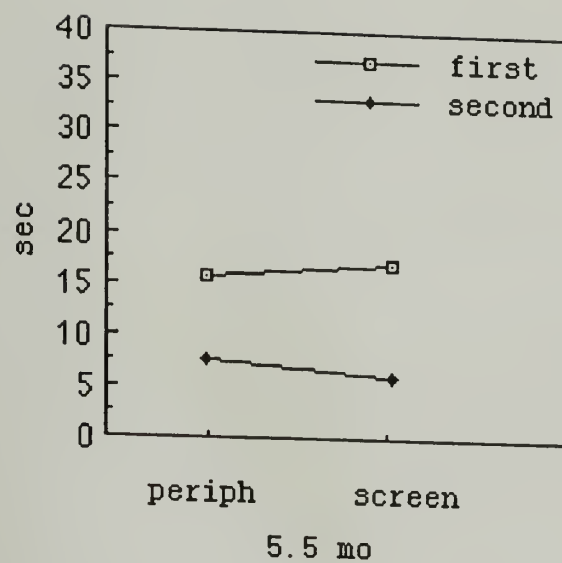
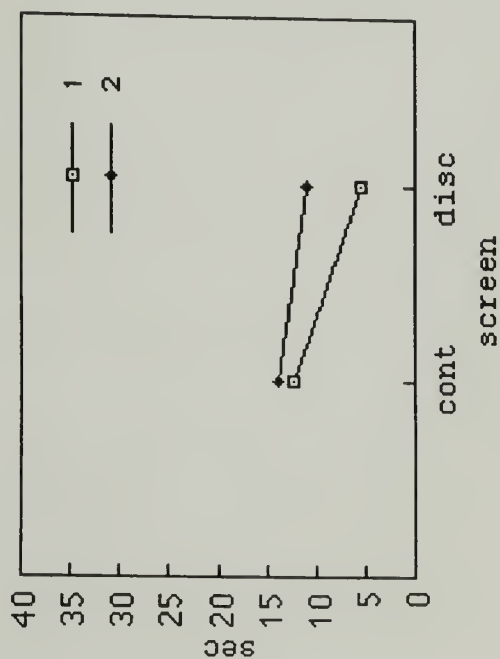
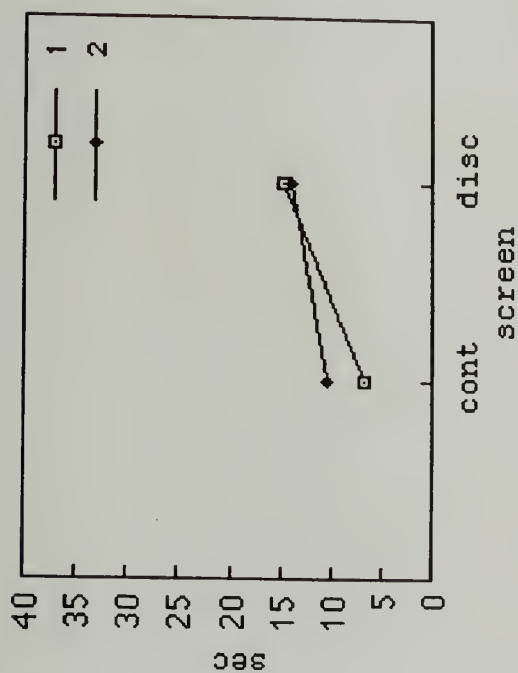
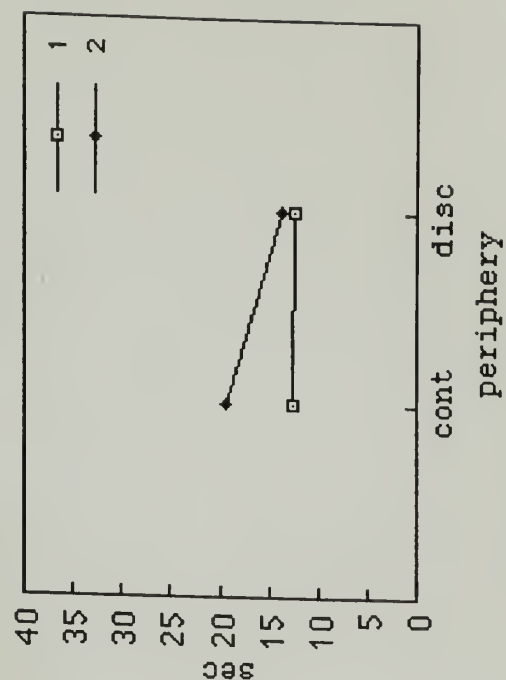
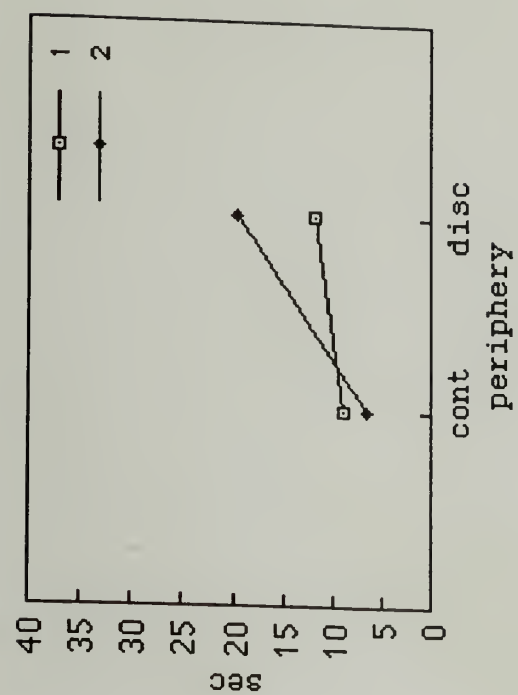


Figure 5. Age x Location x Trial interaction



5.5 MO

10 MO

Figure 6. Age x Movement x Location x Number interaction

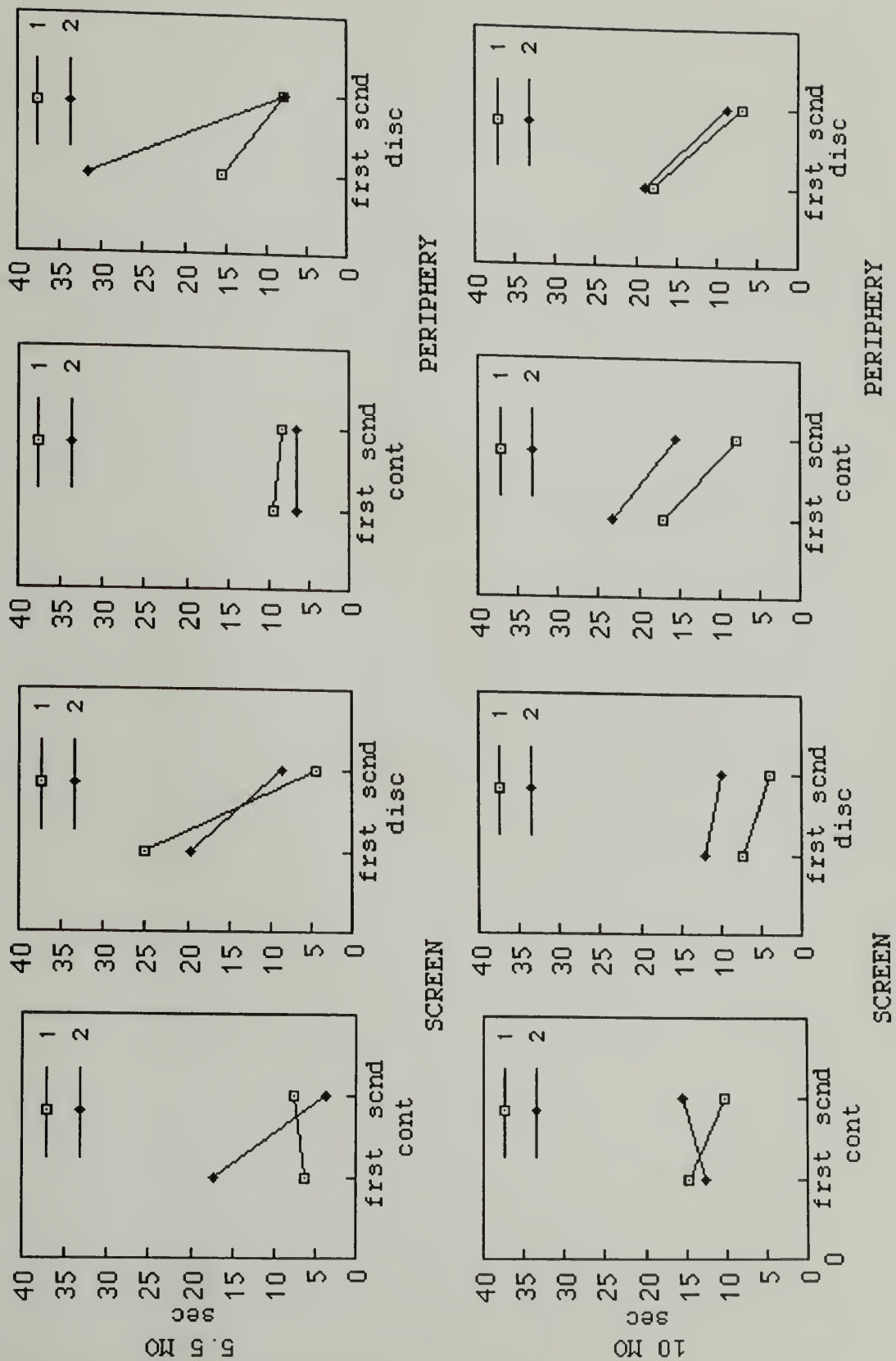


Figure 7. Age x Movement x Location x Trial x Number

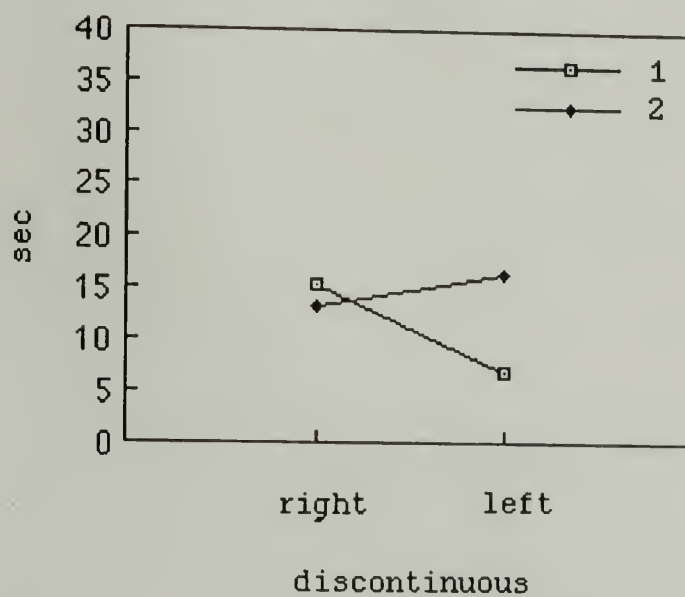
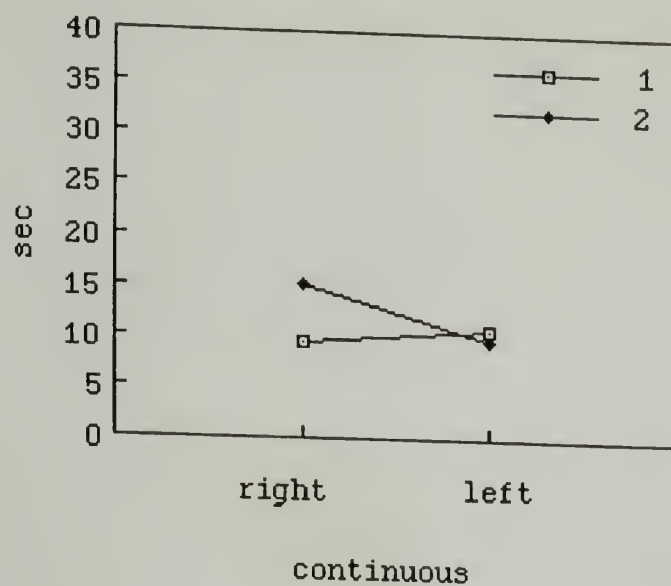


Figure 8. Movement x Side x Number interaction

CHAPTER V

DISCUSSION

Although recent evidence has been interpreted as revealing cognitive processing of occluded objects by young infants, we believe a more parsimonious view involving perceptual processing may account for some results. The present experiment was designed to differentiate between the cognitive processing and perceptual processing hypotheses concerning infants' representations of the number of objects involved in an occlusion event.

Xu and Carey concluded that the 10-month-old infants in their study used spatiotemporal information to infer the number of objects involved in the events. After being familiarized with a discontinuous-screen event involving two objects, infants looked longer at test trials that revealed only one object. After familiarization with a continuous-screen event involving only one object, most infants looked longer at two objects during test trials. Xu and Carey concluded that 10-month-old infants know that an object cannot exist in two places without existing in the intervening space and time, and they use this information to infer that there are two objects in the discontinuous-screen event. Similarly, most of the infants represent the smooth,

continuous path of the toy in the continuous-screen event as implying that only one object is present.

We believe that a simpler explanation may account for these results. The perceptual processing perspective proposes that the presentation of two discrete bundles of activity during familiarization with the discontinuous-screen event contrasts perceptually with the presentation of one object on test trials and captures the infant's attention. Similarly, the smoother tracking in familiarization with the continuous-screen event contrasts with the back-and-forth looking at two objects on test trials and causes the infant to look longer.

We attempted to replicate Xu and Carey's results, and to test the perceptual processing perspective by presenting infants with two additional periphery events. The periphery events were perceptually similar to the two original screen conditions. There were two bundles of activity at either end of the stage in both the discontinuous-screen and discontinuous-periphery events. In the continuous-screen and continuous-periphery events, one object traveled in a smooth path across the stage and back. However, in the periphery events, no objects were left behind the screens at the end of familiarization, and therefore no objects should have been revealed when the screens were raised. Infants who have object permanence knowledge and who can use spatiotemporal information to infer number should look equally long at one and two objects, since both outcomes are unexpected. They

should also look longer in the periphery conditions than in the screen conditions, since the presence of any objects is unexpected.

We tested 10-month-old infants in order to replicate the original study. We tested 5.5-month-old infants because we are not convinced that infants of this age have attained the object concept, although we would not be surprised if 10-month-old infants have. Much of the recent evidence on physical knowledge in infancy is interpreted as showing that infants as young as 3 or 4 months of age have object permanence knowledge. Although the 5.5-month-old infants may not show the same looking patterns as the 10-month-old infants (using spatiotemporal information to infer number), they should look longer at test trials in the periphery events than in the screen events if they have object permanence knowledge.

The Cognitive Processing Hypothesis

The specific predictions of the cognitive processing hypothesis were as follows. 1) The original findings would be replicated: infants would look longer at one object in the discontinuous-screen condition and two objects in the continuous-screen condition. 2) Infants would generally look longer in the periphery conditions than in the screen conditions. 3) Ten-month-old infants, but not 5.5-month-old

infants might look longer in periphery than screen conditions if they have more object permanence knowledge than the younger infants. 4) Infants would look equally long at one and two objects in the periphery conditions, since both outcomes are impossible. 5) Ten-month-old but not 5.5-month-old infants may look equally at one and two objects in the periphery conditions for the same reason given above. 6) On familiarization trials, infants, especially 10-month-old infants, would look longer at screen events than periphery events, since the screen condition actually involves an impossible event.

The cognitive processing hypothesis was not supported by the results of this study. First, Xu and Carey's results were not replicated, and this calls into question the robustness of their findings. This finding is additionally important because Xu & Carey's Experiment 1 was the foundation for the remaining experiments discussed in their paper. If the results of Experiment 1 cannot be replicated, the experiments which followed may be questioned. One qualification that must be added, however, is that our procedure was not identical to Xu and Carey's. Xu and Carey allowed the objects to remain stationary for part of the time during familiarization. In order to accommodate the 5.5-month-old infants in our study, we kept the objects in motion throughout familiarization. It is possible that the novelty of seeing stationary objects for the first time during test

trials may have changed the looking pattern that infants would otherwise have shown.

In terms of the replication prediction, then, infants, even 10-month-olds, did not look longer at one object in the discontinuous-screen condition and two objects in the continuous-screen condition. Second, infants did not look longer in the periphery conditions than in the screen conditions. Five-and-a-half-month-old infants actually looked longer in the screen conditions than in the periphery conditions. Regarding the third prediction, however, a marginal effect supported the finding that 10-month-old infants on the first trial pair only looked longer in the periphery conditions than in the screen conditions (Figure 5). This effect disappeared in the second trial pair, however.

Regarding the fourth prediction, infants did not look equally long at one and two objects in the periphery events. Five-and-a-half-month-old infants looked longer at two objects in the discontinuous-periphery condition and slightly longer at one object in the continuous-periphery condition (Figure 6). Ten-month-old infants looked slightly longer at two objects in both periphery events, so the fifth prediction regarding the 10-month-infants was not confirmed either.

The only looking pattern, although not significant, that seemed to conform to the predictions of the cognitive processing hypothesis was that of the 5.5-month-old infants in the original continuous-screen and discontinuous-screen

conditions for the first trial pair only (Figure 7). In this case, the 5.5-month-old infants did look longer at one object in the discontinuous-screen condition and two objects in the continuous-screen condition. However, that pattern reversed itself in the second test trial pair, and was not exhibited by 10-month-old infants. In addition, the 5.5-month-old infants did not look equally at one and two objects in the periphery conditions, as would be predicted by the cognitive processing hypothesis.

One last prediction of the cognitive processing hypothesis involved looking times on familiarization trials rather than test trials. The screen events are actually impossible because the infants see the screens being lowered onto an empty stage and then immediately see an object emerge from behind one of the screens. The cognitive processing hypothesis would predict that infants with object permanence knowledge would generally spend more time looking at the screen events than the periphery events during familiarization. This was not the case, however. Infants actually looked longer during familiarization to the periphery events than to the screen events.

Although we were somewhat surprised that we did not replicate Xu and Carey's original findings, the fact that the predictions of the cognitive processing hypothesis were not fulfilled in this study further corroborates our doubts about claims that young infants mentally represent hidden objects and can use spatiotemporal information to infer number.

Failure to support the cognitive processing hypothesis in this study lends credence to the hypothesis that results like these may be better explained by an alternative view; we expect, the perceptual processing hypothesis. However, failure to replicate the original results complicates any arguments for the perceptual processing view. The periphery events were designed specifically around the original events, and our predictions about the periphery results were based on the assumption of replication. The predictions of the perceptual processing hypothesis for this study were not fulfilled. We were not able to clearly differentiate the cognitive and perceptual processing hypotheses in this study.

The Perceptual Processing Hypothesis

The specific predictions of the perceptual processing hypothesis for this study were as follows. 1) We predicted replication of the results in the two original conditions, but for perceptual rather than cognitive reasons. 2) Infants, especially 5.5-month-old infants were expected to look equally at the screen and periphery events, since it is not assumed that they have object permanence knowledge. 3) However, we would not have been surprised if 10-month-old infants exhibited object permanence knowledge by looking longer in the periphery conditions than the screen conditions. 4) Infants were expected to show the same

looking pattern at one and two objects in the periphery conditions as in the screen conditions: infants should look longer at two objects in the continuous periphery condition and longer at one object in the discontinuous-periphery condition, for perceptual reasons. 5) If 10-month-old infants have greater object permanence knowledge than 5.5-month-old infants, they may look equally at one and two objects in the periphery conditions, rather than showing the above pattern. 6) Infants were expected not to look longer during familiarization with the screen events than the periphery events.

The first prediction was not fulfilled. Xu and Carey's results were not replicated. The second prediction, however, was confirmed. Infants of both ages looked equally at the screen and periphery events. However, the third prediction was marginally disconfirmed. A marginal effect supported the finding that 10-month-old infants looked longer in the periphery than in the screen condition.

The fourth and fifth predictions were not fulfilled. Infants, even 10-month-old infants, did not look longer at two objects in the continuous-periphery condition and one object in the discontinuous-periphery condition. However, infants did not even show that looking pattern for the original conditions, which clouds our interpretation. We would have been harder pressed to explain this result if the original results had been replicated. However, our other

results are not strongly indicative of object permanence knowledge, even among the 10-month-old infants.

The sixth prediction was confirmed. Infants with object permanence knowledge should have looked longer during familiarization with the screen events than the periphery events, but they did not.

Unpredicted Significant Results

Several significant results occurred which were not predicted. An Age x Movement interaction indicated that 10-month-old infants on average spent more time looking at test trials following the continuous events than those following the discontinuous events, whereas 5.5-month-old infants showed the reverse pattern. We might have expected that the discontinuous events might in general be intrinsically more interesting and generate greater attention across familiarization and test trials, since there are two separate bundles of activity at which to look back and forth. However, this only explains the 5.5-month-old infants' pattern and not that of the 10-month-old infants.

All of the significant interactions involving the side factor were unexpected. The side factor was added only to counterbalance the side on which the single object was shown. In addition, the single object on the test trials was always shown on the same side on which it was last seen during

familiarization, so it cannot be that the infant expected to see the object on the other side. Our initial speculation was that the effect involving the side factor had to do with the mother's presence on the infant's right side. We would not have been surprised if the infant looked away more often while an object was on the right side of the stage, since the infant looked more at the mother when his or her head was oriented to the right. However, the distance between the right and left object was only about 15 cm, and the pattern of results does not conform to the pattern this explanation would predict. Infants sometimes spent more time looking away during test trials on which the single object was on the left, rather than on the right. For example, see the Movement x Side x Number interaction in Figure 8. Infants looked longer at two objects than one in the discontinuous events only when the single object was presented on the left. However, they looked longer at two than one in the continuous-events only when the single object was on the right.

We were surprised that the side factor had any effect at all, much less an effect so great that $p < .001$ in the case of the Movement x Side x Number interaction in Figure 8. We do not know how to interpret the many interactions involving the side factor. In some cases, the results seemed to support one hypothesis or the other, but only when the object was on a particular side. For example, in the marginally significant Age x Location x Side interaction, 10-month-old

infants looked longer following the periphery events, as predicted by the cognitive processing hypothesis, but only when the single object was on the left. Since the side factor is not a psychologically meaningful one, we cannot interpret any of the results in which it is involved as supporting either hypothesis.

Conclusions

Our general conclusions, then, are as follows. The findings of Xu and Carey were not robust enough to be replicated in this study. The predictions of the cognitive processing hypothesis were not fulfilled in this study. We are not convinced that infants can and do use spatiotemporal information to infer number, nor are we convinced that infants exhibit object permanence knowledge in this task.

The perceptual processing hypothesis fared somewhat better than the cognitive processing hypothesis in that some of its predictions were fulfilled. Infants did not indicate that their expectations were violated when objects in the periphery events were revealed where none should have been. Furthermore, infants did not look longer during familiarization when an object emerged from behind a screen, where no objects were before the screens were lowered. However, the main prediction that infants would look longer at two objects in the continuous-periphery condition and one object in the discontinuous-periphery condition was not

fulfilled. We do not believe the perceptual processing hypothesis has failed, however, since the original results were not replicated. We generally conclude that lack of replication has made the results of this study particularly difficult to interpret, and that this specific experimental design was not well-suited for clearly discriminating the cognitive and perceptual processing hypotheses with regard to infants' representations of occlusion events.

We are applying a new design in our lab called the Event Set x Event Set design (see Bogartz et al., 1995), which has already supported the perceptual processing hypothesis in one experiment, and which we are currently using in two additional experiments. Many studies of infants' representations use the two-test design, in which infants are habituated to an event and are then tested on a possible event and an impossible event. Since the perceptual processing view suggests that infants' looking time on these possible and impossible events may be due to other factors, particularly the perceptual differences between habituation and test events, the Event Set x Event Set paradigm was designed to determine what these other factors might be. In this design, three groups of infants are habituated to the three original events (habituation, possible and impossible), and then each infant is tested on all three events. Furthermore, the multiple regression analysis used with this design is better able to pick out the specific elements of the events that influence infants' looking time. It is more

specific than an analysis of variance. We are hopeful that the results obtained with this design will support our belief that many previous results implying cognitive processing of occluded objects in young infants can be explained by invoking lower-level perceptual processing.

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