INFANTS' EXPECTATIONS ABOUT THE SPATIAL AND PHYSICAL PROPERTIES OF A HIDDEN OBJECT

by

Dana Beth Narter

A Disseration Submitted to the Faculty of the

DEPARTMENT OF PSYCHOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

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entitled Infants' Expectations About the Spatial and Physical Properties of a Hidden Object

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy

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I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

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SIGNED: Dana Beth Narter

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DEDICATION

This document is dedicated to my partner in life, Edward Baruch. He has helped me every step of the way in the culmination of this document: from constructing the testing apparatus for this project, to proofreading, to making fabulous posters so that I could share these intriguing findings with others at conferences, to rubbing my feet at the end of especially exhausting days of testing infants. I will not say that I could not have completed this manuscript without him, but his unconditional support and love have certainly made the journey much more enjoyable. I thank him for accompanying me as I follow my dreams, and I hope to return the favor someday.

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ABSTRACT

The purpose of this project was to investigate which spatial and physical object properties 9-month-old infants would use to trace an object in time and space. The particular object characteristics of interest were size, location and features. A two-location violation of expectancy task was used, with looking time as the dependent measure. Infants observed a small toy troll, which was subsequently occluded. When the two flaps were removed, the infants observed either a standard or a change event. During the standard event no change occurred (the small troll was revealed at the same location). During a change event, some sort of physical or spatial change took place; the object might have changed its size (the large troll was revealed at the same location), its location (the small troll was revealed at the other location), its features (the small bear was revealed at the same location), or some combination of these attributes. Infants only observed one type of change event, depending on which of the seven conditions they were assigned to. The findings from this study can be interpreted in terms of two default assumptions: the Same Location/Same Object Rule and the Different Location/Different Object Rule. Nine-month olds use size cues to inform them about object identity in both situations; additionally, they use featural cues to inform them in the second case.

CHAPTER I

INTRODUCTION

Suppose you are playing with an 8-month-old infant, when her favorite toy, a black-and-white striped ball, rolls behind a curtain in the room. Interestingly, the infant might look in the direction of the hidden ball, but she probably will not attempt to retrieve it even though it is her favorite toy. Instead, she will likely move on to another equally exciting activity such as banging pots and pans. Does the infant's inability to manually search for the ball suggest that she does not endow the toy with permanence? Current findings indicate that the answer is no. When assessing object permanence using a manual search task like the one described above, infants will not search for the hidden object until approximately 9 months of age (Piaget, 1954). A manual search task, however, is rather difficult for an infant to perform because it requires her to make coordinated motoric responses, in this case moving the curtain out of the way and retrieving the ball. Alternatively, when methods of assessing object permanence are used which do not require infants to perform coordinated actions, then infants display the ability well before 9 months of age (Baillargeon, Spelke, & Wasserman, 1985; Bower, 1967).

If infants can represent the hidden ball's continued existence, then one might be interested in investigating what other object characteristics the infant is able to represent. One could assess this by "magically" changing one of the spatial or physical characteristics of the hidden ball and measuring the infant's looking time. For example, is the infant surprised when the ball "magically" changes location or size? Is she surprised when the ball “magically” changes shape or color? These types of questions are the impetus for attempts to depict infants’ early representations of objects. If she indeed represents these object characteristics, then she might be surprised (as evidenced by an increase in looking time) when they “magically” change. Some researchers suggest that infants are capable of representing some of the physical and spatial properties of hidden objects (e.g., Baillargeon, 1987b); however, it is not clear *specifically* which object properties babies represent.

It is also interesting to speculate about what is going on inside an infant’s head while she is performing such tasks. The existence of two major fiber bundles emerging from occipital cortex and projecting rostrally in the brain has been well established (Flechsig 1896, 1920). Although the presence of dorsal and ventral pathways is rather clear-cut, their respective roles in vision and visual memory is still not completely understood (Goodale & Milner, 1992; Ungerleider & Mishkin, 1982). Regardless of precisely what is represented in these two cortical visual systems, knowledge of their development is useful in explaining infants’ performance on tasks (e.g., the hidden ball task) at different ages.

To take the hidden ball scenario a step further, one could explore whether the infant has a concept of object identity--the ability to determine whether an object is the same as one experienced earlier. For example, the infant sees the black-and-white ball hidden behind the curtain. Next, she sees an identical black-and-white ball hidden behind the couch across the room. The infant has never seen the ball travel between the curtain and the couch. Will she expect there to be two identical balls or just one ball? If she is able to use spatiotemporal information to trace identity, then she will correctly expect there to be two distinct balls. Property/kind information can also be used to help trace an object's identity over time, though researchers have found evidence that infants use spatiotemporal information to trace identity before they use property/kind information (Bower, 1974; Xu & Carey, 1996).

Before infants can decide whether the toy presently in view is the same object as one they saw earlier, babies must have the necessary prerequisites to this accomplishment. First, infants' must be able to see well enough to examine the toy's physical and spatial properties (e.g., its color, shape, size , location, texture and details). If poor visual acuity and limited color vision are preventing infants from simply seeing objects, then there is no reason to pursue this line of reasoning further. If infants have the visual equipment necessary to examine objects in some detail, then will they also be able to detect and discriminate physical and spatial differences between objects? Logically, a second prerequisite is detectability and discriminability--which focuses on whether or not infants can discriminate objects based upon differences in their attributes. For example, suppose that two stuffed animals are presented to an infant. The toys are identical in every way except that one of the animals is black and the other one is red. Even if infants have the ability to see colors, they still might not prefer one of the stuffed animals over the other based on the dimension of color. If an infant looks significantly longer at the red animal, then one would assume that the infant could detect the difference between the toys and preferred the red stuffed animal over the black one. What if an infant spends equal amounts of time looking at the two toys? It might mean that she does not detect the difference between them, or it might mean that she detects the difference but does not prefer one animal over the other; null results, such as those just mentioned, are inherently ambiguous and should be interpreted with caution.

A third prerequisite is that infants must be able to conceptualize their world in terms of enduring physical objects. They must be capable of representing an object's continued existence when that object is hidden from view. For example, if a parent takes a rattle from an infant and hides it does the infant remember that the object still exists in time and space or does the baby completely deny the object's continued existence?

A fourth prerequisite is what characteristics of the hidden object the infant represents besides its continued existence. Does she remember where the object was hidden? Does she remember how big it was or what color it was? On a neuroscientific level, it is interesting to speculate based on a culmination of both behavioral and neuropsychological research whether infants use the same brain structures as adults do when processing this sort of visual information.

Even if infants possess the prerequisites mentioned thus far, this does not indicate that they will use those spatial and physical object representations for the purposes of determining whether a toy is the same one as the toy just experienced. It is also not entirely clear whether infants and adults share the same set of criteria for making these sorts of decisions about objects. Finally, the set of conceptual criteria might change depending on the age of the infant and the situation presented.

The purpose of the current project was to examine whether 9-month-old infants would use the dimensions of size, location and features to assist them in deciding whether an object was the same one as the object seen 15 seconds earlier. The paradigm used was a two-location nonsearch task with looking time as the dependent measure. During the present experiment, infants would observe objects being hidden and subsequently retrieved on a puppet show stage. Upon retrieval the object might have "magically" changed one or more of its attributes or it might have remained exactly the same as the object that was hidden. The looking time data offer evidence about whether the event was consistent or inconsistent with the infant's expectation. If an event is consistent with the infant's expectation about the world, then the baby will not find this type of event surprising and might not look very long following the event. Conversely, if an event is inconsistent with the infant's expectation, then the baby will be surprised when the event violates her expectation about the world and will probably look longer at such an event as compared to the consistent event. Finding some preliminary answers to this philosophical issue is the ultimate goal of the present research project.

The rest of this dissertation will be organized in the following way: In Chapter II, a review of the literature for each major topic is presented: object permanence, object location, object size, two cortical visual systems and object identity. Chapter III describes the method for the study, and Chapter IV describes the results. Finally, Chapter V is a general discussion of the findings.

CHAPTER II

REVIEW OF THE LITERATURE

This literature review commences by summarizing the research that has been conducted on object permanence in infants. After reviewing the evidence that infants do endow objects with permanence, the paper will focus on how infants respond to the spatial and physical characteristics of objects. Specifically, the literature on object location and object size will be reviewed at length. A brief summary of the two cortical visual systems underlying these abilities will follow. The review will then turn to a more philosophical issue: Object identity. Infants may be able to represent certain object properties, but whether or not they will use that information to trace identity over time is a separate question.

Object Permanence

Although object permanence has been broadly described as the knowledge that an object continues to exist independently of one's perception of that object, more precise definitions and criteria for its attainment appear to be absent from many articles addressing the nature and development of object permanence. The omission of an explicit definition of the term suggests that the meaning of object permanence is universal and agreed upon by all, which is not the case. If the definition of object permanence is not clearly denoted, then the rationale for selecting particular behavioral indicators to assess object permanence cannot be fully understood.

Piaget (1954) conceived of object permanence as the notion that a physical entity exists continuously in time and space. In other words, an object cannot exist temporally or spatially at two separate points without having existed between the two points. Based on his own observations using manual search tasks, he concluded that infants do not conceive of objects as permanent entities. Instead, young infants construe the physical world as being comprised of non-permanent entities that are "made" when they appear and are "unmade" when they disappear. Piaget further maintained that young infants depict the physical world as being dependent upon their actions. For example, if an object is occluded, a young infant might reproduce a specific motor response with the expectation that this action will make the object reappear. Piaget purported that the infant regards objects as being at the disposal of a specific action. If the action fails to make the object appear again, then the young infant does not make alternative movements to retrieve it.

Based on the importance of motor activity in Piaget's theory of cognitive development, it is quite appropriate that he chose a task with a strong motor component, a manual search task, to assess the attainment of object permanence in infants (Piaget, 1954). During a Piagetian manual search task, the infant sees a brightly colored toy which is subsequently covered by a cloth. The goal of the task is for the infant to lift the cloth and retrieve the toy. Piaget made observations about successful searches, failed searches and search errors in infants of different ages. Based on his observations, Piaget identified six stages of object-knowledge attainment. He found that infants younger than 4 months of age (Stages 1 and 2) will not even look for an object that has been completely or partially hidden, although they are capable of performing these actions. The infants may, however, look at a toy, look away from it and then look at it again several seconds later without any perceptual cue reminding the infant of the toy's continued existence. Between 4 and 9 months of age (Stage 3), infants make some progress and are able to retrieve partially occluded objects. Piaget conceded that during Stage 3, infants might look in the direction of a hidden object or produce hand movements following a complete occlusion; however, they do not successfully recover the hidden toy. Furthermore, Piaget observed that Stage 3 infants are able to anticipate the future positions of moving objects. For example, if an infant is tracking an object and the object becomes occluded, she will look further along the object's trajectory to find the object. Similarly, if a Stage 3 infant is holding an object out of view and accidentally drops it, she makes an attempt to recapture it.

Although infants in Stages 1 though 3 demonstrate some knowledge of the physical world around them, Piaget claimed that infants do not endow objects with permanence until approximately 9 months of age (Stage 4), and it is not until then that the infant will retrieve a fully occluded object. According to Piaget, it is during Stage 4 of his theory that infants regard objects in the physical world as being independent of their actions on those objects. During Stage 4, infants will try several different actions to reveal a hidden object. For example, if a ball rolls behind a curtain and the infant cannot recapture the ball by extending her reach, she will try alternative actions to recover the toy (e.g., lifting the curtain, pulling the curtain aside). Piaget interpreted these activities as evidence that Stage 4 infants understand that objects are not at the disposal of a specific action, but they can be retrieved in a number of ways. Other investigators have replicated the Piagetian search tasks and found similar results (see Gratch, 1975, 1977; Harris, 1987; Schuberth, 1983, for reviews).

A notion of object permanence is not a solely human capacity; nonhumans also demonstrate existence constancy. Suppose you are playing with a dog, and you hide his favorite squeaky toy behind your back. The dog will search for the toy behind your back, which suggests that he acknowledges that the toy still continues to exist in absence of his direct perception of that toy. The previous example illustrates that nonhumans might also endow objects with permanence, though more formal methods of assessing object permanence have been adapted for use with animals (see Doré & Dumas, 1987, for a review). The purpose for reviewing the animal literature on object permanence is to highlight parallels and divergences between the cognitive functioning and development of humans and other animals.

Three longitudinal studies of spontaneous behavior related to object permanence have been conducted in non-human species. First, in a longitudinal study of a stump-tailed macaque, Parker (1977) found that the first three stages of development were quite similar to human infants' development; however, the macaque attained object permanence at 3 weeks of age, which is much earlier than the age at which a human infant possesses object permanence. Second, Bergeron (1979) investigated object permanence in chimpanzees and found that the first three stages were similar to a human infant's development, though the chimpanzee had a notion of object permanence by the end of the sixth month, which is two to three months earlier than is generally found in human infants. A third longitudinal study was conducted with kittens, and the researchers found that the first indications of object permanence emerged at five weeks of age, which is significantly earlier than the attainment of object permanence in human infants (Dumas, 1985; Dumas & Doré, 1985).

Across all three studies, animal infants attained object permanence well before human infants. One explanation for this might be that animals need a notion of object permanence for survival earlier than humans do. Thus, such a cognitive capacity has been prewired over time to become functional earlier in animals than in humans. For example, it would be necessary for survival for an animal to acknowledge that when a predator or a potential food source hides behind a bush, the hidden animal still exists as a threat (or a snack).

Although the animal studies of object permanence mentioned thus far involve spontaneous behaviors, most studies of object permanence in animals have used tasks that were designed for humans but have been modified to fit the abilities of the species being investigated. In order to elicit search behavior, the occluded object must have strong incentive properties. In human infants and sometimes in primates (Bergeron, 1979; Wise, Wise, & Zimmerman, 1974) toys have incentive properties; however, in animals it has been found that food and objects that have acquired incentive properties through secondary reinforcement are more appropriate for the hiding tasks. Oddly, odor cues from food do not facilitate search behavior in dogs and cats (Triana & Pasnak, 1981). If secondary reinforcement is used, then the training must be completely separate from the object permanence testing to avoid confusion in interpretation of the results (Bouchard & Mathieu, 1976).

As Bower (1974) noted, errors in object permanence tasks should not be the result of a motor deficit. Although Bower was referring specifically to human infants, his statement certainly applies to animals as well. When conducting hiding experiments with animals, one must be certain that the animal can perform the motoric pattern which will reveal the hidden object. If an animal does not have the motor response in his behavioral repertoire, then he can be trained to perform the response. Again, if training is used it should be completely dissociated from the object permanence task (Mathieu, Bouchard, Granger, & Herscovitch, 1976).

In addition to the motoric consideration mentioned above, researchers must carefully choose the appropriate number of trials to use when developing search tasks for animals. The goal of an object permanence task is to assess a cognitive capacity that underlies spontaneous search behavior in unlearned contexts. The retrieval of a hidden object should not be due to learning taking place during the experiment. Thus, a test of object permanence should include a limited number of trials so that there is no question as to whether the animal is demonstrating true object permanence or learned search behavior.

Human analog tests of object permanence have been administered to several different animal species. Etienne (1973) studied object permanence in chicks by showing the chick a display composed of two screens with a glass tube containing a worm running between the screens. The worm was then pulled through the tube, with the chick following it, until the worm disappeared behind one of the screens. There were three sessions. During the first two sessions the chicks' performance did not differ from chance, whereas during the third session the percentage of correct responses was significantly higher than chance. Etienne (1973) concluded that chicks do not go beyond associative learning. They are not guided by a general cognitive structure; instead they have acquired adaptive responses through experiences with the environment. The errors in Etienne's study occurred during the first trials, which suggests that the search behavior was learned during the experiment. If the errors would have been randomly distributed across trials, then the pattern of errors would have been suggestive of true object permanence.

Several studies of object permanence have been conducted in domestic cats; however, there are discrepancies between the findings of these studies. Gruber, Girgus, and Banuazizi (1971) concluded that object permanence develops in cats in much the same sequence as it does in human infants. The primary difference is that cats reach Stage 4 at approximately 4 months of age, whereas human infants do not reach Stage 4 until 9 months. Other researchers have found that cats attain object permanence even more quickly than Gruber et al.'s findings suggest (Dumas, 1985; Dumas & Doré, 1985). Furthermore, the developmental sequence was not identical in cats and humans.

These discrepancies can largely be accounted for by the different methodologies that were used. Specifically, the nature of the hidden object and the motor response that the cats performed was not the same across experiments. In Gruber et al.'s (1971) task, a soft cloth object was hidden under a white cloth, and the cats had to pull the cloth covering it. In Dumas' (1985) study, a small ball of aluminum foil was hidden. In younger kittens the ball was a primary reinforcement for play, whereas in older kittens the ball was associated with food. When the ball disappeared behind vertical screens, the cats had to walk behind the screen and paw the object. This motor response is part of a cat's natural repertoire of search behavior and was easy for the cats to perform. Pulling a cloth, however, is not a natural response for kittens or even adult cats. Additionally, it seems as though the object incentive value was higher in Dumas' study than in Gruber et al.'s study.

Tests of object permanence have also been conducted on a wide variety of primates. Using squirrel monkeys as subjects, Vaughter, Smotherman, and Ordy (1972) concluded that the development of object permanence follows the same sequence as that described by Piaget. In fact, infant squirrel monkeys as young as 6 months of age exhibited Stage 3 behaviors, which is three months earlier than in human infants. Wise, Wise, and Zimmerman (1974) assessed object permanence in two infant rhesus monkeys and found that the sequence of development was quite similar to that described by Piaget in human infants. Additionally, many studies have been conducted to compare the development of object permanence in human infants and chimpanzees (e.g., Mathieu, 1983; Wood, Moriarity, Gardner, & Gardner, 1980) and gorillas (e.g., Redshaw, 1978). In Mathieu's (1983) longitudinal study, the chimpanzees were slightly ahead of the humans in terms of object permanence development; however, the difference was less pronounced than in gorillas.

The Piagetian notion of object permanence has received some attention in the animal literature, though it has only been thoroughly investigated in a limited number and variety of species thus far. Taken together, these animal studies show that different species display varying degrees of object permanence. Future investigations ought to go beyond the assessment of object permanence and focus on the developmental sequence in which permanence is attained. In addition, search strategies need to be examined in relation to object permanence.

The original Piagetian search task has been modified to fit the behavioral repertoires of animals; however, researchers have criticized the Piagetian task for being rather difficult for human infants to perform. The task requires the infant to coordinate two actions: one action to move the occluder and another action to retrieve the object. T. G. R. Bower (1967) proposed that young infants fail to search for hidden objects because they lack the ability to coordinate actions into means-ends sequences, not because they have forgotten that the hidden object still exists as Piaget had suggested. Bower tested his hypothesis by using a manual search task with a transparent cup, instead of an opaque cover, as an occluder. By using transparent covers, the infants could see the “hidden” object during the entire procedure. He found that 5- to 6-month-old infants did not retrieve the hidden object even when it was visible under the transparent cup, which suggests that their failure stemmed from a lack of coordination of manual skills, not a deficit in acknowledging that the object still existed under the cup. Bower concluded that manual search tasks are more complex than visual search tasks, and the ability to successfully perform the former task develops much later than the ability to perform the latter. Ironically, Piaget (1952) examined the development of action and found that infants do not coordinate actions into means-ends sequences until about 9 months of age; however, the infant must be able to coordinate separate actions in order to succeed on his task.

Bower and his colleagues (Bower, 1967, 1972, 1974; Bower, Broughton, & Moore, 1971; Bower & Wishart, 1972) devised several methods of assessing object permanence that did not require the infants to perform coordinated actions. Using these innovative procedures, Bower and his associates found evidence for object permanence in infants well before 9 months of age. First, Bower (1967) exposed 7-week-old infants to a static red and white bullseye-patterned sphere, which would disappear either in a manner that was consistent with the continued existence of the sphere (e.g., a screen is gradually moved in front of the sphere and stops when it completely covered the object) or in a manner that was inconsistent with the continued existence of the stimulus (e.g., apparent sudden implosion of the sphere). Sucking rate and heart rate were the dependent measures. The findings suggested that 7-week-old infants could discriminate between the two types of disappearances. Second, Bower et al. (1971) examined the tracking behavior of infants using linear and circular trajectories, with partial occlusion of the trajectories. He found that 2-month-old infants would anticipate the reappearance of an occluded object by looking in the direction of the predicted movement path had the object not stopped moving. In another study (Bower & Wishart, 1972), a toy attached to a string was dangled in front of the baby. Before the baby could reach for the toy, all of the lights in the room were turned off, leaving the baby in total darkness. All of the 5-month-old infants in this experiment were able to accurately reach out to grasp the "hidden" object. Collectively, Bower's findings provide evidence for object permanence much earlier than 9 months of age.

Though Bower's conclusions are provocative, some researchers have noted that his findings do not necessarily lend support to the notion of object permanence in young infants. Alternative explanations other than object permanence might explain Bower's findings. First, it is possible that the infants in Bower's experiments were simply extending an ongoing action or reproducing an action as Piaget originally proposed. For example, when an infant anticipates the reappearance of a moving object, they might merely be extending a tracking motion that was performed prior to the object's disappearance. A second interpretation is that infants have expectations about the manner in which objects usually disappear, which are not based on a notion of object permanence. For example, infants often see one object occlude another object; however, they rarely see an object dissolve or implode. Overall, Bower's methodology and interpretation have been questioned by other researchers (e.g., Gratch, 1977; Harris, 1987).

A better procedure for measuring object permanence is needed--one in which the infant is not required to make any type of motor response. The violation of expectancy procedure appears to be the solution. This procedure is based on the classic habituation paradigm, and the sequence of events is as follows: The infant is presented repeatedly with a habituation display with the intention that she will form an expectation based on the display. A habituation trial ends when the infant has accrued a predetermined amount of looking time or not-looking time. Habituation trials continue until the infant reaches a particular criterion that is determined in advance by the experimenter. As in the classic habituation paradigm, the infants' looking time should decrease across habituation trials. To test whether this expectation has been formed, the infant is presented with two test displays: one which is consistent with the expectation and one which is inconsistent. It is looking time that indicates the violation of the expectation due to infants' documented orienting response to novelty. The test display consistent with the expectation formed during the habituation phase will not lead to an increase in looking time, because it is not considered to be a novel event. Conversely, a test display that is inconsistent with the expectation should result in dishabituation, a rapid increase in looking time.

Renée Baillargeon and her associates (Baillargeon, Spelke, & Wasserman, 1985) devised a method of assessing object permanence in infants using the violation of expectancy procedure. First, the infant is habituated to a solid screen that moves back and forth in a 180 degree arc like a drawbridge--from flat on the table pointed toward the infant, to upright, to flat on the table pointed away from the baby, to upright, to flat on the table pointed toward the baby, etc. After the baby is habituated, a solid object (e.g., a yellow box or a brightly colored Mr. Potato Head) is placed in the path of the rotating screen and the infant observes either a possible or an impossible test event. During the possible test event, the screen is pointed toward the infant, rotates past vertical, and stops when it reaches the occluded object. During the impossible test event, the screen is pointed toward the baby and rotates through a 180 degree arc as though the occluded object was no longer there. Using this drawbridge procedure, Baillargeon et al. (1985) found that 5-month-old infants looked significantly longer at the impossible than at the possible event. These results suggest that 5-month-old infants acknowledge that objects continue to exist when occluded. Furthermore, Baillargeon's findings indicate that infants are sensitive to the solidity constraint, which states that a solid object cannot move through the space occupied by another solid object.

Baillargeon (1987a) later extended her original findings by investigating whether even younger infants possess object permanence. She found that 4.5-month-old infants and 3.5-month-old infants who were fast habituators looked significantly longer at the impossible than at the possible event, which indicates that the 4.5-month-old infants and a subgroup of the 3.5-month-old infants possessed object permanence. Specifically, she found that infants who reached the habituation criterion within six or seven trials (fast habituators) tended to look longer at the impossible versus the possible test events; whereas, the infants who reached the habituation criterion within eight or nine trials (slow habituators) tended to look equally at the possible and impossible test events. The distinction between fast and slow habituators in Baillargeon's study is important because it suggests that the fast habituators behaved more like older infants. In other words, the 3.5-

month-old infants who were fast habituators behaved more like the 4.5-month-old infants in the study.

Collectively, Baillargeon's results (Baillargeon, 1987a; Baillargeon et al., 1985) cast doubt upon Piaget's description of the development of object permanence. First, Baillargeon's findings cannot be explained by the extension or reproduction of an earlier action as Piaget would have argued. Because Baillargeon's tasks do not require the infant to perform a motor response, her results could not possibly be explained such actions. Second, Piaget claimed that infants do not search for hidden objects because they do not yet view objects as permanent entities. Baillargeon's findings, however, suggest that infants as young as 3.5 months of age endow objects with permanence.

The question remains as to why Stage 3 infants fail to manually search for hidden objects. One explanation is that their short-term memory is not fully developed, which makes it impossible for them to remember the existence of a hidden object (e.g., Bower, 1967). Baillargeon's results challenge the memory deficit explanation because the infants in her studies were able to remember the presence of the yellow box as long as 10 seconds. Another explanation is that young infants cannot coordinate separate actions into means-end sequences. Uzgiris (1973) observed that infants begin to search for hidden objects at approximately the same age that they begin to exhibit reversible actions, pushing and pulling objects, crumpling and uncrumpling paper, and putting toys in a container and taking them out. At approximately 9 months of age, infants will discover which actions produce which outcomes. A final explanation is that the failure to search reflects the interaction of several factors.

Regardless of why young infants do not manually search for hidden objects, it is clear that they consistently fail manual search tasks. As demonstrated by Baillargeon and her colleagues, young infants display a capacity for object permanence when they are assessed using a nonmanual search tasks. Baillargeon has two explanations of her own to account for the presence of object permanence in young infants. One possibility is that the notion of object permanence is innate (Spelke, 1985). Perhaps infants are born with some fundamental notions about the existence and movement of solid bounded objects in time and space. According to Spelke, these conceptions form the basis for existence constancy in occluded objects. A second possibility is that infants are born with a learning mechanism that enables them to attain object permanence if they are provided with a set of observations involving objects. These observations might involve infants' examination of the interactions between objects or from infants' actions upon objects (Mandler, 1988). Although Baillargeon's findings are not sufficient to reveal the mechanisms underlying object permanence, her clever methodology has allowed researchers to examine the presence of existence constancy in very young infants.

In sum, Piaget (1954) first claimed that infants do not have a complete notion of object permanence until 9 months of age based on his studies using manual search tasks. However, when tasks did not require the infants to perform coordinated actions, evidence for object permanence was found well before 9 months (Baillargeon, 1987a; Baillargeon, Spelke,

& Wasserman, 1985; Bower, 1967, 1974; Bower, Broughton, & Moore, 1971; Bower & Wishart, 1972). If young infants can remember that an object hidden from view continues to exist, then one might speculate that babies can represent some of the spatial and physical properties of hidden objects. Evidence for representation of these object properties will be examined in the next several sections.

Object Location

Although Piaget (1954) found that 9-month-old infants can remember that a object hidden from view continues to exist, he also noted that these same infants committed a particular type of search error known as a perseveration error, or an "A not B" error. The infant first observes an object being hidden at location A and successfully retrieves the object from its location of hiding. On the next trial, the infant sees the object hidden at location B, but she searches at location A instead of at location B. Piaget interpreted this perseverative search error as a type of egocentrism in which the infant is unable to separate the object from the self. The fact that 9-month-old infants search for hidden objects at all suggests that they have at least some basic concept of permanence; however, the search errors observed in these infants indicate that their object concept is not identical to that of an adult. The hidden object is still construed as the extension of the infant's action. Hence, the baby searches where the object was last recovered, not where it was last hidden. Piaget purported that infants will overcome the A not B error by approximately 12 months of age.

The perseveration error first reported by Piaget has spurred many other researchers to examine this curious search error and the Piagetian explanation underlying the behavior. Some researchers (Bjork & Cummings, 1984; Schacter, Moscovitch, Tulving, McLachlan, & Freedman, 1986) have proposed that an immature memory mechanism is responsible for the A not B error. Bjork and Cummings (1984) found that 8- to 12-month-old infants display the classic A not B error; however, the authors claim that this finding is purely an artifact of the two-choice hiding task. When less constrained hiding tasks were used (i.e., tasks with more than two locations), the infants did not commit the perseveration error. Instead they produced a pattern of errors consistent with search errors resulting from a memory inadequacy, not a conceptual problem. Additionally, Schacter et al. (1986) found that amnesic patients exhibit a search error that closely resembles the A not B error found in infants. Schacter et al. used two tasks: a room search task and a container search task. In the room search task, an object was hidden in a room that had many landmarks. A delay of 2.5 minutes filled with conversation was imposed before the subject was allowed to retrieve the hidden object. In the container search task, an object was hidden in one of four drawers differing in both color and location. Again, a delay of 2.5 minutes was imposed before retrieval was permitted. The similar performance of amnesics and infants on object search tasks provides evidence that a memory deficit, not an inadequate object concept, underlies the perseveration error.

Unfortunately, the memory deficit hypothesis cannot account for all the data collected on object search tasks. For example, infants do not exhibit the perseveration error when they can associate a cue with the correct location (Butterworth, Jarrett, & Hicks, 1982). Butterworth and his associates (1982) discovered that infants would search for the hidden object at the correct location when specific spatial cues, such as two different colored covers, were introduced. Furthermore, infants can remember information for much longer periods of time than those used in search tasks (Rovee-Collier & Hayne, 1987). Based on these findings, the memory failure explanation does not look promising.

In opposition to the memory deficit hypothesis, Adele Diamond (Diamond, 1985; Diamond & Goldman-Rakic, 1983) proposes that infants make the A not B error due to immaturity of the frontal lobe system. Diamond (1985) began by investigating the developmental progression of the ability of infants between 6 and 12 months of age to withstand longer delays on the A not B task. The delay required to produce the A not B error increased continuously across age, from delays under 2 seconds for the youngest infants to delays over 10 seconds for the oldest infants. Although infants of all ages demonstrated the A not B error, there were large between-infant differences in the delay needed to produce the error at different ages. Interestingly, the A not B error disappeared when delays were decreased by 2 to 3 seconds, and reaching became random or grossly perseverative when delays were increased 2 to 3 seconds beyond the delay producing the error. For example, 8-month-old infants committed the A not B error with a 3 second delay, but correctly searched when the delay was reduced to 1 second. In addition, the 8-month-olds searched randomly when they were required wait 5 or 6 seconds before retrieving the object. Diamond (1985) concludes from her findings that the A not B task is an index of the ability to carry out an intention based on information stored in memory despite a conflicting tendency to reach to the initial hiding location.

Behavioral evidence from Bower (1967) supports Diamond's claim that failure on the A not B task cannot be explained by memory deficit alone. When Bower used transparent cups instead of opaque cups as occluders, he found that 5- to 6-month-old infants could not successfully retrieve the hidden object even though the object was never hidden from view.

In 1988, Diamond proposed that the frontal lobe system was implicated in the A not B task, and she criticized Schacter et al.'s (1986) study of amnesics which implicated the memory system. First, Diamond claimed that all of the amnesic patients studied by Schacter et al. had frontal lobe damage as well as damage to the memory system. Therefore, Schacter et al.'s choice of subjects did not permit a test of the effects of amnesia versus frontal lobe damage. Second, the length of delay in Schacter et al.'s experiments was quite different from the length of delay generally used in A not B experiments. In Schacter et al.'s study a delay of 150 seconds was imposed; whereas, in Diamond's study delays of 2 to 5 seconds produced the A not B error in 7.5- to 9-month-old infants. Perhaps the long delay used by Schacter et al. made his tasks dependent on the hippocampus instead of on the frontal lobe. It has been noted that the length of delay requiring frontal lobe function is shorter than that requiring hippocampal function. For example, there is no evidence linking damage of the hippocampal system to errors in object search tasks at delays under 10 seconds in monkeys; however, there is evidence linking damage of the frontal lobe system to errors at delays under 10 seconds. Specifically, monkeys with lesions of the dorsolateral prefrontal cortex demonstrate the A not B error at delays of 2 to 5 seconds (Diamond & Goldman-Rakic, 1983; 1986).

Third, Schacter et al. (1986) suggest that proactive interference, which is characteristic of amnesics, may be the reason for the A not B error. Both amnesics and infants have nearly perfect recall of location on the trials in which the object is hidden at location A, which suggests that interference might play a role in subsequent forgetting. Although Diamond (1988) agrees that proactive interference may account for some of the findings, she mentions that only a subgroup of amnesics, those with severe damage to the frontal lobe, are sensitive to proactive interference. Moscovitch (1982) has demonstrated that amnesics without frontal lobe signs show normal release from proactive interference; whereas frontal patients without amnesia are abnormally sensitive to proactive interference. In sum, sensitivity to proactive interference is found in patients with frontal lobe damage whether they are amnesic or not. Finally, Diamond and Goldman-Rakic (1983) have argued against perseveration as an interpretation of frontal lobe damage. Instead they propose that success on the A not B task requires two abilities: (1) memory and/or attention; and (2) inhibitory control (Diamond, 1985; Diamond & Goldman-Rakic, 1985). A lack of inhibitory control may result in perseveration; however, perseveration is not the cause.

Conveniently, the A not B task is quite similar to an object search task used with nonhuman primates called the delayed response (DR) task. In both tasks the subject observes as the experimenter hides the object in one of two wells, and after a brief delay the subject is allowed to reach for the object. In both tasks, the subject must hold some representation of the hidden object in memory during the delay. In the A not B task, the object is hidden at location A over subsequent trials until the subject reaches to that location, and then the object is hidden at location B. In the delayed response task, the location of hiding is varied randomly over trials. The strong similarities between these two tasks allows researchers to compare them both at a behavioral level and at a neuroanatomical level.

Performance on the DR task in nonhuman primates has been shown to be a reliable indicator of frontal lobe functioning. When the animals have damage to the dorsolateral prefrontal cortex, performance on the DR task is impaired; equivalent damage to other areas of the brain does not result in a decline in DR performance. For example, Diamond and Goldman-Rakic (1989) found that adult monkeys with lesions of frontal cortex fail the DR task; whereas, adults monkeys with lesions of the parietal cortex succeed. In another study conducted by Squire and Zola-Morgan (1983), adults monkeys with lesions of the hippocampus were successful on the DR task. Based on the similarities between the A not B task and the DR task, it seems plausible that performance on the A not B task is also dependent on the prefrontal cortex.

Human infants demonstrate a clear developmental progression on the two tasks, with improvement occurring between 7.5 and 12 months of age

(Diamond, 1985; Diamond & Doar, 1989). When infant monkeys are used as subjects, Diamond and Goldman-Rakic (1986) discovered that they also exhibit a clear developmental progression on both tasks, with marked improvement occurring between 1.5 to 4 months of age--the developmental equivalent. In addition, 5-month-old infant monkeys with lesions of the frontal cortex sustained at 4 months of age, fail the tasks (Diamond & Goldman-Rakic, 1986). Not only do human infants and infant monkeys have similar developmental progressions on these tasks, but those subjects who are unsuccessful make similar errors. Both groups of subjects make the perseveration error on the A not B task, and they err on the DR task following a reversal shift. Furthermore, adult monkeys with lesions of the dorsolateral prefrontal cortex produce error patterns that are strikingly similar to the error patterns displayed by infants who search unsuccessfully.

Based on both behavioral and neurological findings, investigators have proposed that the prefrontal cortex integrates information for the purposes of action (Diamond, 1988, 1991). Both the A not B and DR tasks require subjects to integrate several pieces of information over time: where the object was last retrieved and where the object was last seen. Because a reach to location A had previously been reinforced, a subject with a damaged or immature frontal cortex might not be capable of inhibiting that previously executed motor response; thus, they reach to location A again even though they saw the object hidden at location B.

Diamond (1991) reports that infants sometimes reach to location A even when the object is visible at location B. There are also instances when the infant will look at location B (the correct location) and reach to location A (the incorrect location). This lack of inhibitory motor control is apparent in toddlers as well. Paul Kaufmann (personal communication) reports that children in his studies will sometimes correctly verbalize where the object is hidden (e.g., "The toy is under the red cup") yet still reach to the incorrect location (e.g., the blue cup). These sorts of unusual behavioral responses do not seem as strange when one considers the underlying brain structure(s) used to perform the task. As mentioned earlier, an immature frontal cortex cannot inhibit a previously executed action. Based on these findings, Diamond (1991) acknowledges that infants may know much more about the location of hidden objects than they can express through a motor response.

Baillargeon and her colleagues (Baillargeon & Graber, 1988; Baillargeon, DeVos, & Graber, 1989) have devised a way to examine what infants can remember about the location of a hidden object by removing the motor component from the A not B task and rendering a visual-search task with looking time as the dependent measure. In a simple version of this non-search AB task, the infant sees an object standing at one of two locations. Next, screens cover the locations, hiding the object from the baby's view. After the brief delay, a hand reaches behind one of the occluders and retrieves the object. There are two types of retrieval events: a possible event and an impossible event. A possible event would be the hand retrieving the object from the location where it was initially hidden, and the impossible event would be the hand retrieving the object from the other location.

Baillargeon and Graber (1988) used this nonsearch AB paradigm to determine whether 8-month-old infants could remember the location of a hidden object following a 15 second delay. The target object was an inverted white styrofoam cup decorated with stars, dots, pushpins and white cotton balls. There were two experimenters: one manipulated the screens and the other manipulated the target object. To begin the experiment, each infant received two familiarization trials so that she could become acquainted with the display and the two possible locations of the object. Following the two familiarizations, each infant saw three pairs of test trials alternating between possible and impossible test events. The test events began with the decorative cup standing at one of the two locations. Next, an experimenter slid the screens in front of the two hiding locations, which signaled the start of the 15 second delay. During the brief delay, an experimenter's hand entered the display through an opening in the side of the apparatus wearing a silver glove and a bracelet of jingle bells and "tiptoed" to keep the infant looking at the display until the delay was finished. At the end of these 15 seconds, the gloved hand reached behind the correct screen (possible event) or the incorrect screen (impossible event) and retrieved the decorative cup, waving it gently until the computer signaled that the looking time criterion was attained and the trial was over. Baillargeon and Graber (1988) found that the infants looked reliably longer at the impossible event as compared to the possible event. This result suggests that the infants had remembered the object's location during the 15 second delay. Furthermore, these findings indicate that infants' location memory is much better than had previously been suggested by their performance on manual A not B search tasks.

Baillargeon, DeVos, and Graber (1989) used a paradigm quite similar to the one used by Baillargeon and Graber (1988), with the only major difference being that delay times were longer in length. One minor change in procedure was that the gloved hand was now wearing a large Cookie Monster or Oscar the Grouch hand puppet for most of the delay period. During the last 10 seconds of the delay, the puppet was removed and the silver gloved hand retrieved the object and waved it gently. When the delay time was increased to 30 seconds, 8-month-old infants still remembered where the object was initially hidden. Even when the delay time was increased to 70 seconds, the infants still remembered the location of the decorative cup. These findings suggest that 8-month-old infants are far more capable when tested with a visual-search task compared to a manual-search task. Based on the evidence from Baillargeon's lab, it does not seem very likely that infants' failures on manual-search tasks are due to inadequate memory mechanisms or conceptual inadequacies.

If 8-month-old infants can remember a hidden object's location over delays as long as 70 seconds, one might wonder whether younger infants will demonstrate location memory with shorter delays. Using a nonsearch paradigm very similar to Baillargeon's, Wilcox and Nadel (1993) tested infants longitudinally at 2.5-, 4.5-, and 6.5-months of age, using delays of 5, 10, and 30 seconds respectively. In their experiments, the target object was a yellow toy lion. Wilcox and Nadel found that all of their subjects remembered the location of the hidden toy lion and were surprised when it appeared at the incorrect location. These findings imply that infants as young as 2.5 months of age can represent both the existence and location of a hidden object.

The infants in both Baillargeon's and Wilcox's studies looked longer at the impossible event because a physical constraint had been violated--the continuity constraint. The continuity constraint is a principle which states that objects move on connected paths. In other words, an object cannot jump from one point in space to another without having passed through the physical space between the two points. When an object is hidden at one location and retrieved at another location, the continuity constraint has been violated. The infant sees the object being hidden at location A and retrieved at location B without having moved through the space between the two locations. The infant is surprised by this physical violation as indexed by longer looking times.

Both manual and visual AB tasks can be adapted to include more than two wells. Important information can be obtained from the pattern of errors demonstrated in performance on multiple-well tasks. For example, the pattern of errors obtained in a multiple-well task provides researchers with much more information about strategies and underlying brain systems than the pattern of errors obtained in a two-well task, in which the infant can only err to location B. One pattern of errors in a multiple-well task might be suggestive of memory deficit while another pattern might be suggestive of a conceptual difficulty. Sophian (1985) tested 9-month-old infants on both a two- and three-location version of Piaget's manual AB task. There were three major findings: (1) The infants did not systematically perseverate on either the two- or the three-location tasks; (2) They used two sources of location information to perform the task: current hiding information and information from previous trials; and (3) Infants searched in basically the same ways on two- and three-location tasks. Sophian concluded that 9-month-old infants are much more competent searchers than earlier accounts have suggested.

In another multiple-well search task, Diamond and her colleagues (Diamond, Cruttenden, & Neiderman, 1994) tested infants between 9.5 and 10 months of age with a 7-well apparatus. Diamond wanted to determine whether errors were due to memory alone or to memory plus inhibition. If the errors were due to memory alone, then they should be normally distributed around the correct well. If the errors were due to memory plus inhibition, then more errors should occur in the direction of the previous correct well. Based on her results, Diamond concluded that the errors were due to memory plus inhibition.

Finally, Wilcox and her associates (Wilcox, Rosser, & Nadel, 1994) used a 4-location nonsearch task with 6.5-month-old infants to examine the types of information that infants rely on to code the location of a hidden object. Infants watched as a toy lion was hidden at one of four locations. Following a 10 second delay, the object appeared at the location where it was hidden (possible event) or appeared at one of the other three locations(impossible events). Three ways that location information can be encoded were examined: a distance strategy, a general area of hiding strategy and a boundary strategy. An infant using a distance strategy would base her response on the amount of distance that the toy lion moved between hiding and retrieval. Alternatively, an infant using a general area strategy would make her response based on the general area of hiding and recovery. For example, if an object were hidden at location A, an infant would expect it to be recovered in the vicinity of location A, not necessarily at location A. Finally, an infant using a boundary strategy would code spatial location in relation to a boundary. If infants use a boundary strategy, then one would predict that they would have better location memory for objects hidden near boundaries. Wilcox et al. found that the infants did not code location information using any of the strategies they had predicted. The infants did, however, use boundary information in a different way than the investigators anticipated. Increased looking times to impossible events were determined by the location of retrieval, not the hiding location. In other words, infants looked longer when the toy lion was retrieved at a boundary position; however, they did not look significantly longer when the toy lion was retrieved at an inner location. The infants in this study also relied on information about the nature of the change, absence versus presence of the toy lion, to code location.

In summary, the Piagetian manual search task (1954) has inspired many other researchers to examine the A not B error more closely in both human infants and nonhuman primate infants. Based on these findings, it is clear that the dorsolateral prefrontal cortex plays an important role in both the A not B task and the DR task. One function of the prefrontal cortex is to inhibit motor responses that were previously reinforced. When the frontal lobe is damaged or immature, it cannot perform its function adequately. When the motor component is removed from the A not B task, 8-month-old infants can remember the location of a hidden object up to 70 seconds (Baillargeon, DeVos, & Graber, 1989). Additionally, infants as young as 2.5 months of age can remember the location of a hidden object during a 5 second delay (Wilcox & Nadel, 1993). Finally, A not B tasks with multiple wells give us additional information about the types of errors infants make and the proposed mechanisms underlying the errors.

Object Size

When an observer acknowledges that the perceived properties of objects remain the same even though their sensory representations have changed, she is demonstrating perceptual constancy. For example, a person who possesses visual size constancy realizes that an object's apparent size is unchanged with changes in the size of the retinal image due to variations in object-observer distance. Prerequisites to a complete notion of size constancy include object size discrimination and object distance discrimination. Although one assumes that adults and children can make such discriminations, these basic prerequisites should not be assumed in infants. Thus, the section will begin with a review of the literature on size and distance discrimination, followed by a review of size constancy and memory for an object's size.

One prerequisite for size constancy is the ability to discriminate objects based on size. Bower (1972) examined size discrimination in infancy by investigating whether or not 2-week-old infants could accurately perceive the size of an object as measured by finger-thumb separation prior to contact with the object. Two pairs of objects were used as the stimuli: cylindrical rods (.5 cm and 2.5 cm cross sections) and plastic balls (3.5 cm and 7.0 cm diameters). All testing sessions were recorded on videotape using a telephoto lens so that finger-thumb separation on the third frame prior to contact could be measured. If an infant reached for the object with both hands, then interhand separation was measured. Bower found that finger-thumb or interhand separation increased with object size. His experiment has been criticized because his method of single-camera recording reduces three-dimensional events to two-dimensional records, which yields ambiguous results.

Similarly, Bruner and Koslowski (1972) provided a demonstration of size discrimination in infants by examining arm and hand movements in relation to object size. Infants were tested every two weeks between 8 and 22 weeks of age. Two bright red balls decorated with gold beads and blue pipe cleaners served as the stimuli for the experiment. The small ball and the large ball were 1.25 and 10 inches in diameter respectively. The investigators found that the infants brought their hands and arms to the midline of the body and exhibited greater hand activity when they were reaching for the small ball versus the large ball. Some researchers (e.g., Lockman & Ashmead, 1983) have suggested that the infants may have been responding to location rather than to size. Specifically, the boundaries of the larger ball extended further from the infant's midline, and the smaller object's boundaries were located nearer to the midline. Although Lockman and Ashmead's interpretation is reasonable, Bruner and Koslowski's findings still suggest that the infants discriminated the object's size prior to contact.

Duration of visual fixation has also been used as an index of size discrimination in both visual preference and habituation paradigms, and this index has provided more convincing evidence. From birth, infants look longer at large rather than small objects; however, this preference disappears by approximately 8 weeks of age (Fantz & Nevis, 1967). Newborns have also been reported to prefer patterns with large and more numerous elements to those with small and less numerous elements (Miranda & Fantz, 1971). Fantz and Fagan (1975) varied the size and number of elements in patterns independently so that they could evaluate the influence of these dimensions together and separately. The investigators reported that between 5 and 25 weeks of age, infants have a preference for patterns with larger and more numerous elements. Furthermore, the influence of size diminished with age. The findings from these three studies are not completely consistent with one another, probably due to differences in stimuli and procedure; however, all three studies indicate that the ability to discriminate size is present early in the first year after birth.

One important consideration in size discrimination experiments is whether the stimuli are two- or three-dimensional. McKenzie (1972) presented infants between 7 and 19 weeks of age with large and small unpatterned two- and three-dimensional objects. A habituation paradigm was used with looking time as the dependent measure. During the habituation phase, the infants were repeatedly presented with an object of one size until the infant became bored with the object as indexed by decreased looking times across trials. During the test phase, they were shown an object of another size. If the infants are responsive to the size change, then dishabituation or recovery should result, as indexed by an increase in looking time during the test phase. Although the infants in this study dishabituated to the size change with three-dimensional objects, they did not do so when two-dimensional objects were used.

Based on McKenzie's (1972) findings, Ruff and Turkewitz (1979) decided to investigate the age at which infants can make size discriminations when two-dimensional stimuli are used. To answer this question, the investigators presented 6-, 9- and 24-week-old infants with pairs of stimuli which varied among four stimulus sizes. Using visual fixation time as the dependent measure, Ruff and Turkewitz reported that infants at all ages preferred the larger patterns to the smaller ones, and these preferences decreased with age. Thus, the findings indicate that two-dimensional stimuli size differences can be discriminated as early as 6 weeks of age.

Lawson and Ruff (1984) examined the effects of size on visual tracking by presenting 4- and 8-week-old infants with three-dimensional moving stimuli: a small doll's head and a large doll's head. The researchers found that at both 4 and 8 weeks of age, the infants followed the large head more than the small head, which suggests that they could discriminate the heads on the basis of size. Taken together, the findings from studies of size discrimination in infants generally agree that size is a discriminable object property for very young infants. Of course the somewhat impoverished vision of newborn infants will act as a constraint on size discrimination. The subtle differences in results from size discrimination experiments are probably due to differences in the indexing response selected and the stimuli used in the experiment.

The discrimination of horizontal object distance is another prerequisite for a notion of size constancy. Although there have been many studies involving perception of depth or "downward" distance (e.g., Walk, 1966), there are few studies which have examined horizontal distance. Bower (1972) presented 7- to 15-day-old infants with a small foam rubber sphere at a close distance and a large foam rubber sphere at a far distance. He found that infants made more attempts to reach for the closer object than for the farther object. Similarly, Field (1975) noted that 5-month-old infants adjusted their reaching according to object distance, whereas 2-month-old infants did not make such adjustments. In sum, it appears that by at least 5 months of age, infants make few attempts to grab for objects that are out of their reach.

McKenzie and Day (1972) found that object distance was a determinant of visual fixation of solid objects in infants. They tested infants ranging between 6 and 20 weeks of age by presenting them with a white cube at either 30 or 90 centimeters. The investigators found that before 20 weeks of age, infants would fixate on the cube when it was located at 30 centimeters; however, they would not fixate on the cube when it was at 90 centimeters. Similarly, Field (1975) observed a decrease in looking time in 5-month-old infants as object distance increased. McKenzie and Day (1976) investigated 2- and 4-month-old infants' attention to stationary and moving objects at different differences, and they found that fixation duration of stationary objects was inversely related to object distance, whereas fixation duration of moving objects was not. Specifically, fixation duration to a rotating patterned cylinder did not decrease as object distance increased from 30 to 90 centimeters. Conversely, fixation duration to a stationary patterned cylinder decreased as object distance increased.

An example of infants' ability to respond to object distance is provided by their reaction to objects as they move toward them. Infants display avoidance responses such as opening the eyes wide, throwing the head back or raising the hands when an object rapidly approaches them. Optical flow information provides the baby with an expanding contour or "looming" pattern as the object approaches. Bower and his associates (Bower, Broughton, & Moore, 1970) found that infants as young as 6 days of age responded to a small looming object at a closer distance, but they did not respond to a larger looming object at a further distance. Bower interpreted these findings in the following way: Newborns make defensive responses when presented with optical information for collision, and these responses indicate depth sensitivity. Ball and Tronick (1971) replicated Bower et al.'s findings with infants ranging in age from 2 to 11 weeks. In addition to replicating Bower's results, Ball and Tronick found that infants will respond to symmetrical expansions which specify a collision, but they will not respond to asymmetrical expansions or contracting flows which respectively specify a "miss" or an object moving away from the baby.

Yonas, Bechtold, Frankel, Gordon, McRoberts, Norcia, and Sternfels (1977) have suggested that the infants' response to a looming pattern might be attributed to tracking the upper contour of the display, rather than a defensive reaction. Yonas and his associates have evidence from infants in several age groups to support this hypothesis. There were three conditions in the experiment: a collision course, a "miss" trajectory and a non-expanding, rising contour. The investigators found that although the collision display evoked more upward head rotation than the noncollision display in subjects as young as 1 month of age, it was the non-expanding, rising contour that elicited the greatest amount of backward head movement. Yonas et al. concluded that infants will visually track a rising contour as early as 1 month of age; however, they do not exhibit defensive behavior (increased blinking) to impending collision until they are approximately 4 to 5 months old. Furthermore, Yonas and his colleagues have contended that the defensive response to impending collision is not fully established until the infant reaches 8 to 9 months of age.

In a later study, Yonas, Pettersen, and Lockman (1979) reported that 3- to 4-week-old infants did not demonstrate backward head movements following exposure to an approaching object on a collision course, except when some of the object's contours rose in the infant's visual field. Conversely, displays specifying collision evoked significantly more blinking than displays specifying an object's withdrawal, whether or not rising contours were present. This prompted Yonas et al. to conclude that blinking is the initial defense response exhibited by infants subjected to optical collision.

Even more recently, José Náñez (1988) tested 3- to 6- week-old infants' ability to specify the presence or absence of impending collision under three conditions: (a) rapid versus slow visual display expansion and contraction; (b) figure-ground contrast reversal of the display; and (c) rapid change in illumination without display expansion or contraction. Náñez found that rapid and slow expansions of a dark display on a light background elicited significantly more blinking and backward head movements than their contractions, whereas this was not the case when the display was lighter than its background. In addition, a sudden brightening of the screen did not elicit defensive behavior relative to a sudden darkening. He concluded that given high-contrast visual information, infants exhibit sensitivity to impending collision quite early in development.

The results from many studies suggest that the ability to perceive impending collision is innate in a variety of species (e.g., Schiff, 1965; Schiff, Caviness, & Gibson, 1962). Schiff (1965) reared chicks and kittens in the dark from birth, then exposed them to a looming shadow. All of the chicks and most of the kittens responded defensively to the expanding shadow. Additionally, young and adult fiddler crabs and frogs responded defensively to the loom (Schiff, 1965). A second set of studies (Schiff, Caviness, & Gibson, 1962) found that both infant and adult rhesus monkeys displayed avoidance responses to looming patterns but not to zooming patterns. In sum, both human and nonhuman subjects perceive impending collision very early in life, and they respond avoidantly and directionally to it. Furthermore, the behavior was found to be relatively independent of shape and magnification rate.

As previously mentioned, complete size constancy is present when one acknowledges that an object's apparent size is unchanged with changes in the size of the retinal image due to variations in object-observer distance. A thorough review of research on size constancy in infancy can be found in a chapter by R. H. Day (1987). The review of the of the size constancy literature will begin with a summary of some early studies of size constancy conducted in the 1940s and 1950s. In Cruikshank's (1941) experiment, subjects ranging in age from 10 to 50 weeks were presented with a rattle at a particular distance while they were lying in their cribs. In Conditions 1 and 2, a small rattle was presented at different distances depending on which condition the subject was assigned (rattle at 25 cm for Condition 1 and 75 cm for Condition 2), resulting in different visual angles. In Condition 3, a larger rattle was presented at the further distance resulting in the same visual angle as the smaller object at the nearer distance (Condition 1).

Infants were shown each rattle for 30 seconds, and the their reaching responses were observed. If the infants responded similarly to all three conditions, then one would assume that they could not discriminate between the objects in the stimulus arrays. If responses to Conditions 2 and 3 were similar but different from the response to Condition 1, then distance would be implicated. Finally, if responses to Conditions 1 and 2 were similar but different from Condition 3, then real size would be implicated suggesting that the infant demonstrated a capacity for size constancy. Unfortunately, Cruikshank's experiment had some flaws in its design and procedure which result in inconclusive outcomes. For example, if distance perception were assumed, then the subjects could perceive that the object was the same size at two different distances (Conditions 1 and 2), yet they would reach more frequently for the nearer object (Condition 1). Additionally, there was not a condition in which the two objects were at the same distance. Thus, no conclusions can be drawn about differences in reaching when the two rattles were at different distances.

Another early study of size constancy in infancy was conducted by Misumi (1951) with infants between 12 and 59 weeks of age. Misumi recognized the problems with Cruikshank's study and remedied them by presenting pairs of objects at the same and different distances. He conducted eight experiments. In the first three experiments, toy goldfish served as the stimuli. The next four experiments used small balls, and in the final experiment the stimuli were red cubes between 1 and 15 cm along an edge. In six of the eight experiments, the two objects were at the same distance, and in two experiments the objects were at different distances. The reason that very small objects were used in some experiments was that infants reached significantly more for small objects than for large objects. Because of the low frequency of reaching to large objects, the experiments using large stimuli produced inconclusive outcomes. When infants were presented with different size balls at different distances, they reached significantly more for the larger ball even if a smaller visual angle resulted. For subjects 26 weeks and older, 82% reached more frequently for the larger, further objects. When the two objects were at the same distance, 88% of responses were made to the larger ball.

Misumi's findings are important because they address several issues that are necessary to consider when studying size constancy in infants. First, Misumi found that young infants will not usually reach for objects that are too large for infants to manipulate. Thus, it is not suitable to use large objects in experiments where frequency of reaching is the dependent measure. Second, it is unclear how the very small balls were presented to the subjects. If the objects were held by an experimenter, then the objects could have been partially occluded by the experimenter's fingers. Last, Misumi did not describe the criteria for reaching toward one object versus reaching toward the other object. In all eight experiments, the two objects were separated laterally by 5 cm. The experimenter must be extremely careful when determining the direction of reaching due to the small distance between the two stimuli. Although Misumi's experiments had some flaws, they were the first experiments to provide some evidence for visual size constancy during the first year after birth. In sum, the early studies of size constancy are not considered conclusive in determining the presence of size constancy in infancy.

Based on the work of Cruikshank (1941) and Misumi (1951), Piaget and Inhelder (1969) proposed that size constancy emerges at approximately 6 months of age. They found that if you trained an infant to choose the larger of two boxes, then the infant continued to choose correctly even if you move the larger box further away so that its retinal image is smaller. Additionally, Piaget and Inhelder (1969) claimed that size constancy develops earlier than object permanence.

Bower's (1964, 1965) size constancy experiments were quite different than the studies conducted by Cruikshank (1941) and Misumi (1951) in terms of the response index used and the size and distance of the stimuli. In Bower's experiments, conditioned head turning was the response index, the objects were larger, and the distance was farther. Bower's (1964) first experiment was an operant analysis designed to determine whether premotor infants, 10 to 12 weeks old, can discriminate changes in the position of objects independently of variations in the size of the retinal image. To assess this, Bower had the infants lie in a slightly inclined crib; the infants' heads were positioned between two pads, the left hand one of which contained a microswitch. Each time the microswitch was activated, an experimenter emerged from below the table and "peek-a-booed" at the infant, then crawled back under the table. A 12-inch white paper cube, which served as the conditioned stimulus, was placed three feet from the infant on the table during training. The leftward head turn was the operant response, and the peek-a-boo was the reinforcement. Following training, generalization testing was conducted using four generalization presentations: (1) 12-in cube at 36 in (training situation); (2) 12-in cube at 108 in; (3) 36-in cube at 36 in; and (4) 36-in cube at 108 in. The mean number of leftward head turns for these four conditions were 102.70, 66.03, 54.10 and 22.92 respectively.

Though the size of the retinal image was the same in Conditions 1 and 4, the number of responses in those two conditions were quite different, which does not lend support to the claim that premotor infants can only discriminate distance based on the size of the retinal image. The smallest reduction in number of responses was found in Condition 2, which suggests that size at a particular distance was specified and size constancy is functioning in infants at 10 weeks of age. The large number of responses in Condition 3 compared with Condition 4 suggested that distance was also discriminated.

The purpose of Bower's (1965) second experiment was to examine whether motion parallax is a necessary variable for the perception of size and distance. To test this, Bower tested infants between 6 and 10 weeks of age. The procedure and stimuli were quite similar to those used in Bower's (1964) experiment. The conditioned stimulus for each of the three conditions is as follows: The Binocular Condition--a 30 cm cube at 1 m viewed binocularly; The Monocular Condition--a 30 cm cube at 1 m viewed monocularly; and The Projection Condition--a 30 cm square of light, of approximately the same luminance as the cubes viewed by the other two groups, at 1 m viewed binocularly. The test conditions were as follows: (a) a 30 cm cube or projection at 1 m (the training condition); (b) a 30 cm cube or projection at 3 m; (c) a 90 cm cube or projection at 1 m; or (d) a 90 cm cube or projection at 3 m. The pattern of results for the binocular and monocular groups is similar to the pattern of findings from Bower's (1964) earlier study. Specifically, the mean number of head turns across all three conditions for Presentations B and C are less than for presentation a but greater than for Presentation D. The pattern of responses in the Projection Condition differs from that of the other two conditions for Presentation D, for which the response frequency is about the same as that for Presentation A.

Bower interpreted these findings to mean that infants between 6 and 10 weeks of age can discriminate object size and object distance and that size constancy is sustained when the distance of the object is changed. The mean response frequency across conditions in Presentation D is rather interesting. The frequencies for Presentation D were quite low in the monocular and binocular conditions in which three-dimensional cubes were used. Conversely, the response frequency for the project condition in which two-dimensional projections were used, was comparatively high. Bower's interpretation was that motion parallax specifies distance with three-dimensional objects but not with two-dimensional objects. His explanation does not appear to apply in all situations, though. For example, when one examines the close similarity in response frequencies across all three conditions for Presentations B and C, then the motion parallax interpretation does not work. Bower responds to this criticism by suggesting that the information might have been specified by the size of the retinal image instead of motion parallax. Although Bower's two-tiered explanation is plausible, it certainly lacks parsimony. In summary, Bower's (1964, 1965) experiments indicate that his subjects responded to object size and object distance.

McKenzie and Day (1972) used alternative methods to determine if they could replicate Bower's findings. McKenzie and Day tested infants between 6 and 20 weeks of age by habituating them to an 18-cm cube at 90 cm from the infant. In this experiment, the degree of recovery from habituation of visual fixation was used as an index of the apparent size of the white cubes. There were four test conditions: (1) 18-cm cube at 90 cm (the habituation condition); (2) 18-cm cube at 30 cm; (3) 6-cm cube at 90 cm; and (4) 6-cm cube at 30 cm. If object size and object distance were discriminated as suggested by Bower's results, then one would predict that infants would demonstrate the least dishabituation for Condition 1 (same object at same distance), intermediate dishabituation for Conditions 2 and 3 (same object at different distance and different object at same distance) and the greatest dishabituation for Condition 4 (different object at different distance). Contrary to Bower's (1964, 1965) expectation, McKenzie and Day (1972) found that the infants in their study responded solely to changes in object distance. In McKenzie and Day's experiments, the subjects only dishabituated in Conditions 2 and 4 where the distance had changed. There was no change in duration of fixation when objects were presented at 90 cm. The discrepancy could have been due to differences in the procedure and the indexing responses used.

More recent studies of size constancy (Day & McKenzie, 1981; McKenzie, Tootell, & Day, 1980) have also used the habituation paradigm and found that size constancy occurs by 26 weeks of age and possibly as early as 18 weeks of age. McKenzie et al. (1980) examined visual size constancy for distances up to 70 cm with 4-, 6- and 8-month-old infants. Subjects were habituated to a colored "realistic" model of a human head. During test trials, infants saw one of four conditions: (1) the standard test condition in which neither size nor distance changed; (2) a change in distance only; (3) a change in size only; or (4) a change in both distance and size. McKenzie and his associates found size constancy occurred for the 6- and 8-month old infants for the head model up to 70 cm, whereas size constancy was not demonstrated at 4 months of age at this distance. The results do, however, show a trend toward the attainment of size constancy in the 4-month old group at distances of 30 to 60 cm, though this trend was not significant. Eighteen-week-old subjects with low variance relative to the median variance behaved much like the older subjects in the study, which suggests that these young infants may perceive the invariant size of an object with changes in the object's distance. Conversely, 18-week-old infants with high variance had similar recovery scores across all four conditions, indicating that size constancy was not present in these particular subjects.

Based on the findings of McKenzie et al. (1980), Day and McKenzie (1981) set out to demonstrate that size constancy is present in 18-week-old infants under certain conditions. First, all of the experiments on size constancy presented so far have used stationary stimuli, but Day and McKenzie decided to use moving stimuli for their study. It has been found that stationary stimuli have significantly lower attractiveness for young infants than moving stimuli (McKenzie & Day, 1976; Volkmann & Dobson, 1976). Second, shape constancy has been shown to emerge at approximately 12 weeks of age (Caron, Caron, & Carlson, 1979; Caron, Caron, Carlson, & Cobb, 1979). Although there is no *a priori* reason to doubt that shape constancy is present before size constancy in perceptual development, a difference of 14 weeks in their emergences seems intuitively excessive.

Following from this logic, Day & McKenzie (1981) habituated 18-week-old infants to a model female head (small or large) that repeatedly moved toward and away from the subjects along the medial axis. During the test phase, infants saw the same model head moving back and forth as it did during the habituation phase or a model head of a different size moving in the same manner. Dishabituation was greater for the moving head of a different size than for the moving head of the same size, suggesting that visual size constancy was functioning. The authors concluded that the infants perceived and responded to the invariant physical size of the model head as its visual angle varied. Taken together, these two studies (Day & McKenzie, 1981; McKenzie et al., 1980) provide some evidence that size constancy is functional in infants as young as 18 weeks of age.

Even more recently, investigators (Granrud, 1987; Slater, Mattock, & Brown, 1990) have suggested that size constancy may be present at birth. In Granrud's (1987) study, newborn infants were tested in either a "Constant-Size" or a "Variable-Size" condition. The subjects in the Constant-Size group were shown a sphere at three distances: 16, 24 and 32 cm. In the Variable-Size condition, infants were sequentially shown three different-sized spheres presented respectively at 16, 24 and 32 cm from the infant. The Constant-Size group showed a significant decrease in looking time across the six trials, suggesting that they were seeing the same-sized sphere across trials. On the other hand, the Variable-Size group did not show a significant decrease in fixation time across trials, which suggests that the babies in this group perceived different-sized spheres over trials. Granrud's findings indicate that newborn infants possess at least some degree of size constancy.

Slater et al. (1990) also were looking for the presence of size constancy at birth. In their first experiment, they used the preferential looking procedure to determine the way in which size preferences at birth are influenced by retinal and/or real size. The infants were presented with pairs of black and white cubes which varied in real size and viewing distance. Slater and his associates found that these infants based their preference solely on retinal size. In Slater et al.'s second experiment, the researchers used a familiarization/recovery-to-novelty procedure to assess whether newborns can perceive an object's constant real size across changes in distance (i.e., changes in retinal size). Newborns were familiarized to a either a small or large cube at six different distances. The purpose of the familiarization phase was to desensitize infants to changes in retinal size in hopes of directing their attention to the cube's real size. During the two test trials, small and large cubes were shown at different distances so that their retinal sizes were the same. One of the cubes used during the test phase was the same cube that was used during the familiarization period, but shown at a different distance. Slater and his colleagues found that these newborns strongly preferred a different sized object to the familiar one, which suggests that the real size had been perceived as constant across the six familiarization trials. These two experiments confirm Granrud's (1987) results that size constancy is present at birth.

Other recent studies have not examined size constancy per se, but have focused on other facets of size such as infants' sensitivity to changes in size and infants' memory for object size. Granrud, Haake, and Yonas (1985) conducted two experiments to examine 7-month-old infants' sensitivity to the familiar size of an object. During the familiarization phase, the infant played with a pair of brightly colored, different-sized objects made of wood for 10 minutes. During the test phase, a pair of objects that was identical to those seen during familiarization but now equal in size, were presented at a fixed distance. The infants in the monocular condition showed a significant preference to reach for the object that resembled the smaller object during familiarization; however, infants in the binocular condition reached equally to the two test objects. Granrud et al.'s (1985) findings suggest that the infants in his study used memory to mediate spatial perception.

Using her drawbridge apparatus that was described in some detail in the section of this paper on object permanence, Baillargeon (1987b; 1991) investigated young infants' representation of the size or height of a hidden object. In the first study (Baillargeon, 1987b), 7-month-old infants were habituated to a screen that rotated in a 180 degree arc like a drawbridge. During the test phase of the experiment, infants saw two test events in which the screen rotated through a 165 degree arc. During the horizontal-box event, a red box 4 cm tall was presented in the path of the rotating screen, but the screen stopped when it contacted the box. During the vertical-box event, a red box 20 cm tall was introduced, and the screen seemed to rotate through the top part of the box as the screen completed its 165 degree rotation. Baillargeon found that the infants looked significantly longer at the vertical-box event, which suggests that 7-month-old infants represented the height of a hidden object, and they used this information to judge when the screen should stop.

Baillargeon (1991) used the same drawbridge apparatus in another study to examine 4.5- and 6.5-month-old infants' ability to represent the size of a hidden object. Again, the infants were habituated to a screen that rotated back and forth through a 180 degree arc. During test trials, a yellow box decorated with a clown face was introduced into the display. In the possible event the screen rotated until it reached the occluded box, and in the impossible event the screen rotated through either the top 50% or the top 80% of the space occupied by the box. The results indicated that the 6.5-month-old infants looked significantly longer when the screen rotated through the top 80% of the box, but they did not look significantly longer when the screen rotated through only the top 50% of the box. Additionally, the 4.5-month-old infants did not look significantly longer at either the 50% or the 80% violation. As mentioned in an earlier section of this paper, 4.5-month-old infants do look significantly longer when the screen rotates through the entire box (Baillargeon, 1987b). When the infants in Baillargeon's (1991) study were provided with a second, identical box placed to the side of the original box, to help them remember the size of the box, their performance improved. This second box did not interfere with the screen's path and remained visible during test trials. Baillargeon found that with the second box present, the 6.5-month-old infants now looked significantly longer during the 50% violation condition, and the 4.5-month-old infants looked significantly longer when the screen rotated through either the top 80% or the top 50% of the box.

Using a different procedure, Baillargeon and Graber (1987) examined 5.5-month-old infants' ability to represent the height of a hidden object. Subjects were familiarized to a tall toy rabbit and a short toy rabbit which traveled along a horizontal track, disappeared behind a rectangular screen, and came out the other side. During test events, the rectangular screen was replaced with a screen that had a large window in its upper half.

In the possible event, the short rabbit (which was shorter than the window's lower edge) traveled along the track, disappeared behind the screen without appearing in the window, and reappeared at the other end of the track. In the impossible event, the tall rabbit (which was taller than the window's lower edge) disappeared behind the screen without appearing in the window and reappeared at the other end. Baillargeon and Graber found that infants looked reliably longer at the impossible event, indicating that the subjects represented the height of the rabbit behind the screen and were surprised, as indexed by an increased looking time, when the tall rabbit did not appear in the window.

Using a variation on the "rabbit procedure", Baillargeon and DeVos (1991) conducted a study to determine whether infants younger than 5.5 months of age could represent the size of a hidden object. The researchers tested 3.5-month-old infants to see how they would perform on such a task. This time the pink and green rabbits were replaced with short and tall orange carrots with green bowties. During test events, either the short carrot (possible test event) or the tall carrot (impossible test event) passed behind the screen but did not appear in the window. These infants looked significantly longer at the tall carrot event, which suggests that babies as young as 3.5 months of age can represent the height of a hidden object.

In Baillargeon's experiments (Baillargeon & DeVos, 1991; Baillargeon & Graber, 1987), the infants only had to hold a representation of the hidden object in memory for a few seconds. But would babies be able to remember the size of an object over much longer delays? Adler and Rovee-Collier (1994) assessed whether 3-month-old infants could remember the size of the letter L on a block mobile following a 24 hour delay. The general paradigm for Rovee-Collier's work on infant memory is as follows. The infant lies in her crib with a block mobile positioned above her. One end of a satin ribbon is attached to the infant's ankle and the other end is attached to the mobile stand. Infants receive two 15 minute training sessions on two consecutive days. The first and last 3 minutes of the training sessions are nonreinforcement periods, during which the infant could see the mobile but kicks did not move it. The intervening 9 minute period is the acquisition phase, during which kicks activated the mobile. Delayed recognition is tested 1 or several days later with either the same or a different display. In this particular experiment (Adler & Rovee-Collier, 1994), infants were trained with a mobile decorated with either "large" Ls (2.5 x .75 cm) or 25%-reduced Ls (1.9 x .56 cm) and tested with the other type one day later. The results indicated that these infants discriminated the test mobile from the training mobile after 1 day. These findings suggest that 3-month-old infants can remember the size of a letter over a 24 hour delay period.

To summarize, size and distance discrimination are prerequisites to a complete notion of size constancy. The findings from studies of size discrimination indicate that object size is a discriminable property for infants very early in life, with the size of three-dimensional objects being discriminated earlier than the size of two-dimensional objects. Studies of distance discrimination provide evidence that size is also discriminable for young infants. Rather recently, some researchers (e.g., Granrud, 1987; Slater, Mattock, & Brown, 1990) have found that size constancy is present at birth. Other experiments have examined other facets of size such as infants' sensitivity to changes in size and infants' memory and representation for an object's size. These studies suggest that infants as young as 3.5 months of age can represent an object's size when the object is hidden for a brief period of time. Using much longer delays, Adler and Rovee-Collier (1994) found that 3-month-old infants can remember the size of a letter.

Two Cortical Visual Systems

It has been firmly established that there are two major fiber bundles which emerge from the occipital cortex and project rostrally in the brain (Flechsig, 1896; 1920). The ventral path traverses the inferior temporal cortex and continues to the frontal lobe, whereas the dorsal path traverses the posterior parietal cortex on its way to the frontal lobe. In addition, both systems have connections to limbic structures; however, the functional significance of limbic structures is still somewhat unclear (Brickson & Bachevalier, 1984; Parkinson, Murray, & Mishkin, 1988). Although these two pathways are generally portrayed as two rather distinct systems, it is important to note that there is at least one cortical site where they are functionally and neuroanatomically integrated (Baizer, Ungerleider, & Desmione, 1991; Boussaoud, Ungerleider, & Desmione, 1990).

The precise function of these two systems is still a source of controversy among neuroscientists. Probably one of the most classic distinctions is the "what" versus "where" dichotomy put forth by Ungerleider and Mishkin (1982). Based on electrophysiological, anatomical and behavioral studies with monkeys, they have proposed that the two cortical visual systems in monkeys are best conceptualized as an object vision system ("what") and a spatial vision system ("where"). The object vision system analyzes the physical properties of a visual object such as size, color, shape and texture; the spatial vision system analyzes the visual location of objects.

Mishkin, Ungerleider, and Macko (1983) have found two behavioral tasks which are sensitive to cortical visual lesions in monkeys: the object discrimination task and the landmark discrimination task. These two tasks are mentioned here because they could easily be adapted for use with human infants (using looking time as the dependent measure) or children. The object discrimination task is based on the idea of non-matching to sample. The monkeys are familiarized with one object of a pair in a central location. During test trials, the monkeys are shown both objects and are rewarded for choosing the unfamiliar object. After a few days of training, unlesioned adult monkeys are quite successful on this task. If the inferior temporal cortex (area TE) is removed bilaterally in monkeys, then they are severely impaired on object discrimination. In the landmark task, there are two food wells and one landmark (e.g., a tall cylinder). The landmark is positioned randomly from trial to trial either nearer to the left or right well. The monkey is rewarded for choosing the covered foodwell closer to the landmark. Unlesioned adult monkeys can be successfully trained to perform the landmark discrimination task; however, if the posterior parietal cortex is removed bilaterally, it produces severe impairment on landmark discrimination.

Other researchers have challenged Ungerleider and Mishkin's classic conceptualization and offered alternatives. For example, Goodale and Milner (1992) have accumulated neuropsychological, electrophysiological and behavioral evidence which suggests that the distinction is not accurately described as "what" versus "where", but rather "what" versus "how". The "what" system or "perception" system plays a major role in the perceptual identification of objects; the "how" system or "action" system mediates the visually guided actions upon those objects.

Neurological patients have provided evidence for a dissociation between perceiving an object and making spatially accurate motions toward that object (Goodale, Milner, Jakobson, & Carey, 1991). Patient D. F. has damage to the lateral occipital region and the occipitoparietal region, and neuropsychological tests have revealed that she has a profound visual form agnosia. Goodale et al. (1991) assessed D. F.'s orientation perception using a variety of tasks: (1) She was asked to choose which of four line orientations depicted on a card matched the orientation of a slot in a disc; (2) She was asked to turn a hand-held card until its orientation matched that of the slot; and (3) She was asked to indicate verbally the orientation of an oblong block placed on the table in front of her. D. F.'s performance on all three of these perceptual tasks was grossly impaired. Conversely, when D.F. was asked to reach out and put the hand-held card through the slotted disc, her performance was excellent. Additionally, when asked to asked to imagine a slot at different orientations with her eyes closed, D. F. could accurately rotate the hand-held card to the imagined orientation, which suggests that her deficit is in using visual orientation information for perceptual or cognitive purposes.

Goodale et al. (1991) also investigated D. F.'s ability to use other aspects of object form such as size. The stimuli were five pairs of white plaques of equal area but differing dimensions. During a perceptual matching task, D. F. was presented with pairs of plaques and was asked to tell the experimenter if the objects were alike or different. D. F. scored no better than chance. Furthermore, when D. F. was asked to indicate with the index finger and thumb of her right hand the width of plaques placed one at a time on the table in front of her, her estimates did not change as a function of the width of the plaques. Conversely, when the experimenter asked D. F. to reach out and pick up a plaque her performance was normal. Goodale and his associates concluded that D. F. is able to act motorically with respect to an object's orientation and size, but she possesses an inability to report, either verbally or manually, these same visual properties of objects. Thus, there is a dissociation between perceiving objects and acting upon them.

A major difference between Ungerleider and Mishkin's model and Goodale and Milner's model is their focus on inputs and outputs respectively. Ungerleider and Mishkin propose that there are separate inputs to the "what" and "where" systems. For example, when you look at an apple its shape, color, size and texture are inputs to the "what" path, whereas its location on the table is an input into the "where" path. Goodale and Milner, on the other hand, claim that the inputs to the systems are identical but the outputs are different depending on how vision is going to be used. For example, if you were asked “Is the orange or the apple larger?” then the dimension of size would be an input to the perception pathway. If you were asked to pick up the larger piece of fruit, then size would be an input to the action pathway. In sum, Ungerleider and Mishkin’s classic model emphasizes the difference in the incoming information; Goodale and Milner’s newer model emphasizes the difference in how such incoming information will subsequently be used.

Although the controversy about what is represented in the two cortical visual pathways is not yet resolved, there is some data about how these systems develop. There is little data on the development of the inferior temporal and posterior parietal lobes, so a coarser distinction (temporal lobes versus parietal lobes) will be discussed first. Prenatally, the temporal and parietal lobes develop most rapidly during the final month of gestation (Rabinowitz, 1967). Chugani, Phelps, and Mazziotta (1987) investigated the functional development of the temporal and parietal cortices and found that their functional developmental begins by at least 3 month of age. Chugani et al. (1987) used positron emission tomography (PET) in order to examine developmental changes in local cerebral metabolic rates. They discovered that by 3 months of age metabolic activity had significantly increased in parietal, temporal and occipital cortices. By 6 to 8 months of age, frontal regions showed a significant rise in metabolic activity. Adult rates of activity were reached by the latter part of the second decade.

Although there does not appear to be any data on the development of the posterior parietal cortex, there are some data available on the development of the inferior temporal cortex. Hagger, Bachevalier, Macko, Kennedy, Sokoloff, and Mishkin (1988) studied metabolic activity in the monkey inferior temporal cortex, and they discovered that the inferior temporal cortex may be functionally immature until the monkey is 4 to 6 months of age. Conversely, Rodman, Skelly, and Gross (1991) found that monkeys exhibited adult-like responses to face and non-face visual stimuli as early as 6 weeks of age, based on electrophysiological recordings from inferior temporal neurons. In sum, it appears that both the temporal parietal cortices are functional by approximately 3 months of age, but they are not fully mature. This may explain age-related differences in recognition memory abilities observed in human infants (Olsen & Sherman, 1983) and baby monkeys (Brickson & Bachevalier, 1984).

To summarize, the neural pathways which underlie vision are clearly delineated; however, the particular functions of these two cortical visual systems are still controversial among neuroscientists. Ungerleider and Mishkin claim that the temporal path is for object perception while the parietal path is for spatial perception. Goodale and Milner propose that the distinction is more accurately portrayed as perceiving objects versus acting on them. Regardless of the type of information represented in these two systems, they seem to be functional by approximately 3 months of age though they are not fully mature.

Object Identity

Suppose you place your Van Gogh coffee mug on the desk in your office, intending to use it later when you need a coffee break. At ten o'clock in the morning, you reach for your mug and find that a Snoopy coffee mug is on your desk instead of your own mug. Rather than claiming that your coffee mug seems to have changed its physical features, you assume that someone has come into your office, taken your coffee mug, and replaced it with a different coffee mug. The issue of object identity is also reflected in the English language, lexicalized as count nouns. For example, if questioned as to whether the coffee mug currently on your desk is the same coffee mug that was there this morning, you would correctly answer "no." Issues of object identity, however, are not always as simplistic as the coffee mug scenario. Even adults sometimes have difficulty deciding whether an object is the same object as one experienced earlier.

As adults, we have criteria for tracing an object's identity over time. Although philosophers agree that these criteria are part of an adult's conceptual system, they tend to disagree about the nature of the criteria (Hirsch, 1982). Some aspects of these criteria are probably innate while other aspects are constructed through interactions with objects in the world and through language learning (specifically the acquisition of count nouns). Thus, the epistemological issues surrounding object identity are rather important. How early in life does a notion of object identity emerge? What sort of criteria do we use initially to trace an object's identity and what types will we use later? To answer these questions, a review of the literature on the development of a concept of object identity is necessary.

There are two basic categories of criteria used for tracing identity over time: spatiotemporal information and property/kind information. When dealing with common physical objects, the most basic criteria are spatiotemporal in nature. Spatiotemporal criteria are constraints on how physical objects can and cannot exist and move in time and space. For example, one object cannot be in two places at the same time, two objects cannot be in the same place at the same time, and objects travel along continuous paths. Property/kind criteria include constraints on both the physical properties of objects (e.g., color, texture, detail) and the ontological category to which an entity belongs.

A great deal of evidence indicates that infants as young as 4 months of age use spatiotemporal information to form representations of individual objects and to trace that object's identity over time (Baillargeon & Graber, 1987; Spelke, 1988; Spelke & Kestenbaum, 1986). To assess whether infants can trace identity in accordance with the continuity principle, Spelke and Kestenbaum (1986) presented 4-month-old infants with two screens, separated in space. Infants were habituated to either a continuous or a discontinuous event. During the continuous event, a single object moved continuously across the display, disappearing as it passed behind each screen;the reappearance of the object in the gap between the two screens acted as a spatiotemporal cue. The discontinuous event was identical to the continuous event except that no object appeared between the two screens: an object disappeared behind the first screen, then reappeared from behind the second screen. During test trials, the infants saw either one or two objects in motion without the screens. Infants exposed to the continuous event did not expect either one or two objects. They are in fact correct, as continuous events are consistent with any number of objects. However, infants shown the discontinuous event dishabituated to the one-object display, providing evidence that they perceived the discontinuous event as involving two objects. Spelke and Kestenbaum concluded that infants use spatiotemporal information such as the continuity constraint to make decisions about an object's identity.

Although Bower (1974) agreed that babies use spatiotemporal information before 4 months of age, he also made a further claim regarding the criteria that infants use for object identity. He proposed that babies use spatiotemporal information for tracing an object's identity before they can use other property information. To investigate the age when infants first use property information to trace an object's identity, Bower (1974) examined the way in which infants track objects that have disappeared momentarily. First, the baby is habituated to an object which disappears behind an occluder or into a tunnel, then reemerges from the other side. Following the habituation event, the infant is shown a test event in which the initial object disappears behind the occluder, but a new object emerges from the other side. Bower found that 5-month-old infants were surprised, as indexed by a disruption in looking behavior. From this finding, he concluded that the infants were surprised because they realized that the object that emerged from behind the screen was different from the object that entered. In other words, the babies were able to use property information to trace identity and were surprised when one object apparently transformed into another object.

Other researchers have failed to replicate Bower's findings (Gratch, 1982; LeCompte & Gratch, 1972; Meicler & Gratch, 1980; Muller & Aslin, 1978). Using visual tracking as a dependent measure, Muller and

Aslin (1978) conducted studies with 6-month-old infants to examine whether the babies' tracking would be disrupted by a change in the object's shape or color during occlusion. They found that altering the target object's properties during occlusion did not disrupt visual tracking. Similarly, Meicler and Gratch (1980) tested 5- and 9-month-old infants and found that on transformation trials, trials in which one object disappeared behind an occluder but another object appeared from the other side, the 9-month-olds were more likely to be puzzled by the transformation than the 5-month-olds. Gratch (1982) examined visual tracking in 5-, 9-, and 16-month-old infants using two toys, a Confederate flag and a toy bug made of styrofoam, and found that his 5-month-old subjects were not surprised when the flag disappeared behind an occluder and emerged as a bug; however the 9- and 16-month-old infants were surprised by this event. Similarly, LeCompte and Gratch (1972) used an object transformation game with 9-, 12- and 18-month-old infants to assess their concept of object identity. During the game, infants were shown a big, colorful, noisy toy which was transformed into a small, drab-colored, plastic object or vice versa. The investigators found that only the 18-month-olds were extremely surprised by the transformation and searched for the missing toy; the 9-month-olds seemed mildly surprised but only focused on the new toy.

The fact that infants were surprised in these studies does not necessarily mean that the babies inferred that there were two objects present. Baillargeon and Graber (1987) have established that infants expect objects to maintain their properties when out of sight. The subjects in these studies may have just been responding to the differences in properties between the first and second objects. In other words, the infants might have been surprised that one object changed its properties when hidden and came out looking differently without representing them as two distinct objects.

Xu and Carey (1996) felt that a more sensitive methodology was necessary to evaluate how many objects an infant represents when she is provided with spatiotemporal or property/kind information. They used a procedure which is a variation on Spelke and Kestenbaum's (1986) split screen procedure to confirm that 10-month-old infants use spatiotemporal information to trace an object's identity over time. As in Spelke and Kestenbaum's study, infants in Experiment 1 were assigned to either a continuous movement condition or a discontinuous movement condition. The stimuli used were bright yellow toy ducks and white foam balls. Xu and Carey found that the infants in the discontinuous movement condition looked longer at one object, suggesting that they interpreted the event as involving two objects. Infants in the continuous movement condition, however, looked equally whether one or two objects are present. Hence, the authors concluded that the continuous event is compatible with one or two objects.

In Experiments 2 and 3, the investigators tested 10-month-old infants in a spatiotemporal condition and a property/kind condition to determine whether infants will use one type of information before the other for purposes of object identity. A single occluder was used, which was the same width of the two screens plus the gap in between them in Experiment

1. Four toys, all approximately the same size, were used as the stimuli: a white foam ball, a yellow rubber toy duck, a bright red toy truck and a light blue rubber toy elephant. During the property/kind condition, the screen was introduced and an object (e.g., truck) emerged from left-hand side of the screen then returned behind the screen. A second object (e.g., elephant) emerged from the right-hand side of the screen then returned behind the screen. Finally, the screen was removed revealing either an expected (two objects) or an unexpected (one object) outcome. During the spatiotemporal condition, the screen was introduced and two objects (e.g., truck and elephant) emerged simultaneously from opposite ends of the screen and returned behind the screen. Then one object (e.g., truck) emerged from the left-hand side of the screen and returned behind the screen. Next, a second object (e.g., elephant) emerged from the right-hand side of the screen and returned behind the screen. Last, the screen was removed revealing either an expected (two objects) or an unexpected (one object) outcome. Xu and Carey found that 10-month-old infants in Experiment 2 did not use property/kind information to trace an object's identity; however, they succeeded at using spatiotemporal information. Even when the objects were left stationary in full view during familiarizations to provide the infants with additional time to encode their properties (Experiment 3), the results replicated Xu and Carey's findings from Experiment 2.

In Experiments 4 and 5, the researchers used highly familiar objects (e.g., toy truck, tennis ball, sippy cup) to find out if familiarity would assist the infants in using property/kind information. The procedure for was similar to the one used in Experiment 2 except that the babies in Experiment 4 saw familiar objects and they were fully habituated to the objects instead of just presented with brief familiarizations. Despite the differences between Experiments 2 and 4, the findings are virtually identical. Again, the 10-month-olds used spatiotemporal information to individuate objects, but they did not use property/kind information. The investigators (Xu & Carey, 1996) were still interested in determining the age at which infants will use property/kind information to trace an object's identity. Thus, in Experiment 5 the subjects were 10- and 12-month-olds. They found that the 10-month-old infants could not use property/kind information, whereas the 12-month-olds could.

Taken together, Xu and Carey's five experiments demonstrate the consistent inability of 10-month-old infants to use property/kind information to individuate and trace an object's identity. Furthermore, the researchers found that these infants failed under a variety of conditions. Even when a different dependent measure (number of reaches) was used, Xu and her colleagues (Xu, Carey, Raphaelidis, & Ginzbursky, 1996) again found it is not until 12 months of age that infants use property/kind information to trace identity

Wilcox and Baillargeon (1996a) have used a different paradigm to answer the object identity question, and they have yielded positive results with much younger infants. The procedure is called a size comparison paradigm and it proceeds as follows: A ball disappears behind one edge of a screen and after a brief delay, a box appears at the other edge of the screen. Half of the infants saw a screen that was too narrow to hide both objects simultaneously (narrow-screen condition); the other half saw a screen that was wide enough to hide both objects simultaneously (wide-screen condition). The researchers found that 7.5-month-old infants looked significantly longer at the narrow-screen event than at the wide-screen event, which suggests that the infants realized that there were two distinct objects involved in the event, and they judged that both objects could fit behind the wide screen but not the narrow screen.

In another experiment using the size comparison paradigm (Wilcox & Baillargeon, 1996b), 7.5-month-old participants watched a ball disappear behind one edge of a screen and after a brief delay, the same ball (ball-ball event) or a box (ball-box event) appeared at the other edge. This time the infants looked significantly longer at the ball-box event than at the ball-ball event. The investigators concluded that infants used featural information to ascertain that the ball-ball event involved one object and the ball-box event involved two objects. Furthermore, the infants judged that the screen was wide enough to hide the ball, but it was not wide enough to hide both objects. Wilcox and Baillargeon concluded that based on numerous findings using their size comparison paradigm, 7.5-month-olds are capable of using featural information to reason about object identity. They concede that the specific paradigm one uses, either the size comparison paradigm or the object mapping paradigm, will greatly affect one's results. When Wilcox and Baillargeon used an object mapping paradigm similar to the one used by Xu and Carey (1996), they yielded positive results in infants 11.5 months and older just as Xu and Carey did.

Many habituation studies have shown that infants younger than 10 months of age are sensitive to certain categories of objects; however, they might not use this information as the criteria for identity. In these studies, infants are habituated to a series of objects from the same category, then shown an object from a different category to which they dishabituate. For example, Quinn, Eimas, and Rosenkrantz (1993) familiarized 3- and 4-month-old infants to pairs of exemplars from natural basic-level categories (e.g., cats). During test trials, the infants would see a novel exemplar of the familiar category (e.g., a cat they had not seen before) paired with a novel member of the novel category--birds. The researchers found that the infants looked significantly longer at the bird, which suggests that they could form categorical representations of cats (and dogs) that excluded birds. Other researchers have used the visual habituation paradigm and found that by the second half of the first year of life infants respond to categories such as stuffed animals (Cohen & Caputo, 1978), faces (Cohen & Strauss, 1979), food and furniture (Ross, 1980). Finally, Rosemary Rosser and her colleagues have found that 7-month-old infants are sensitive to the aggregate/individuated object distinction (e.g., a pile of rubber french fries versus a toy lion) (Rosser, Narter, & Paullette, 1995), and also the animate/inanimate distinction (e.g., a “fake” fuzzy hamster versus a live hamster) (Rosser, Narter, & VanWyhe, 1996).

Mandler and her associates (Mandler & Bauer, 1988) have proposed that a more active task should be used to examine infants’ conceptual abilities because an object manipulation task would be more comparable to the sorting tasks commonly used to examine conceptual capabilities in older children. Mandler and Bauer's procedure is as follows: Subjects are presented with an array of objects from two groups, and the infants' behavior toward these objects is recorded. Because infants do not consistently sort objects into groups until approximately 18 months of age or older, researchers have examined patterns of touching to uncover early categorization ability. If infants are sensitive to the categorical distinctions represented by the objects, then they will tend to touch objects from the same category in sequence more frequently than would be expected by chance. Although Mandler's object manipulation procedure is more active than visual habituation procedures, it might not be as reliable. It is fairly well established that if babies are habituated to one category, then they will display a gradual decreases in looking time. When a second category is presented the infant will continue to habituate if she does not register a difference between the two categories or she will dishabituate, as evidenced by a dramatic increase in looking time, is she notices that the two categories are different. However, it is not firmly established that sequential touching of objects in the same category is an accurate measure of conceptual ability.

Using an object manipulation task, Mandler and her colleagues (e.g., Mandler & Bauer, 1988; Mandler, Bauer, & McDonough, 1991; Mandler, Fivush, & Reznick, 1987) have examined a variety of conceptual distinctions. For example, Mandler et al. (1987) studied the extent to which 14- and 20-month-olds are sensitive to contextual categories (e.g., kitchen things versus bathroom things) even when there was a lack of perceptual commonalty among the category members. Additionally, Mandler and her associates (Mandler & Bauer, 1988; Mandler et al., 1991) posit that global contrasts (e.g., animal/artifact, animal/vehicle) are the first categorical distinctions that infants make. Conversely, other researchers (e.g., Roberts & Horowitz, 1986) have found that 9-month-old infants are able to make basic-level distinctions within the category *bird.*

The results from the visual and manual categorization tasks mentioned previously inform us about the conceptual distinctions to which infants are sensitive; however, they do not tell us if and how these early distinctions will be manifested in thought and later language. For example, an infant may habituate to vehicle-shape without representing the sortal *vehicle*. The notion of sortals was first introduced by philosophers. Sortals provide criteria for individuation and identity (Hirsch, 1982) and are lexicalized as count nouns in English. It would be impossible to for someone to count individuals without specifying a sortal. Suppose you are at a party and your hostess places a bowl of M&Ms in front of you and asks, "How many are there?" You cannot give her a definite answer because she has not specified a sortal--*what* you should count. You might answer "two bags of M&Ms", "500 M&Ms", "two bowls" or "over a zillion grams of fat". If your hostess specifies a sortal, "How many M&Ms are there?", you could probably give her a definite answer by counting the candies in the bowl. Similarly, we can only express object identity under a sortal concept. For example, most people know that tadpoles grow up to be frogs. If someone asks you "Is it the same animal?", you would say yes; if someone asks you "Is it the same tadpole?", you would say no; if someone asks you "Is it the same frog?" you would say no.

How do individuals learn sortal concepts? Two major theories have been proposed: The first theory (Macnamara, 1987) states that children initially learn sortal concepts by establishing gestalts for basic-level kinds. For example, once a child possesses a gestalt for cats that is separate from other categories, then the child is able to represent the sortal *cat*. The second theory stems from the work of T. G. R. Bower (Bower, 1974), although Bower was not specifically concerned with sortals in his research. Bower claimed that infants use spatiotemporal information to trace an object's identity before they use other property information. Xu and Carey (1996) agree with Bower and have incorporated his findings into their framework. Xu and Carey propose "the *Object*-first Hypothesis", which states that infants might have the sortal *object* before they have more specific sortals such as ball.

Based on their experiments, Xu and Carey found that 10-month-old infants represent at least one sortal concept, *physical objects*. They can use spatiotemporal information to trace a physical object's identity over time. The 12-month-olds, however, were able to represent concepts that were more specific than *physical objects* (e.g., *bottle*, *duck*, *book*). The authors are not certain what causes the changes observed between 10- and 12-month-olds, though they have some ideas. The change might be maturational or it might be the result of a learning process. One proposed learning process involves infants noting which properties remain constant and which ones change for various categories of objects (Xu and Carey, 1996). A second possibility is that infants have the concept of more specific kinds/sortals innately (Pinker, 1984). Finally, Baldwin, Markman and Melartin (1993) have suggested that infants may expect kind distinctions to predict functional distinctions between objects in the absence of any example. Perhaps all of these proposed mechanisms play a role in attaining sortals that are more specific than *object.*

In summary, there are two fundamental categories of information used to trace an object's identity over time: spatiotemporal criteria and property/kind criteria. Research findings indicate that babies use spatiotemporal information to trace identity before they use property/kind information. Infants as young as 4 months of age have been found to use spatiotemporal criteria to trance an object's identity (Baillargeon & Graber, 1987; Spelke, 1988; Spelke & Kestenbaum, 1986), whereas they may not use property/kind information until as late as 12 months of age (Xu & Carey, 1996). The concept of sortals is also important in any discussion of object identity. Xu and Carey propose that babies learn the sortal *object* before they learn more specific sortals. Conversely, other researchers (e.g., Macnamara, 1987) claim that infants learn sortals for basic-level kinds first. Much more research needs to be conducted in the area of object identity before a complete picture of this complex issue unfolds.

Summary

It is evident from reviewing the literature on object permanence, location, size and identity, that infants display impressive capabilities in each of these areas. Based on findings from manual search tasks, human infants do not endow objects with permanence until approximately 9 months of age because before then babies believe that an object's existence is tied to their own actions (Piaget, 1954). When Piagetian manual search tasks are adapted for use with animals, the findings indicate that animals develop object permanence in much the same sequence as humans; however, animal infants generally possess object permanence much earlier in life than human infants (see Doré & Dumas, 1987, for a review). Perhaps the manual search task is too difficult and complex for infants. T. G. R. Bower (1967) proposed that young infants fail to search for hidden objects because they do not have the ability to coordinate actions, not because they have forgotten that the hidden toy still exists. When methods of assessing object permanence are used which completely remove the motor component from the task, rendering looking time as the dependent measure, researchers have considerable evidence that infants possess object permanence well before 9 months. For example, Baillargeon (1987a) used her drawbridge procedure with looking time as the dependent measure and concluded that infants as young as 3.5 months of age demonstrate attainment of object permanence.

It seems infants realize that objects continue to exist when hidden from view, but do they remember where the object is located? Piaget (1954) reported that when 9-month-old infants are presented with a two-location manual search task, they commit a perseveration error, also referred to as an A not B error. According to Piaget, the infant stops exhibiting this search error at approximately 12 months of age. Some researchers (Schacter, Moscovitch, Tulving, McLachlan, & Freedman, 1986) have proposed that an immature memory system is the culprit for failure on the A not B task, others claim that infants make the A not B error due to immaturity of the dorsolateral prefrontal cortex, which manifests itself as a lack of inhibitory motor control (Diamond, 1985). Baillargeon and her associates (Baillargeon & Graber, 1988; Baillargeon, DeVos, & Graber, 1989) again removed the motor component from the two-location task rendering a visual-search task with looking time as the dependent measure. Baillargeon (Baillargeon, DeVos, & Graber, 1989) has found that 8-month-old infants can remember where an object was hidden for delays as long as 70 seconds. Using a similar paradigm, Wilcox and Nadel (1993) found that infants as young as 2.5-months of age can remember where an object is located using a 5 second delay. Based on the findings from Baillargeon and Wilcox, it does not seem likely that infants' failures on manual search tasks are due to inadequate memory mechanisms.

Object size, or the amount of space an object occupies, is another characteristic to which infants are sensitive quite early in life. Size discrimination and distance discrimination are prerequisites to size constancy. Based on findings from size discrimination experiments, infants begin to make object discriminations on the basis of size within the first one or two months of life. Infants are also capable of making horizontal distance discriminations very early in life, as well. Recent studies of size constancy demonstrate that size constancy is present at birth (Granrud, 1987; Slater, Mattock, & Brown, 1990). Other studies have focused on whether infants are sensitive to changes in an object's size when the object is occluded from view. Baillargeon (1987b) has conducted a series of experiments examining infant's memory for an object's size over brief delays, and she found that infants as young as 3.5 months of age can represent the height of a hidden object. It has also been found that 3-month-old infants can remember the size of an object over much longer delays (Adler & Rovee-Collier, 1994).

There are two cortical visual pathways that are the foundation for infants perception of the spatial and physical characteristics of objects in their world. Both systems emerge from the visual cortex and travel rostrally--one path proceeding dorsally and the other proceeding ventrally. Though the precise function of these two systems is far from being settled, some plausible functions have been proposed. Ungerleider and Mishkin (1982) have proposed the "what" versus "where" distinction, a classic dichotomy which is still adhered to by many. Recently, Goodale and Milner (1992) have put forth an alternative distinction: "knowing" versus "doing". Regardless of what is represented in these two cortical visual systems, their neurological development will constrain infants' performance on a variety of tasks such as those mentioned in this paper. Based on evidence from PET, both the temporal and parietal lobes are functional by 3 months, though they are not yet fully mature (Chugani, Phelps, & Mazziotta, 1987).

It seems that infants can represent some of the spatial and physical characteristics of objects, but it is not clear whether infants will use this information for purposes of object identity. There are two basic types of criteria used for tracing an object's identity over time: spatiotemporal information and property/kind information. Bower (1974) proposed that babies use spatiotemporal criteria before they use property information.

Spelke and Kestenbaum (1986) found that 4-month-old infants can use spatiotemporal information to trace identity. The age at which infants are able to use property/kind information, however, is not yet firmly established. Using their object mapping procedure, Xu and Carey (1996) found that infants cannot use property/kind information until approximately 1 year of age. Wilcox and Baillargeon (1996a) have developed a different procedure, a size comparison paradigm which demonstrates that 7.5-month-olds can use featural information in an object identity task.

Even though developmental researchers have made a good deal of progress within the area of physical and spatial reasoning in infants, more research needs to be conducted in this domain before it is fully understood. The present study was an investigation of which spatial and physical object characteristics (size, location and features both alone and in combination with one another) 9-month-old infants would represent over brief delays for the purposes of object identity. Perhaps infants rely on spatial characteristics of objects such as changes in location (where an object is located in space) and size (how much space an object occupies) before they rely other physical changes such as changes in color, texture and details when making decisions about an object's identity.

Hypotheses

When infants are required to trace an object's identity, research has shown that they expect objects to trace spatio-temporally continuous paths (Spelke, 1988) governed by two fundamental constraints: (1) One object cannot be in two places at the same time (Rosser, Narter, & Paullette, 1995; Wilcox, Nadel, & Rosser, 1996); and (2) Two objects cannot be in one place at the same time (Spelke, 1990).

Perhaps infants represent and reason about objects in a rather crude manner and do not rely on an object's unique and individual attributes (e.g., color, texture, details) when making identity decisions. If this were the case then an object's characteristics could change spontaneously (e.g., from one color to another, from one size to another). Following from this logic, the infants' ontological scheme would consist of only one category: PHYSICAL ENTITIES; all bounded entities would be considered equivalent category members. Conversely, infants might capable of using the unique characteristics of an object to assist them in making decisions about an object's identity. If this were the case, then infants should be surprised to see an object's attributes change spontaneously.

Researchers have found that infants use spatiotemporal information, such as the two constraints mentioned previously, for purposes of object identity at an earlier age than they use property/kind information (Bower, 1974; Wilcox & Baillargeon, 1997; Xu & Carey, 1996). Infants as young as 4 months of age are capable of using spatiotemporal criteria to trace an object's identity (Baillargeon & Graber, 1987; Spelke, 1988; Spelke & Kestenbaum, 1986); whereas, infants do not appear to use property/kind information until later in infancy (Wilcox & Baillargeon, 1997; Xu & Carey, 1996).

Where does size fit into this spatiotemporal versus property/kind dichotomy? Wilcox (1997) conceptualizes size as a specific type of property or featural information, which infants can use for making decisions about an object's identity as young as 4.5 months of age. She further claims that infants fail to use other types of featural information (e.g., color) in identity tasks until 11.5 months. It is possible that changes in an object's size might be more appropriately categorized as a spatial change rather than a featural change. The logic behind this conjecture is that size is the amount of space an object occupies, so it might be considered more of a spatial attribute than a featural attribute.

Regardless of where the dimension of size fits into the continuum, it is clear that infants are sensitive to changes in object size very early in life. Researchers have discovered that infants possess a notion of size constancy at birth (Granrud, 1987; Slater, Mattock, & Brown, 1990), and they can represent an object's size for delays up to 24 hours (Adler & Rovee-Collier, 1994). Furthermore, infants are not only able to reason about an object's size in an absolute sense but also in a more relative manner. For example, Baillargeon (1987a) has found that infants 4.5-month-old infants are surprised when one object appears to completely violate the space of another object by passing through it, which illustrates that babies can reason about size in an absolute sense. Additionally, 6.5-month-olds were surprised by partial violations (e.g., 50% or 80% violations) of an object's solidity, which suggests that these older infants could represent the hidden object's size in a more relative sense.

Based on their research with infants over the past several years, Rosser and Narter (1997) have proposed that infants may rely on two default expectations to guide their reasoning about an object's identity. The proposed default rules are called the Same Location/Same Object

Assumption (which follows from the constraint that two objects cannot occupy same location at the same time) and the Different Location/Different Object Assumption (which follows from the constraint that one object cannot occupy two locations at the same time). These two rules may govern the way that infants make decisions about an object's identity.

The Same Location/Same Object Rule can be defined as follows: If an infant sees an object hidden at one location and sees an object revealed at that same location, then she will expect that the object revealed is the *same object* as the one she saw hidden earlier. The physical and spatial information provided to the infant can either be consistent with this default assumption or it can conflict with it. If the information is powerful enough to conflict with the Same Location/Same Object Expectation, then the assumption will be overridden. There are two hypotheses which follow from this default rule:

> <u>Hypothesis 1:</u> A change in an object's size occurring at the same location will conflict with and override the Same Location/ Same Object Assumption as indexed by a significant increase in looking time.
>
> <u>Hypothesis 2:</u> A change in an object's features (e.g., its color, texture and details) occurring at the same location will be consistent with the Same Location/Same Object Assumption as indexed by no significant increase in looking time.

The Different Location/Different Object Rule can be defined as follows: If an infant sees an object hidden at one location and sees an object revealed at a different location, then she will expect that the object revealed is *a different object* from the one she saw hidden earlier. The physical and spatial information provided to the infant can either be consistent with this default assumption or it can conflict with it. If the information is powerful enough to conflict with the Different Location/Different Object Expectation, then the assumption will be overridden. There are three hypotheses which follow from this second rule:

> Hypothesis 3: A change in an object's location alone will conflict with and override the Different Location/Different Object Assumption as indexed by a significant increase in looking time.
>
> Hypothesis 4: A change in an object's features and its location will be consistent with the Different Location/Different Object Assumption as indexed by no significant increase in looking time.
>
> Hypothesis 5: A change in an object's size and its location will be consistent with the Different Location/Different Object Assumption as indexed by no significant increase in looking time.

CHAPTER III

METHOD

Participants

Participants were 112 full-term infants (56 males and 56 females), ranging in age from 8 months, 15 days to 9 months, 14 days (M = 9 months, 2 days; SD = 7 days). Sixteen babies were assigned to each of the seven conditions. These infants were born less than three weeks before their due dates and had no serious perinatal complications, by parental report. An additional 33 infants participated, but were excluded due to fussiness or sleepiness (20), experimenter error (10) or equipment failure (3).

The infants were recruited from the birth announcements in a local newspaper. Parents were contacted initially by phone, then sent a letter explaining the study in more detail. They later received a follow-up phone call to answer any further questions and to schedule an appointment if they were interested in participating. Informed written consent was obtained from parents prior to testing. Individuals were not paid for their participation in this study; however, parking was provided and each infant received a colorful certificate after participating.

Apparatus

The display apparatus consisted of a box with a puppet stage sitting on top of it (see Figure 1). The box was composed of a wooden frame (88 cm high, 62 cm deep and 82 cm wide) covered with heavy black cloth on all four sides and left open on the top and on the bottom. One of the experimenters sat in the box during testing, and there was a small door cut into the material on the back of the box through which she entered and exited the apparatus. The top of the box was covered with a rectangular piece of particle board wrapped with black felt (61 cm long and 105 cm wide) and was securely fastened to the top of the wooden frame with Velcro. Two circles (12 cm in diameter spaced 20 cm apart) were cut into the particle board and served as the hiding locations. Both hiding locations were marked with white felt rings so that it was clear that these were two distinct locations. The two circular cut-outs were filled with round trap doors affixed with magnets; the trap doors were manipulated by the experimenter sitting in the box, and they allowed her to place and remove objects from the two hiding locations without the baby noticing the activity. The infant only saw the trap doors when they were in place, flush with the tabletop. Between the two hiding locations was a rectangular slit (23 cm long and 8 cm wide) in the center of the tabletop running from front to back. The slit was the space in which the experimenter's hand entered and exited the display.

A puppet stage made of foam core covered with black felt (49 cm high, 45 cm deep, and 105 cm wide) sat on top of the box. The opening at the front of the stage was 41 cm high and 78 cm wide. A small hole (6 cm in diameter) was cut into the top center portion of the back wall of the stage, and a video camera was positioned behind the apparatus so that the camera lens fit in the small hole. This allowed the baby's face to be recorded during the test session without being intrusive. Two tubular lights (13 cm long), each with a 60 watt light bulb, were affixed to the inside front corners of the stage to illuminate the display. Two small speakers were hidden in the back wall of the stage so that music could be played at specified times during the test session. The front edge of the stage sat 8 cm from the front edge of the tabletop and was centered left to right.

Two flaps were used to occlude the two hiding locations when appropriate. Each flap was constructed from two rectangular pieces of foam core (18 cm tall and 21 cm wide) fastened together to form a 90° angle. The flaps were covered with light blue felt on their front sides and black felt on their back sides, and they were fastened to the tabletop with Velcro. When the locations were not being occluded, the fronts of the flaps would be flush with the tabletop and the sides of the flaps would frame the display. The sides of the flaps were necessary to hide any shadows made by the objects. A large, black, foam core screen (23 cm tall and 50 cm wide) was used to shield the display between trials. Both the flaps and the screen were manipulated by a second experimenter who was standing to one side of the infant.

The four target stimuli were a small toy troll (9 cm tall and 8 cm wide at its widest point), a large toy troll (13 cm tall and 10 cm wide at its widest point), a small toy bear (9 cm tall and 8 cm wide at its widest point) and a large toy bear (13 cm tall and 10 cm wide at its widest point). The two toy trolls were identical in every respect except for size; they both had tan skin, bright red hair tied in a ponytail with a white ribbon and a red jewel in their navels. The two toy bears were also identical except for size; they were both white and furry with black eyes and a black nose. The objects were secured to and easily removed from the trap doors with small pieces of Velcro. Again, the objects were manipulated by the experimenter sitting in the box. This experimenter wore a pair of long white gloves during the test session, and she would point at the objects and wave in the center slot at predetermined times. The purpose of the gloved hand was to add contrast and movement to the display. The experimenter also had a small squeaky toy in the box with her, which she would squeak rhythmically while pointing at the objects.

Testing was conducted in a darkened room with overhead track lighting. Two video cameras were used: one was mounted behind the stage and recorded the infant's face, while the other was mounted behind and above the infant's head to record the stage. The second camera was useful for double-checking experimenter procedures. The wall to the left of the infant was painted off-white; behind the infant and behind the apparatus were off-white curtains, and to the right of the infant was a large, portable, off-white screen that acted as a temporary wall. The curtains and the screen were used to eliminate any potential distractions from the rest of the room.

The infants' looking behavior was monitored by an observer seated on the other side of the curtain behind the apparatus. The observer viewed the infant on a video monitor and was not aware which condition and order were being presented. The observer held a handgrip with a button on the top linked to a Compaq PC; she pressed the button when the infant was looking at the display and released the button when the infant was not looking at the display. A small synthesizer placed on top of the video monitor was controlled by the observer. A brief melody was programmed into the synthesizer and was played at specific points throughout the test session.

Procedure

The paradigm used for the study was a violation of expectancy procedure with looking time as the dependent measure. After a standard set of questions was asked to the parent and the consent form was signed, the parent was instructed to sit in an office chair (50 cm from the floor), centered in front of the display 55 cm away. The infant sat on the parent's lap during testing, and the parent was instructed not to interact with the baby during the session.

Experimenter 1 (E1) sat in the box and Experimenter 2 (E2) stood next to and slightly behind the infant and the parent during testing. An Observer (O) monitored the infants' looking behavior from a video monitor located behind one of the curtains. Twenty-eight of the 112 test sessions were later rescored by a second observer to obtain interobserver reliabilities. Reliabilities were calculated with Pearson's r, using looking times from the familiarization and test period for each trial. The mean reliability coefficient was .93.

Each trial consisted of three parts: a familiarization, a delay and a test event.

Familiarization. Each familiarization began with E2 raising the black screen to occlude the display. When the screen was lowered the infant saw the small troll at one of the two locations and looking time was measured. The small troll was placed at the same location for all 6 familiarizations. E1's gloved hand entered the display through the rectangular slit in the tabletop with fingers waving, moved toward the target location, pointed at the small troll while squeaking a toy under the box and exited through the slit with fingers waving. The entire hand sequence lasted approximately 5 seconds. The familiarization ended when: (a) the infant looked away from the display 3 times (2 seconds each time after having looked for at least 10 cumulative seconds) or (b) the infant looked at the display for 30 cumulative seconds. The computer beeped to signal the end of the familiarization.

Delay. Following the familiarization, E2 lifted the blue flaps simultaneously to occlude the two hiding locations. The placement of the shields signaled the start of the 15 second delay. O counted from 1 to 15 aloud so that El and E2 knew when to perform their respective duties. Music was played during the first 10 seconds of the delay to encourage the infant to look toward the display and to mask the sounds made by the trap doors. During the first 5 seconds of the delay, El placed the appropriate object at the appropriate location (depending on which condition was being performed). Access to each location was gained by releasing the trap door. During the next 8 seconds, the gloved hand moved front to back in the center slit with the palm facing the baby and the fingers waving. During the last 2 seconds of the delay, the hand moved toward the target location (the location where the object was) with fingers wiggling. Right before the count of "15", E2 lowered both flaps.

Test. The lowering of the flaps indicated the beginning of a test event. At the count "15", O began measuring looking time. Immediately after the flaps were lowered, El's gloved hand pointed at the target object while squeaking a toy under the box and exited the display with fingers waving.

Test events were of two types: “standard” events and “change” events. E1 made sure that the sounds (e.g., the clicking of magnets on the trap doors and the sound of the Velcro) during these two types were the same. During standard events, the small troll was revealed at the location where it was hidden (see Figure 2 for schematic representations of the familiarization, delay and standard test events). During change events, one of the following changes occurred, depending on which condition the infant was assigned to (see Figure 3 for schematic representations of the change test events):

Small troll revealed at opposite location	(Location Condition)
Large troll revealed at initial location	(Size Condition)
Small bear revealed at initial location	(Feature Condition)
Large troll revealed at opposite location	(Size/Location Condition)
Large bear revealed at initial location	(Size/Feature Condition)
Small bear revealed at opposite location	(Location/Feature Condition)
Large bear revealed at opposite location	(Size/Location/Feature Condition).

Infants were randomly assigned to one of the seven conditions. Therefore, each infant only saw one type of change event. A sample test session for an infant in the Location Condition can be found in Table 1.

The test period ended when: (a) the infant looked away for 2 consecutive seconds after having looked for at least 10 cumulative seconds; or (b) the infant looked for 60 cumulative seconds without looking away for 2 seconds. The computer beeped to indicate when the criterion had been attained.

Each infant was assigned to one of the seven conditions with 16 infants tested in each condition. Within each condition, half of the infants were always familiarized to the small troll at location A, and the other half were always familiarized to the small troll at location B. Additionally, 42 infants saw the standard event first, whereas 70 saw the change event first. The rationale for running more infants with the change event first was as follows: Preliminary analyses performed on pilot data indicated that there was an order effect. Participants receiving the standard event first were so disinterested (as indexed by a decrease in looking time to all test events) after seeing the small troll three times consecutively (once during the first familiarization, once during the first standard test event and once during the second familiarization) that by the time they saw a change event their attention and interest had attenuated. The reason that some infants were run in the standard event first group was so that O was blind to the event order, she was never certain whether a standard or surprise event was being presented first. If all participants were tested in the surprising first group, then this might have influenced the manner in which looking time was measured by O. Each test session was to consist of 6 trials, with test periods alternating between standard and change events; however, not all participants could complete all 6 trials due to fussiness. Infants completing 1 to 3 trials were dropped from all analyses, and those completing 4 to 6 trials were included in the sample.

CHAPTER IV

RESULTS

Baseline Looking Times to the Stimuli

In order to make sure that the baseline looking times to the four test stimuli were equal, 12 nine-month-old infants were involved in the baseline portion of the experiment; these infants were not participants in the regular test session. Baseline looking times to the small troll, large troll, small bear and large bear were collected. The baseline period was identical to the familiarization described in the previous chapter except that the baseline period could involve any of the four stimuli, whereas familiarizations always involved the small troll. The criteria for ending baseline trials were identical to the criteria for ending familiarizations. A one-way analysis of variance (ANOVA) was conducted with Stimulus (4 levels) as the between-subjects variable. The stimulus presented did not have a significant effect on looking time, *F*(3, 8) = .09, *p* >. 05. The means for the four stimuli were as follows: small troll (*M* = 22.4 sec, *SD* = 6.8), large troll (*M* = 23.1 sec, *SD* = 5.2), small bear (*M* = 20.5 sec, *SD* = 8.5) and large bear (*M* = 23.7 sec, *SD* = 10.9).

Raw Score Analyses

Familiarization. Although there were six trials in a complete session, approximately 6% of the participants (20 infants) were unable to complete more than four trials due to fussiness, crying or tiredness. Thus, only 92 of the 112 participants completed all six trials. Instead of eliminating participants who could not complete all six trials, a decision was made to include all 112 infants but to only examine the first four trials.

The infants' looking times during the first four familiarization events were averaged and subjected to a one-way ANOVA with Condition as the between-subjects factor. The analysis showed that there was not a significant main effect for Condition, $\underline{F}(6, 105) = 1.6$, $\underline{p} > .05$, indicating that the infants in the seven conditions did not differ in their mean looking times during the familiarization events. This outcome was predicted because all infants observed the small troll during familiarizations, so one would not have expected any differences across the seven conditions.

Test. The mean looking times and standard deviations to the six test events are presented in Table 2. To test for gender and order effects, the raw looking time scores were subjected to an ANOVA with Gender, L/R Order (familiarized to the small troll on the left or the right) and Event Order (standard or change event seen first) as the between-subject variables. There were no significant main effects or interactions for any of these variables, so they were omitted from subsequent analyses.

A repeated measures ANOVA was conducted with Condition (7 levels) as the between-subjects factor and Trial (4 levels) as the within-subjects factor. This analysis included the data from all 112 participants. The ANOVA yielded a significant main effect for Trial, $\underline{F}(315, 3) = 6.05$, $\underline{p} < .01$, which was consistent with the observation that looking times generally attenuate quickly across trials as the infants become disinterested in the static display. Furthermore, once an infant has observed her first change test event, her expectations about what can and cannot happen in the world may have been altered by the experimental manipulation. Therefore, it is probably most valid to use only the first pair of test trials.

For descriptive purposes, the mean cumulative looking times to the standard and change events for the first pair of test trials is presented in Figure 4.

Proportion Difference Score Analyses

The raw looking times to the standard and change events were transformed into proportion difference (PD) scores where:

$$PD = \frac{LT(change) - LT(standard)}{LT(change) + LT(standard).}$$

The PD score compares looking times to the standard and change events for each participant, relative to the total amount of time she spent looking at the standard and change events overall. This provides the researcher with an absolute criterion such that when LT(change) and LT(standard) are equal, then PD equals zero. A PD score greater than zero indicates that the baby looked longer at the change event, and a PD score less than zero indicates that the infant looked longer at the standard event. Additionally, the PD score allows each infant to serve as his or her own control. The mean PD score for each condition is presented in Table 3.

To determine whether infants looked significantly longer to change events for particular conditions, mean PD scores (for the first two trials only) for each of the seven conditions were contrasted with zero. Only the first two test trials were used because once an infant has seen the change event once, then an expectation has been constructed by the researcher that anything (even impossible events) can occur within the experiment. The data from all participants was used for the following contrasts ($\underline{n} = 112$), with 16 babies assigned to each of the seven conditions. The statistical procedure performed was Dunn's multiple comparison procedure for *a* *priori* non-orthogonal comparisons (Bonferoni t). For the contrasts, the critical t value (k = 7, df = 15) = 3.48 with alpha set at .05. Infants in the Location Condition ($t = 5.07$, $p < .05$) and the Size/Location Condition ($t = 4.26$, $p <. 05$) looked significantly longer at the change event; the rest of the contrasts were non-significant. The robustness of the Location (small troll at initial location to small troll at the other location) and Size/Location (small troll at initial location to large troll at the other location) effects might lead one to propose that the participants were treating all objects as the same (e.g., small troll equals large troll, small troll equals small bear, small troll equals large bear), and they were surprised when the object violated the continuity constraint. However, if this were the case then the contrasts for all four of the conditions involving a change in location should have been significant. The findings indicate that the Location/Feature Condition (small troll at initial location to small bear at the other location) and the Size/Location/Feature Condition (small troll at initial location to large bear at the other location) did not result in longer looking times to the change events, which suggests that these 9-month-olds were not representing these objects as the same object. One explanation for these null results is that there was too much variability in the data when all 112 infants were used in the analysis.

In order to reduce the variability, a decision was made to analyze only the subset of participants who received the change event first ($n = 70$). It was determined after careful examination of the data that infants who had seen the standard event first had lost interest and attention by the time they had the opportunity to view a change event. Infants seeing the standard event first had already been exposed to the small troll three times (once during familiarization #1, once during standard test event #1 and once during familiarization #2) before they had the opportunity to see a change event. By the time the change event was performed, these 9-month-old infants did not seem interested in looking at any events--regardless of whether they were standard or change events. Once an infant has become bored and is looking around the room, it is nearly impossible to get her to look back at the display. This sort of attenuation effect is generally less pronounced with younger infants because it seems to take them longer (i.e., more exposures) to lose interest.

Thus, subsequent analyses were performed using only the participants receiving the change event first ($\underline{n}$ = 70) (see Figure 5 for mean PD scores for each condition). Since the important contrast is across condition (not across event), it is reasonable to use only the infants who received the change event first in the analysis. As before, the mean PD scores for each condition were contrasted with zero. The critical t value (k = 7, df = 9) = 3.48 with alpha set at .05. The analyses revealed that infants in the Location Condition ($\underline{t}$ = 6.09, $\underline{p} < .05$), Size Condition ($\underline{t}$ = 4.35, $\underline{p} < .05$) and Size/Feature Condition ($\underline{t}$ = 3.91, $\underline{p} < .05$) looked significantly longer at the change event; the other conditions yielded nonsignificant contrasts with zero.

Planned comparisons were conducted across conditions to address specific predictions. First, it was hypothesized that when an object's other characteristics (e.g., size and/or features) change in combination with location, infants will treat the object in the new location as a different object--not as the same object. Based on other studies conducted using the same paradigm, infants are consistently surprised by the same object in a different location; however, they are not generally surprised to see a new object at a different location (e.g., Rosser, Narter, & Paullette, 1995). This might seem counterintuitive based on the finding that young infants are generally surprised by the "magical" disappearance of an object (e.g., Bower, 1967); however, the nature of the present task may be the culprit in this situation. Perhaps infants are not looking at the location of disappearance, but rather they are looking at the location of reappearance. If infants in this study were focusing on the disappearance alone, then they should be surprised in all conditions in which location changes (Location, Size/Location, Feature/Location, and Size/Feature/Location Conditions). As the results from the PD analysis indicate, infants were not surprised in all conditions in which location changed. In fact, they were only surprised when location changed but other attributes remained constant, which violates the Different Object/Different Location Assumption.

To evaluate this first proposition, the Location Condition was contrasted with the following conditions: Size/Location, Feature/Location and Size/Feature/Location. All three of the contrasts were significant at the .05 level with t values equal to 4.50, 7.39 and 7.39 respectively. This indicates that the infants looked reliably longer when the same object appeared in a different location (Location Condition) than when a new object was revealed at a different location (Size/Location, Feature/Location and Size/Feature/Location Conditions), which was consistent with the hypothesis.

Second, it was proposed that a change in an object's size would be a more salient change for 9-month-old infants than a change in an object's features when the hiding and retrieval events are at the same location. The hypothesis was that infants would be sensitive to a spatial change (e.g., size--the amount of space an object occupies in space), but would not necessarily be sensitive to non-spatial, physical changes (e.g., features such as color, texture and details). The rationale behind this prediction is based on the finding that infants are sensitive to spatial information before they are sensitive to non-spatial information (e.g., Rosser, Narter, & Paullette, 1995; Xu & Carey, 1996). To assess this prediction, the Size Condition was contrasted with the following conditions: Feature and Size/Feature Conditions. Based on this hypothesis, one would predict that infants would look reliably longer at a change in an object's size than in a change in its features. The contrast between the Size and the Feature Conditions was significant ($\underline{t} = 5.22$, $\underline{p} < .05$) as anticipated; however, the contrast between the Size and the Size/Feature Conditions was not, which suggests that infants were sensitive to the size change in both situations. To summarize, participants in the Size/Feature Condition did not seem to be using featural information to determine whether the object was the same as one encountered earlier; rather they were relying on size information in order to make this determination.

Third, it was anticipated that the Location Change and the Size Change would not differ significantly in magnitude. The rationale for this prediction was that size and location are both spatial object characteristics: Size is the amount of space an object occupies, and location is where the object is located in space. Researchers have consistently found that infants younger than 9 months of age can remember the location of a hidden object (Baillargeon & Graber, 1988; Baillargeon, DeVos, & Graber, 1989). In fact, this robust finding has been replicated several times using the same procedure described in this study (Rosser, Narter, & Paullette, 1995; Wilcox & Nadel, 1993; Wilcox, Nadel, & Rosser, 1996). As alluded to in the literature review, size is a discriminable property for infants quite early in life. Recently, some researchers (Granrud, 1987; Slater, Mattock, & Brown, 1990) have found that size constancy is present at birth. Studies of changes in an object's size have demonstrated that 3.5-month-olds can represent an object's size over brief delays (Baillargeon & DeVos, 1991). In addition, Adler and Rovee-Collier (1994) found that 3-month-olds can remember an object's size over a 24 hour delay period. Based on prior research, it seemed apparent that location and size are attributes which infants are sensitive to early in life. Following from this, one might predict that infants would also use the two spatial characteristics--location and size--when making decisions about identity. The contrast was not significant, consistent with the proposition that infants were equally surprised when the small troll appeared at a new location as compared with when the small troll changed into a large troll at the same location.

Finally, it was predicted that the Feature Change and the Location Change would differ significantly in magnitude, with infants looking significantly longer at a change in location (small troll at initial location to small troll at other location) as compared to a change in features (small troll to small bear in the same location). Data obtained with this same paradigm suggests that infants as young as 7 months of age are not surprised when an object undergoes a featural transformation (e.g., toy lion to toy tractor, toy lion to toy elephant, toy hamster to toy tractor) (Rosser & Narter, 1997). As anticipated, the contrast was significant (t = 6.96, $p < .05$), with the Location Condition having significantly larger PD values than the Featural Condition.

First-Look Analyses

Cumulative looking time may not always be the most appropriate way to measure an infant's surprise to a violation of an expectation. Spelke and her colleagues (Spelke et al., 1992) found that older infants have reacted to "impossible" events by turning away from the display to look at a parent or experimenter or by attempting to look behind the display apparatus. Neither of these reactions is accurately depicted by using a cumulative looking time measure. Some of the 9-month-old infants in the present study would look initially at an event they found novel or surprising, but then look away from the display. The reasons that infants might look away are varied: They might just be bored (even if the event was initially surprising); they might be searching for an apparently "missing" object, or they might be looking at the parent for a reaction or for reassurance (i.e., social referencing). Regardless of the reasons that infants look away from the display, it is clear that they do exhibit this type of behavior. Given the looking-away behavior displayed by older infants, it follows that cumulative looking time might not be the most appropriate measure in this case. An alternative to the traditional cumulative looking time assessment is a first-look measure--the amount of time an infant looks at an event initially before looking away from the display.

First-look data was obtained for participants receiving the change event first (n = 70). Mean first-looks for the first two trials can be found in Figure 6. A repeated measures ANOVA with Condition as the between-subjects factor and Trial as the within-subjects factor was performed on the first-look data. The ANOVA yielded a significant interaction between Condition and Trial, $F(63, 6) = 2.61$, $p < .05$.

The participants' data were divided into two groups based on which default expectation was addressed: The Same Location/Same Object Assumption or the Different Location/Different Object Assumption. The rationale for dividing the participants into these groups was that the types of physical and spatial information relevant for making identity decisions depends on which expectation, the Same Location/Same Object Expectation or the Different Location/Different Object Expectation, is being made. The conditions addressing the Same Location/Same Object Assumption were the Size, Feature and Size/Feature Conditions; the Location, Size/Location, Location/Feature and Size/Location/Feature Conditions addressed the Different Location/Different Object Assumption.

Independent unidirectional t-tests were performed within each of the seven conditions to compare the mean duration of first-looks to the first standard event to the mean duration of first-looks to the first change event. For both groups, the critical t value (df = 18) = 1.7 with alpha set at .05 for the Same Location/Same Object Group. The contrasts for the Size Condition ($t = 2.89$, $p < .05$) and the Size/Feature Condition ($t = 3.03$, $p <$

.05) were significant; the t-test for the Feature Condition was not significant. These results suggest that change in an object's size is powerful enough that it conflicts with the Same Location/Same Object Assumption and informs the infant that a different object is present at the same location. Featural information, however, does not appear to conflict with the default assumption.

For the Different Location/ Different Object Group, only the Size/Location test was significant ($t = 2.3$, $p < .05$). The other three conditions yielded t's which were not significant; this finding indicates that infants did not look significantly longer at the change event under those circumstances. The significant finding in the Size/Location Condition suggests that infants did not use information about the object's size to infer that a different object was present at a different location. Instead, they treated the small troll and the large troll as the same object and were surprised when that object violated the continuity constraint. Furthermore, the findings from the other three conditions examined here indicate that the change events in those conditions were consistent with the default assumption (Different Location/Different Object). Although it was predicted that the test conducted on the Location Condition would have been significant, it was not significant using first-look data. It should be noted, however, that the Location Condition is proceeding in the correct direction--infants looked longer at the change event, but they didn't look significantly longer according to the first-look data. The results suggest that the information was not powerful enough to override the Different Object/Different Location Assumption.

To summarize, two dependent measures were used to examine infants' behavior: a cumulative looking measure time and a first-look assessment. Cumulative looking times were transformed into proportion difference scores to establish an external criterion for comparison. For participants in the Same Location/Same Object Situation, the results are as follows: Across both methods, infants seemed to use size information, but not featural information, to override the Same Location/Same Object Expectation. For babies in the Different Location/Different Object Situation, the findings are somewhat different. In this case, infants seemed to utilize both size and featural information to decide that there was a new object at a new location.

CHAPTER V

GENERAL DISCUSSION

Before offering an interpretation of the present findings, a brief overview of the results is necessary. Again, the data were analyzed in two ways: (1) a proportion difference (PD) score comparing cumulative looking time to the standard and change events; and (2) a first-look measure which assessed how long infants looked at the test events initially before looking away from the display. For the Size Condition, both types of analyses yielded significant results; this means that the infant in the Size Condition looked reliably longer at the change event. For the Location Condition, the PD analysis was significant when contrasted with zero, and the first-look analysis was in the correct direction (infants looked longer at the change event), but it did not reach significance. Both types of analyses performed on infants in the Feature Condition yielded nonsignificant results; infants did not look significantly longer at either type of test event.

For the Size/Feature Condition, the infants looked significantly longer at the change event regardless of which method of analysis was utilized. For infants in the Size/Location Condition, the two types of analysis revealed slightly different findings: The PD analysis was not significant when contrasted with zero; however, the first-look analysis produced results which were significant at the .05 level. The Feature/Location Condition was more clear cut, with both analyses producing nonsignificant outcomes; the infants in the Feature/Location change did not look significantly longer at either type of test event.

Finally, infants in the Size/Location/Feature Condition did not look significantly longer at the change event regardless of which procedure was used. This finding is especially intriguing given that the most amount of change is occurring in this condition (size, location and features are changing together), yet the data from this condition does not yield the most looking. Such a result provides evidence to argue that it is not change per se that leads to an increase in looking time, but change vis a vis expectations.

If an infant sees an object at the same location as she saw an object before, the Same Location/Same Object Assumption would inform the baby that it must be the same object she saw before; there is an inherent expectation that it must be the same object because it is at the same location. The physical attributes of the object can either be consistent with (i.e., no increase in looking time to the change event) or conflict with (i.e., an increase in looking time to the change event) the assumption. On the other hand, when a baby sees an object revealed at a different location from where she saw it hidden previously, the Different Location/Different Object Assumption informs her that it must be a different object. Again, the physical characteristics of the object can either be consistent with (no increase in looking time to the change event) or conflict with (increased looking time to the change event) the principle. These two default assumptions need not be equally present or equally powerful.

The findings from the present study can be interpreted in terms of the two default assumptions. First, the infants assigned to the experimental situations in which the Same Location/Same Object Rule might apply were in one of three conditions: the Size/Feature Condition, the Size Condition or the Feature Condition. In all three of these cases, the location remained constant so the infant should expect that the object is also the same unless she is provided with spatial and physical information about the object that conflicts with this default assumption. Babies in the Size/Feature Condition looked significantly longer at the first change event (small troll to large bear at the same location) as compared with the first standard event (small troll to small troll at the same location--no change). This finding suggests that a change in an object's size, its features, or both its size and its features is a powerful enough alteration to conflict with and subsequently override the Same Location/Same Object Assumption. The infant is surprised when the small troll becomes the large bear because she represents them as *different* objects at the same location--a violation of the default assumption.

Next, it was necessary to determine which specific component or components of the change (size, features, or both size and features) were responsible for the increased looking time. To find the etiology of the surprise, size and features were examined in isolation of one another. As evidenced by PD scores and first-look data, infants in the Size Condition looked significantly longer at the first change event (small troll to large troll at the same location); whereas participants in the Feature Condition did not look significantly longer at the change event (small troll to small bear at the same location) as revealed by both methods of analysis. Together these findings suggest that a change in an object's size is salient enough to conflict with the Same Location/Same Object Assumption;

however, featural changes may not be salient enough to override this default principle. Thus, a change in size provides the infant with information that is in conflict with the Same Location/Same Object Principle, so the infant is surprised when a *different* object appears at the same location.

Conversely, the babies did not look longer when the object underwent a strictly featural change; this finding was consistent with the default expectation and suggests that 9-month-old infants were treating the small troll and the small bear as essentially the same object. Hence, they were not surprised by this change because it was in accordance with the Same Location/Same Object Rule. Using a different paradigm than the one presented here, Bower (1974) claimed that 5-month-old infants were surprised when one object (e.g., a toy rabbit) turned into another object (e.g., a red ball); however, other researchers (e.g., Gratch, 1982; Meicler & Gratch, 1980; Muller & Aslin, 1978) have not been able to replicate Bower's findings even with much older infants. Gratch (1982) reported that 9-month-old infants were surprised when an object underwent a featural change. Similarly, Xu and Carey (1996) found that infants will not use featural information for the purposes of object identity until approximately 12 months of age. Thus, it appears that infants do not use featural information to trace an object's identity until 9 to 12 months of age.

Participants assigned to conditions in which the Different Location/Different Object Assumption might apply were in one of four conditions: the Location Condition, the Size/Feature/Location Condition, the Size/Location Condition, and the Feature/Location Condition. The participants in the Location Condition looked longer at the change event (small troll at one location to small troll the other location) when analyzed using the PD score. When duration of first-look was the dependent measure the effect was not significant, but was in the correct direction (longer first-looks to the change event); the first-look analysis might not have been powerful enough to pick up on this impossible change in an object's location, given the variability within that condition. All other factors being constant, the smaller the standard deviation is, the more powerful the statistical test is. When doing research with infants looking time as the dependent measure, there is often too much variability in the data which decreases the power of the statistical test being conducted. This Location Change Effect has been quite robust with infants younger than 9 months of age in earlier research (e.g., Baillargeon & Graber, 1988; Baillargeon, DeVos, & Graber, 1989; Wilcox & Nadel, 1993; Wilcox, Nadel, & Rosser, 1996). In fact, the impossible change in location is in direct conflict with the Different Location/Different Object Assumption because the *same* object has appeared in a different location without visibly passing between the two locations--a violation of the continuity constraint. It has been demonstrated that infants as young as 2.5 months of age are sensitive to violations of the continuity constraint over a 5 second delay (Wilcox & Nadel, 1993; Wilcox, Nadel, & Rosser, 1996). Again, the marginal results in the Location Condition using first-look data in the present study are probably due to the large amount of variability in first-looks.

Infants in the Size/Feature/Location Condition did not look significantly longer at the change event (small troll at one location to large bear at the other location), which suggests that infants were treating the large bear as a different object at a different location and is consistent with the Different Location/Different Object Expectation. To investigate whether size, feature or a combination of both was responsible for this outcome, the Size/Location and Feature/Location Conditions were examined separately.

Babies in the Size/Location Condition did not look significantly longer at the change event (small troll at one location to large troll at the other location) when cumulative looking time (i.e. the PD analysis) was the dependent measure; however, the findings were significant at the .05 level when duration of first-look was used. Based on cumulative looking time, it appears as though the infants are using the object's size to inform them that large troll is a different object at the new location, which is consistent with the default assumption. Based on duration of first-look, the infants seem to be treating the large troll as the same object at its new location, resulting in increased looking time due to a violation of the continuity constraint. It seems reasonable to expect that the infants might have originally thought that the object revealed (the large troll) was the same object that was hidden (the small troll), which would result in longer first-looks because an expectation had been violated. As the trial progressed, the infants seemed to overcome their initial surprise which resulted in equal cumulative looking times to the standard and change events. Thus, the cumulative looking measure is suggesting a more mature response than the first-look data. Perhaps it is difficult for infants to represent the precise size of the troll when it has changed location. The small and large troll only differ in height by 4 cm, and there are no landmarks in the display that the infants could use as a frame of reference to represent an object's size. Possibly, the infants do not always acknowledge that the large troll is a different object than the small troll due to the small difference in size combined with the location change. Interestingly, it seems that these 9-month-olds are consistently sensitive to a change in size when location remains constant, but not when location changes.

Infants in the Feature/Location Condition did not look reliably longer at the change event (small troll at one location to small bear at the other location). In this case, the participants might have been using featural information to infer that the small bear is a different object at a different location, which is consistent with the default principle. Therefore, changes in an object's size and/or its features may be in conflict with and subsequently override the Different Location/Different Object Assumption.

In summary, the object attributes which are informative to 9-month-old infants will vary depending on which default assumption applies to the particular situation. In the Same Location/Same Object Situation, a change in size (but not features) conflicts with the default rule. Thus, a change in size seems to be salient enough to inform the infant that there is a different object at the same location; however, changes in an object's color, texture and details might not be salient enough to conflict with the assumption. On the other hand, infants in the Different Location/Different Object Situation, appear to be sensitive to changes in size and features (both in isolation and in combination with one another) and use this information to determine that there is a different object at a different location. The only condition that seemed to be in conflict with the Different Location/Different Object Assumption was the Location Condition; infants expected to see a different object at the new location and were surprised to see the same object at a different location--a violation of the continuity constraint.

Though it may seem somewhat counterintuitive that infants use featural information to inform them about an object's identity in one situation but not in another, this same finding has been replicated (e.g., Rosser, Narter, & Paullette, 1995; Rosser, Narter, & VanWyhe, 1996). To reiterate, the finding is that infants are not surprised (as indexed by no increase in looking time to the change event) when an object's features change in the same location because they are treating the old and new objects as the *same* object at the same location. In addition, they are not surprised when an object's features and location change because they may be using featural information in deciding that a *different* object is at a different location. In the Same Location Situation, infants do not seem to rely on featural information for object identity, which is consistent with the default rule; however, infants in the Different Location Situation appear to use featural information to decide that a new object is present, which is consistent with the default assumption. In both cases, the infants are using featural information (or not using featural information) in a manner which is consistent with their expectation. Rosser and her colleagues have replicated this result using of variety of dimensions: changes within categories (e.g., yellow toy lion to green toy elephant, changes across categories (e.g., yellow toy lion to a blue toy tractor), changes from individual object to an aggregate of objects (e.g., yellow toy lion to french fries), and changes across the animate/inanimate boundary, (e.g., a toy hamster to a live hamster). Across all of these experiments, the finding is the same: Infants might use featural information when location changes, but they do not seem to rely upon it when location remains constant.

An alternative interpretation of this data might be that infants are simply responding to the change in which gloved hand E1 used to point at the object during familiarization and retrieval when any type of location change occurred. Perhaps the participants were surprised because the right hand pointed at the object during the familiarization and the left hand pointed at the object when it was revealed at its new location following its occlusion regardless of which objects were being presented. However, if this were the case then infants would show an increase in looking time to any test event involving a change in location (e.g., the Location Condition, the Size & Location Condition, the Location & Feature Condition, and Size, Location & Feature Condition) regardless of the other types of changes occurring simultaneously. The only condition involving a change in location in which infants looked significantly longer at the change event was in the Location Change Condition. Conversely, if participants were merely responding to a change in which hand E1 was using to point at the objects, then there should be no increase in looking time to any of the test events in which location remains constant (e.g., Size Condition, Feature Condition, and Size & Feature Condition) regardless of the objects being used. The findings from the present experiment indicate that infants look longer at the change event in both the Size Condition and the Size/Feature Condition, but they do not look longer in the Feature Condition. Thus, the hand explanation is not a plausible alternative to attempting to explain the data.

Another possible explanation might be that infants are surprised by (as indexed by an increase in looking time) any sort of object disappearance regardless of the object that subsequently appears. Since all seven conditions involve some sort of object disappearance, then infants should look significantly longer at all change events regardless of the characteristics of the object that is subsequently revealed. The results indicate that infants only looked significantly longer in the following conditions: The Size Condition, the Size/Feature Condition and the Location Condition. Hence, this interpretation does not explain the findings presented here.

Two caveats should be put forth before further discussing the present findings vis a vis the proposed default assumptions. The first caveat concerns the visual acuity of 9-month-old infants. If the acuity of these infants is not good enough to see the featural changes presented (e.g., small troll to small bear), then it is not necessary to proceed to more complicated issues such detectability and identity. Norcia and Tyler (1985) used the visual evoked potential (VEP) to measure grating acuity in infants and discovered that babies have 15 cycles/degree (20/40) acuity by 6 months of age. In addition they noted that by 8 months of age, acuity measured by VEP was not significantly different from adult levels of acuity obtained using the same apparatus. Similar estimates of infants' visual acuity have been found using an operant preferential looking procedure (e.g., Birch, Gwiazda, Bauer, Naegele, & Held, 1983; Mayer & Dobson, 1982). Both groups found that 9-month-olds have 10 cycles/degree (20/60) acuity by approximately 9 months of age. This might not be good enough to see very fine details, but it is certainly good enough to see the sorts of changes exhibited in the present study (e.g., a brown plastic troll with bright red hair tied in a pony tail versus a furry bear with tiny white ears).

The second caveat involves infants' detectability of specific spatial and physical characteristics of objects. As reviewed in Chapter I, size is a discriminable property for infants quite early in life. In fact, size discrimination is one of the prerequisites to a complete notion of size constancy. Recently, researchers have found that size constancy is present at birth (e.g., Granrud, 1987; Slater, Mattock, & Brown, 1990). Additionally, infants as young as 3.5 months of age can represent an object's size when the object is occluded during a brief delay (Baillargeon & DeVos, 1991).

Young infants can also discriminate objects based on other physical dimensions. For example, Adam and Courage (1995) reported that 1-month-old infants can discriminate red objects from green objects; however, they cannot discriminate either of these colors from yellow. At 2 months they can discriminate green objects from yellow objects, and by 3 months of age they can discriminate red objects from yellow objects. Thus, by approximately 3 months of age infants can see and discriminate colors much like an adult can. Furthermore, they can represent an object's color over a brief delay (Catherwood, Skoien, & Holt, 1996). Catherwood et al. (1996) familiarized 16- to 31-week-old infants to triads of faces, with one face being the target face and the other two acting as distracters. The only difference between the faces was that the target face was a different color. When tested after a brief delay, the infants used the dimension of color to recognize which faces they had seen before.

Thus, nine-month-old infants have the visual competence to see objects clearly, and they have perceptual and cognitive skills to discriminate them and represent their physical and spatial attributes, but one important question remains: Will they use this information to make decisions about an object's identity? If infants are capable of using physical and spatial information to trace an object's identity in time and space, then will they always use the same object characteristics to make decisions about identity or will the attributes they use change depending on which default expectation is being challenged?

The present findings suggest that only size informs the infant about an object's identity in the Same Location/Same Object Situation, whereas both size and features are informative in the Different Location/Different Object Situation. Why might this difference exist? One possibility is that the Different Location/Different Object Expectation is more powerful than the Same Location/Same Object Expectation. The Different Location/Different Object effect has been demonstrated in numerous studies (Rosser, Narter, & Paullette, 1995; Rosser, Narter, & VanWyhe, 1996). In both of the aforementioned studies, infants as young as 7 months of age did not look significantly longer when a new object appeared at a different location, which is consistent with the Different Location/Different Object Assumption. For example, 7-month-olds did not look longer when they saw a white, furry toy hamster hidden at one location and a white, furry live hamster appear at the opposite location even though the two hamsters were perceptual quite similar. Although the striking similarities between the two hamsters might lead infants to expect that they were the *same* object, their spatiotemporal beliefs (i.e. one object cannot be in two places at the same time) lead them to expect differentness. Thus, when differentness is the default assumption, all types of information about the object (e.g., size, color, texture, detail, ontological category) are available to the infant to assist her in making a prediction consistent with the default principle.

Interestingly, the Same Location/Same Object Rule does not seem to be as powerful and true in the physical world as the Different Location/Different Object Rule, and one can probably think of several situations in which the sameness assumption is violated or at least appears to be violated. For example, if the location is large enough two different objects can be in the same location at the same time; babies probably would not be surprised to see a small troll occluded and a large troll revealed at the same location if that location was large enough to hold both objects. A second violation might be if one object can fit inside another object. A live hamster inside a cage is an example of two objects being in the same place at the same time, which is technically a violation of the Same Location/Same Object Expectation. However, Rosser, Narter and VanWyhe (1996) found that 7-month-old infants are not surprised to see a hamster in a cage. Finally, if the entities presented are not solid bounded objects, then it is possible for two entities to be in the same place at the same time. For example, Baillargeon (1987b) found that when a soft, compressible object, such as an irregular ball of gauze, was placed in the path of the rotating drawbridge apparatus described in the literature review in Chapter II, 7.5-month-old infants were not surprised when the drawbridge appeared to violate the space of the sponge; however, they were surprised when the drawbridge appeared to violate the space of a solid block. These findings suggest that infants not only represented the height and location of the objects hidden behind the screen, but also the compressibility of these objects. In sum, it is not difficult for one to come up with examples in which the Same Location/Same Object Rule is violated. Given the many exceptions to this rule, it seems logical that the assumption of sameness may indeed be weaker than the assumption of differentness.

A related issue is that the Difference Assumption may actually emerge earlier in development than the Sameness Assumption. It seems logical that the expectation that an object can only occupy one location at a time would be present earlier than the expectation that two objects cannot occupy one location, based on the number of exceptions to the latter rule. To examine why the assumption of differentness might be utilized earlier than the assumption of sameness, it is useful to take an evolutionary approach and investigate why the attainment of one rule might be more crucial for an animal's survival than the attainment of another rule. There are many examples within the animal domain that violate the two objects in one location rule. A predator hiding in a bush, an animal swimming in a lake and a bear sleeping inside a cave are all exceptions to the rule that two objects cannot occupy the same location. Because animals experience so many exceptions to this rule, it makes sense that it might take longer to emerge. There are far fewer exceptions to the Different Location/Different Object Expectation. The only illustration that comes to mind would be if an animal moved from one location to another, but did not appear to have passed between the two locations. For example, suppose a rattlesnake was sunning himself in the sand, then slithered into a hole and appeared next to a rock several feet away. This is not an example of one object being in two places at the exact same time; however, it does exemplify and apparent violation of the continuity constraint. In terms of survival, it would be necessary for an animal to be sensitive to the more predictable and true rule (i.e., the Different Location/Different Object Rule) very early in life. For example, suppose a rabbit sees a coyote over by a prickly pear cactus. A few seconds later the rabbit notices that there is another coyote resting near a mesquite tree. It is unlikely that the rabbit will assume that the same coyote has moved from one location to another without traveling between the two locations. Instead the rabbit will probably assume that there is a second predator present, and she will cover her tail!

When the present behavioral findings are coupled with neuroscientific data about the development of the two cortical visual systems, the emerging story becomes even more complex and interesting. There are two major fiber bundles, a ventral bundle and a dorsal bundle, which emerge from occipital cortex and project rostrally in the brain

(Flechsig, 1896; 1920). However, the precise functions of these two systems are still an area of debate among neuroscientists. Ungerleider and Mishkin (1982) proposed that the two systems are best characterized as an object vision system ("what" system) and a spatial vision system ("where" system). The "what" system analyzes the physical properties of an object, and the "where" system analyzes the location of objects. In the three conditions in which the Same Location/Same Object Expectation was being tested (the Size, Feature and Size/Feature Conditions), location remained constant while physical properties varied. Thus, it follows that the "what" system might have been responsible for processing this visual information. Since location clearly remained constant in these three situations, the "where" system was probably inactive. In the four conditions in which the Different Location/Different Object Expectation was being assessed (the Location, Size/Location, Feature/Location and Size/Location/Feature Conditions), it seems that both the "what" and "where" systems were being activated. The infants have to process both the location and the physical characteristics of the object in order to represent the sequence of events.

An alternative conceptualization to the "what" versus "where" distinction has been proposed by Goodale and Milner (1992). They describe the dichotomy as "perception" versus "action". The perception system mediates the perceptual identification of objects, whereas the action system mediates the actions upon those objects. According to this conceptualization, the perception system underlies all seven conditions in the present project because the infants were looking at the objects and not acting upon them. It would be interesting to see if and how the results would have been different if reaching would have been used as the dependent measure. Presumably, the action system would underlie reaching behaviors.

To establish a more comprehensive theoretical stance explaining how a concept of object identity might develop, it is imperative to compare the present findings with other studies of object identity in infants. There are two basic types of studies: those in which the same object appeared both sides of an occluder and those in which different objects appeared. The studies in which the same object appeared on both sides of the occluder is comparable to the Location Condition in the current study. In a set of experiments by Spelke et al. (1995), 4-month-old infants were shown an occlusion event in which the same object (a cylinder) appeared on either side of a wide screen. Following habituation, the screen was lowered revealing either a one- (expected) or two-cylinder (surprising) test event. The infants in this study looked equally at the one- and two-cylinder test events, which suggests that they made no assumption about whether one or two objects were involved in the event.

Spelke et al.'s conclusion, however, is inconsistent with results obtained by Baillargeon and her associates (e.g., Aguiar & Baillargeon, 1997; Baillargeon & DeVos, 1991; Baillargeon & Graber, 1987). In one experiment (Aguiar & Baillargeon, 1997), 3-month-old infants were habituated to a toy mouse that moved back and forth behind a screen. During test events, a portion of the screen's midsection was removed to create a large window. In the possible event, the cut-out was located in the screen's upper half, and the mouse was shorter than the window's lower edge, so it did not appear in the window. In the impossible event, the cut-out was located in the screen's lower half, and the mouse should have appeared in the window but did not. Three-month-olds looked reliably longer at the impossible than at the possible event, which suggests that they assumed there was a single object involved.

Aguiar & Baillargeon (1997) attribute the discrepancy to the different reasoning processes required for each task. They propose that Spelke et al.'s task requires a more complex sort of reasoning which they call event mapping; whereas, Baillargeon's task requires simpler reasoning which they deem event monitoring. An event mapping task requires the infant to retrieve a representation of the habituation event, map it onto the test event, and decide whether the two events are consistent with one another. In an event monitoring task, the infant does not have to compare the habituation to the test event; she only is required to reason about a single event (the test event) and judge whether the successive sequences of the event are internally consistent. For example, when watching the impossible test event, the infants only had to compare successive segments of the event to acknowledge that the mouse's emergence at the screen's right edge was inconsistent with the mouse's earlier failure to appear in the window. To summarize, the main difference between the two tasks is that the event mapping task requires infants to compare distinct events and judge whether they are consistent with one another; the event monitoring event requires infants to reason about a single event and judge whether successive portions of the same event are consistent.

The present task is more similar to the event mapping task because the infants must map what was hidden during the familiarization onto what was revealed (and where it was retrieved) during the test event. There are a few differences between the current study and the experiments conducted by Baillargeon and Spelke and their colleagues that should be mentioned. First, different stimuli were used: trolls (in the present study), cylinders (in Spelke's study) and mice (in Aguiar and Baillargeon's study). Also, in the present set of experiments the stimuli remained stationary, whereas in the other two studies the stimuli where in motion. Infants generally will be more engaged (as evidenced by longer looking times) when stimuli are dynamic versus when they are static. Recent findings suggest that infants as young as 3 months of age inferred that a single object was involved, and the participants were surprised when they were shown two objects (Aguiar & Baillargeon, 1997).

Xu and Carey (1996) have examined same-object occlusion events with 10-month-olds. Like Spelke et al., they used an event-mapping task. In their first experiment the infants had to use spatiotemporal information, and in the second experiment infants had to use featural information. Xu and Carey found that 10-month-olds used spatiotemporal but not featural information to trace the object's identity. This task is probably the most similar to the current task because two occluders are used and the task requires event-mapping.

They also examined the responses of 10- and 12-month old infants to different-objects occlusion events (Xu & Carey, 1996). Again, the investigators used an event mapping task. The infants observed one object emerge from behind the left edge of a wide screen to the left wall of the apparatus and then returned behind the screen. A different object then emerged from behind the right edge of the screen to the right wall of the apparatus and returned behind the screen. This process was repeated several times. Then, the screen was turned aside to reveal either one object or two distinct objects. The researchers found that 12-month-olds were surprised by the one-object display, which suggests that they were able to use featural information to infer how many objects were involved in the trial. Ten-month-olds were unable to use featural information in this situation. Based on their results, Xu and Carey (1996) concluded that the capacity to use featural information for purposes of identity emerges between 10 and 12 months of age. However, the findings from the present study provide some evidence that 9-month-old infants are capable of using featural information in certain situations. Using an event-monitoring task, Wilcox & Baillargeon (1997a, b) have found that infants as young as 4.5 months of age can use featural information to interpret different-object occlusion events. These infants can use shape and size, but it is not until 11.5 months of age that they use color to individuate objects (Wilcox, 1997).

The numerous discrepancies in the findings on object identity reflect the ambiguity surrounding the definition of this term, which is reflected in the various paradigms used to study identity. Xu and Carey's (1996) concept of object identity seems like a more complete notion than the one proposed by Baillargeon and her associates. Carey's concept seems more quantitative in nature--the infant needs to determine how many distinct object are involved in an event. Baillargeon's definition seems more qualitative--determining what objects are involved in an event. The present study focuses on whether infants use certain object attributes to confirm or conflict with default assumptions of sameness and differences.

Although these research teams have the same ultimate goal (to study the development of a concept of object identity), they are approaching the problem in different ways based on their differing perspectives about what a concept of object identity entails. Possibly, there are different milestones along the way to a complete concept of identity--just as Piaget proposed several milestones on the way to the attainment of a complete object concept. Perhaps Baillargeon is tapping into some earlier level of identity which is more qualitative in nature, while Carey is tapping into a more complete quantitative notion.

Once an infant has demonstrated that she has some rudimentary concept of object identity, how does the concept become further differentiated? Answering this question should be a primary focus for future studies. In the present study, the two locations were quite distinct and separate from one another. What would happen if the locations were not clearly marked? Maybe infants would still treat them as two locations and expect a new object to appear at the new location, or perhaps babies would treat them as one location and predict sameness. What if the hiding locations were moved closer together? Would infants still expect sameness or differentness? More importantly, how close together would the two locations need to be before infants would switch from relying on the

Different Location/Different Object Rule to the Same Location/Same Object Rule?

All of the size changes in the present set of experiments proceeded from small to big. What would happen if the size changes were reversed--always changing from big to small? In addition, how small would the size change need to be before infants would treat the small object and the big object as the same object. The research in the area of object identity has relied on behavioral measures only; it would certainly be illuminating to use behavioral measures in combination with electrophysiological measures such as event-related potentials (ERPs) to examine the neural circuitry that underlies this process. These questions and others must be addressed in order to further delineate the development of a concept of object identity.

APPENDIX A

TABLES AND FIGURES

Table 1

Sample Test Session for a Participant in the Location Change Condition Receiving the Change Event First

Familiarization #1	small troll at initial location
Delay #1	flaps lifted
Test #1 (change)	flaps lowered revealing small troll at opposite location
Familiarization #2	small troll at initial location
Delay #2	flaps lifted
Test #2 (standard)	flaps lowered revealing small troll at initial location
Familiarization #3	small troll at initial location
Delay #3	flaps lifted
Test #3 (change)	flaps lowered revealing small troll at opposite location
Familiarization #4	small troll at initial location
Delay #4	flaps lifted
Test #4 (standard)	flaps lowered revealing small troll at initial location
Familiarization #5	small troll at initial location
Delay #5	flaps lifted
Test #5 (change)	flaps lowered revealing small troll at opposite location
Familiarization #6	small troll at initial location
Delay #6	flaps lifted
Test #6 (standard)	flaps lowered revealing small troll at initial location

Table 2

Mean Raw Looking Times (and Standard Deviations) to Test Events for All Participants across All Six Trials

Condition	S1	C1	S2	C2	S3	C3
Loc	12.8 (2.5)	16.9 (8.2)	13.0 (3.1)	14.1 (5.4)	13.2 (3.4)	12.9 (3.1)
Size	15.5 (5.3)	17.7 (6.5)	12.1 (2.3)	15.3 (6.0)	12.5 (1.9)	13.7 (4.3)
Feat	17.7 (8.9)	18.6 (8.2)	15.1 (5.1)	13.8 (3.6)	14.4 (4.7)	14.3 (2.9)
Size/Loc	14.5 (5.1)	17.0 (5.0)	13.8 (5.2)	15.9 (4.2)	13.8 (4.4)	13.8 (3.5)
Size/Feat	15.1 (3.7)	15.8 (3.8)	13.5 (4.3)	13.8 (2.5)	13.1 (2.4)	13.4 (2.5)
Loc/Feat	15.2 (4.4)	14.9 (5.7)	14.4 (4.4)	14.5 (5.8)	13.3 (3.6)	16.8 (13.6)
Size/Loc/Feat	15.7 (5.5)	15.6 (4.7)	15.3 (12.1)	13.8 (4.8)	13.6 (5.5)	14.2 (4.7)
TOTAL	15.2 (5.4) n = 112	16.6 (6.2)	13.9 (5.9) n = 112	14.5 (4.7)	13.4 (3.9) n = 92	14.2 (6.2)

S = standard test event

C = change test event

Table 3

Mean PD Scores (and Standard Deviations) to Test Events for All Participants across All Six Trials

Condition	PD1 (1st pair)	PD2 (2nd pair)	PD3 (3rd pair)
Loc	.10 (.22)	.02 (.16)	-.01 (.08)
Size	.06 (.19)	.09 (.17)	.03 (.12)
Feat	.02 (.24)	-.03 (.16)	.00 (.14)
Size/Loc	.08 (.21)	.08 (.17)	.00 (.16)
Size/Feat	.02 (.13)	.02 (.13)	.01 (.12)
Loc/Feat	-.02 (.22)	.00 (.16)	.03 (.22)
Size/Loc/Feat	.00 (.22)	.00 (.23)	.02 (.17)
TOTAL	.04 (.20) *n* = 112	.03 (.17) *n* = 112	.02 (.15) *n* = 92

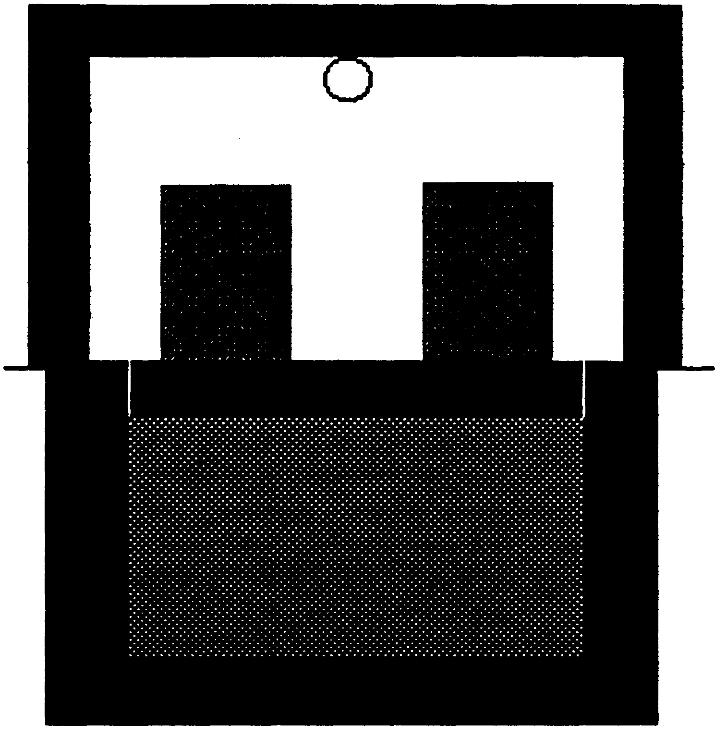
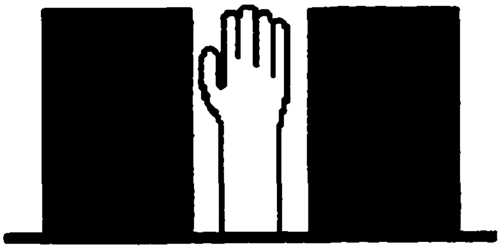


Figure1. A schematic representation of the display apparatus: the box and the stage.

(a) Familiarization for All Infants in All Conditions:

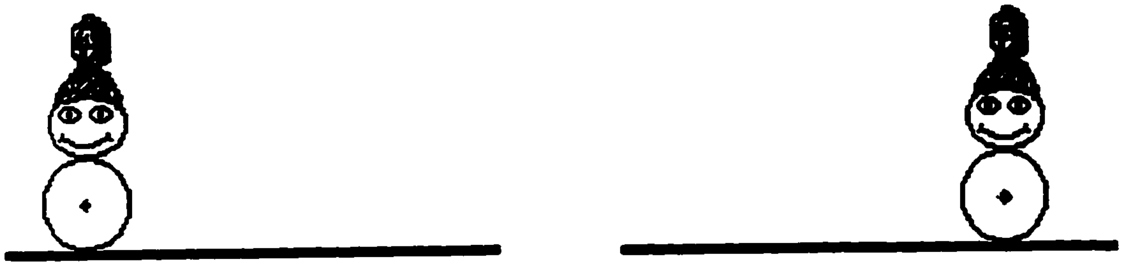
(b) Delay for All Infants in All Conditions:



(c) Standard Test Event for All Infants in All Condtions:

Figure 2. Schematic representations of (a) the familiarization, (b) the delay and (c) the standard test event for all infants in all conditions.

Location Change:



Size Change:

Size & Location Change:

Feature Change:

Location & Feature Change:

Size & Feature Change:

Size, Location & Feature Change:

Figure 3. Schematic representations of the change test events for each of the seven conditions.

Figure 4. Mean cumulative looking times to the standard and change events for the first pair of test trials (n = 112).

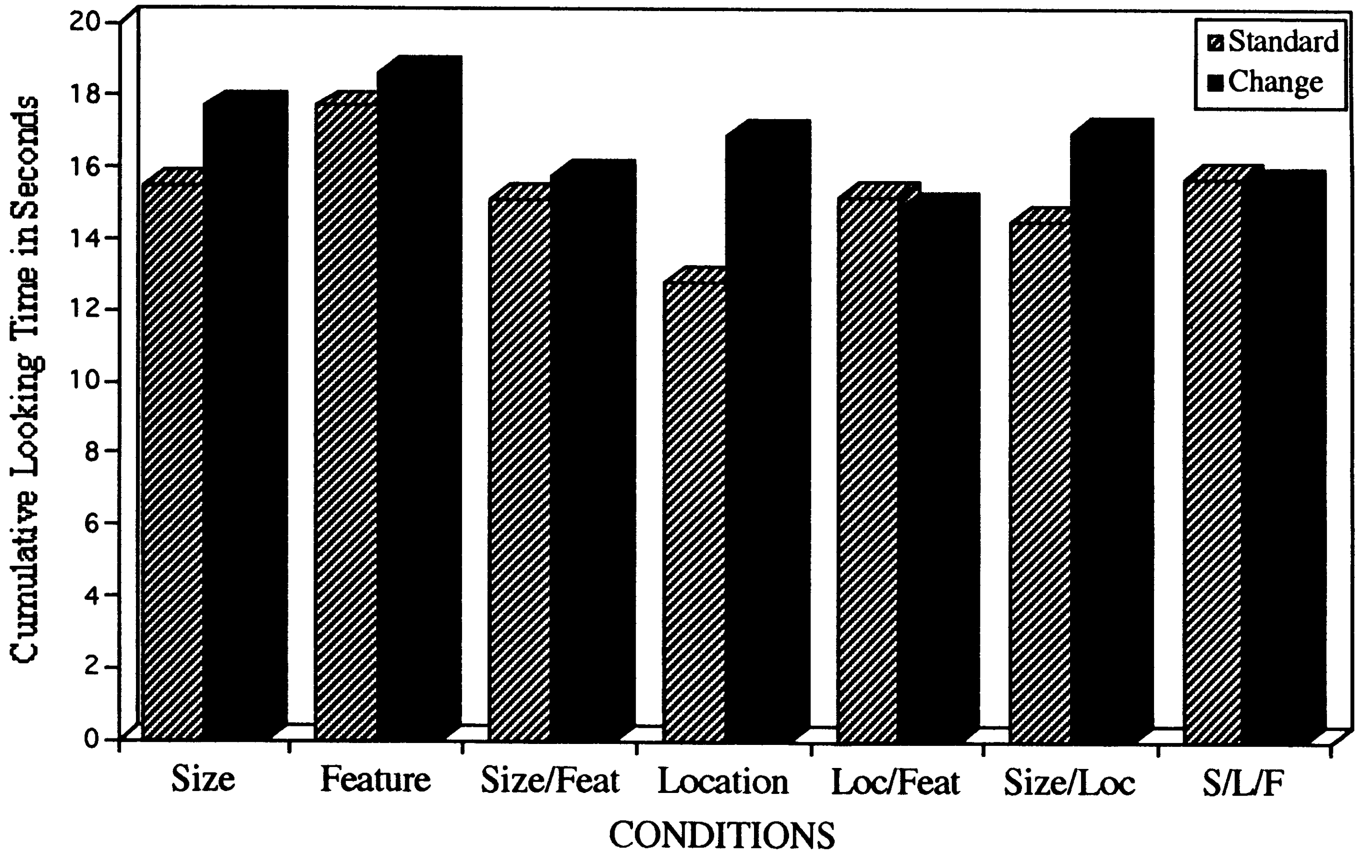
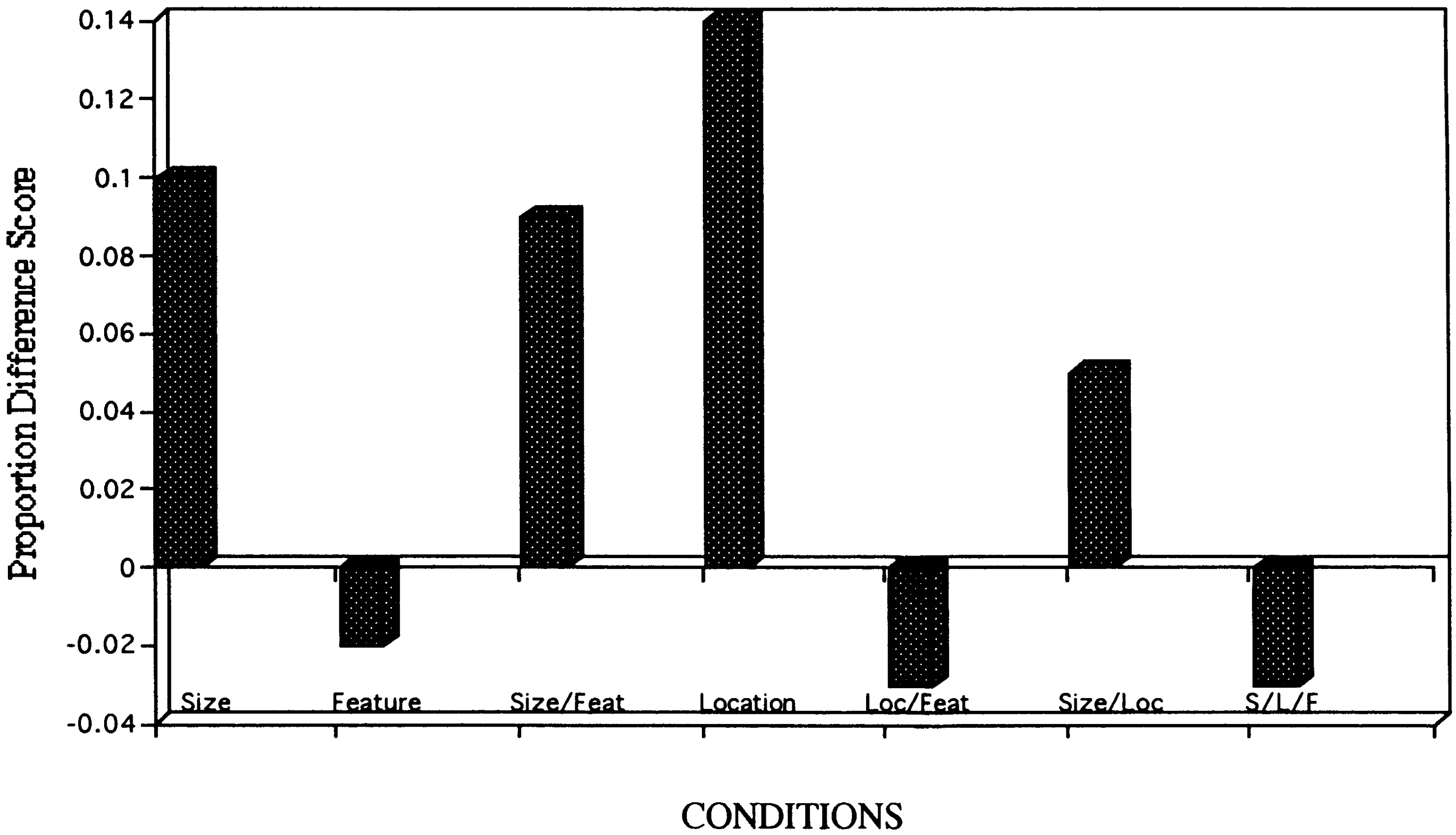
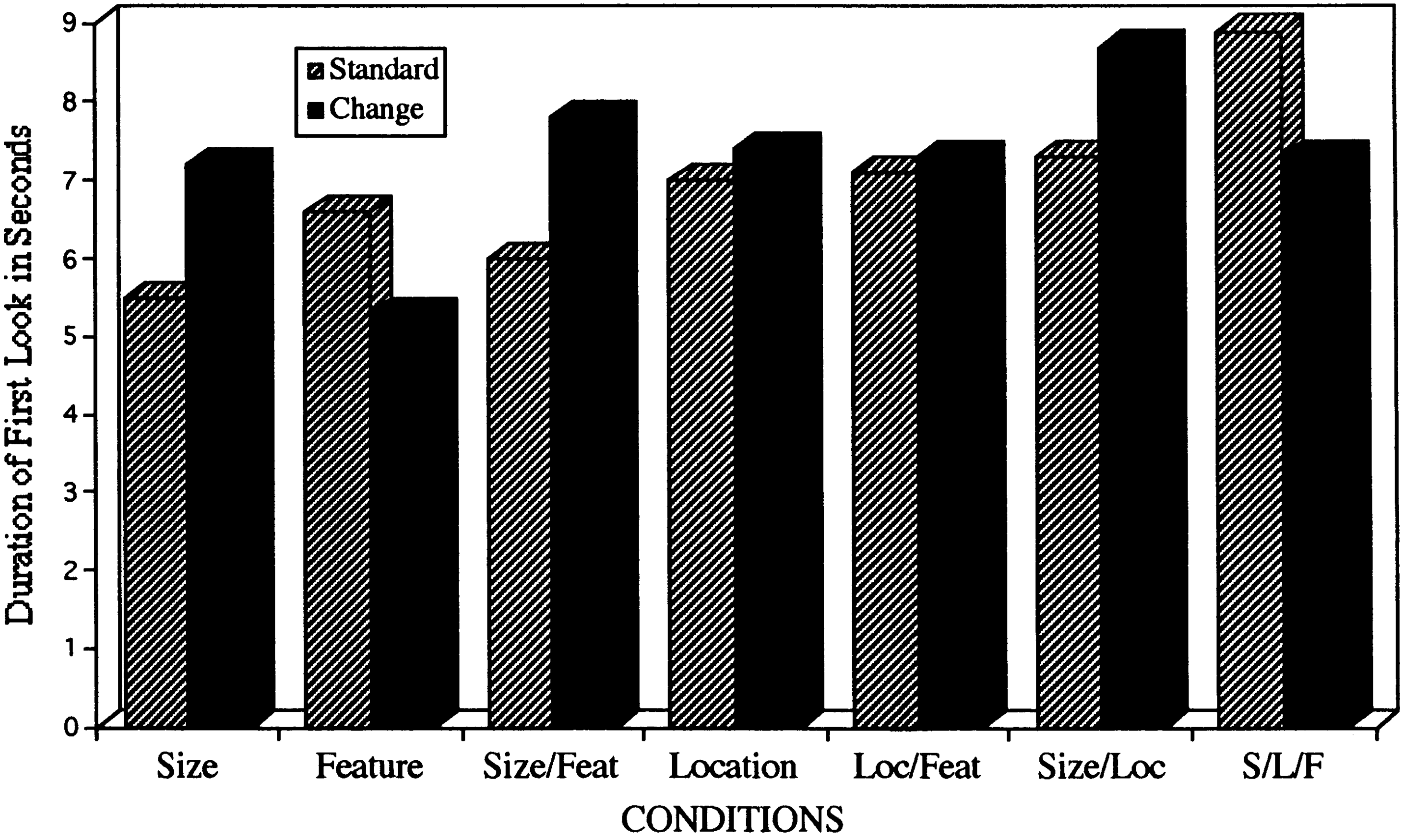


Figure 5. Mean proportion difference scores for the first pair of test trials for infants receiving the change even first (n = 70).



Note: PD scores for the Size, Size/Feature, and Location Conditions were significant when contrasted with zero.

Figure 6. Mean duration of first looks on the first two test trials for infants receiving the change event first (n = 70).



Note: The Size, Size/Feature, and Size/Location Conditions yielded significant contrasts.

REFERENCES

Adam, R. J., Courage, M. L. (1995). Development of chromatic discrimination in early infancy. Behavioural Brain Research, 67, 99-101.

Adler, S. A., & Rovee-Collier, C. (1994). The memorability and discriminability of primitive perceptual units in infancy. Vision Research, 34, 449-459.

Aguiar, A., & Baillargeon, R. (1997). Can young infants generate explanations for impossible occlusion events? Manuscript submitted for publication.

Baillargeon, R. (1987a). Object permanence in 3.5- and 4.5-month-old infants. Developmental Psychology, 23, 655-664.

Baillargeon, R. (1987b). Young infants' reasoning about the physical and spatial properties of a hidden object. Cognitive Development, 2, 179-200.

Baillargeon, R. (1991). Reasoning about the height and location of a hidden object in 4.5- and 6.5-month-old infants. Cognition, 38, 13-42.

Baillargeon, R., & DeVos, J. (1991). Object permanence in young infants: Further evidence. Child Development, 62, 1227-1246.

Baillargeon, R., DeVos, J., & Graber, M. (1989). Location memory in 8-month-old infants in a non-search AB task: Further evidence. Cognitive Development, 4, 345-367.

Baillargeon, R., & Graber, M. (1987). Where's the rabbit? 5.5-month-old infants' representation of the height of a hidden object. Cognitive Development, 2, 375-392.

Baillargeon, R., & Graber, M. (1988). Evidence of location memory in 8-month-old infants in a nonsearch AB task. Developmental Psychology, 24, 502-511.

Baillargeon, R., Spelke, E. S., & Wasserman, S. (1985). Object permanence in five-month-old infants. Cognition, 20, 191-208.

Baizer, J. S., Ungerleider, L. G., & Desmione, R. (1991). Organization of visual inputs to the inferior temporal and posterior parietal cortex in macaques. The Journal of Neuroscience, 11, 168-190.

Baldwin, D. A., Markman, E. M., & Melartin, R. L. (1993). Infants' ability to draw inferences about nonobvious object properties: Evidence from exploratory play. Child Development, 64, 711-728.

Ball, W., & Tronick, E. (1971). Infant responses to impending collision: Optical and real. Science, 171, 818-820.

Bergeron, B. (1979). Sensorimotor development of chimpanzee infants in semi-captivity. Unpublished master's thesis, University of Montreal, Quebec, Canada.

Birch, E. E., Gwiazda, J., Bauer Jr., J. A., Naegele, J., & Held, R. (1983). Visual acuity and its meridional variations in children aged 7-60 months. Vision Research, 23, 1019-1024.

Bjork, E. L., & Cummings, E. M. (1984). Infant search errors: Stage of concept development or stage of memory development. Memory and Cognition, 12, 1-19.

Bouchard, M. A., & Mathieu, M. (1976). A critical analysis of the delayed reaction task and the Piagetian object concept. Canadian Psychological Review, 17, 22-28.

Boussaoud, D., Ungerleider, L. G., & Desmione, R. (1990). Pathways for motion analysis: Cortical connections of the medial superior temporal and the functions of the superior temporal visual areas in the macaque. Journal of Comparative Neurology, 296, 462-495.

Bower, T. G. R. (1964). Discrimination of depth in prenatal infants. Psychonomic Science, 1, 368.

Bower, T. G. R. (1965). Stimulus variables determining space perception in infants. Science, 149, 88-89.

Bower, T. G. R. (1967). The development of object permanence: Some studies of existence constancy. Perception and Psychophysics, 2, 411-418.

Bower, T. G. R. (1972). Object perception in infants. Perception, 1, 15-30.

Bower, T. G. R. (1974). Development in infancy. San Francisco: Freeman.

Bower, T. G. R., Broughton, J. M., & Moore, M. K. (1970). Infant responses to approaching objects: An indicator of response to distal variables. Perception and Psychophysics, 9, 193-196.

Bower, T. G. R., Broughton, J. M., & Moore, M. K. (1971). Development of the object concept as manifested in changes in the tracking behavior of infants between 7 and 20 weeks of age. Journal of Experimental Child Psychology, 11, 182-193.

Bower, T. G. R., & Wishart, J. G. (1972). The effects of motor skill on object permanence. Cognition, 1, 165-172.

Brickson, M., & Bachevalier, J. (1984). Visual recognition in infant rhesus monkeys: Evidence for a primitive memory process. Society for Neuroscience Abstracts, 10, 137.

Bruner, J. S., & Koslowski, B. (1972). Visually preadapted constituents of manipulatory action. Perception, 1, 3-14.

Butterworth, G., Jarrett, N., & Hicks, L. (1982). Spatiotemporal identity in infancy: Perceptual competence or conceptual deficit? Developmental Psychology, 18, 435-449.

Caron, A. J., Caron, R. F., & Carlson, V. R. (1979). Infant perception of the invariant shape of objects varying in slant. Child Development, 50, 716-721.

Caron, R. F., Caron, A. J., Carlson, V. R., & Cobb, L. S. (1979). Perception of shape-at-a-slant in the young infant. Bulletin of the Psychonomic Society, 13, 105-107.

Catherwood, D., Skoien, P., & Holt, C. (1996). Colour pop-out in infant response to visual arrays. British Journal of Developmental Psychology, 14, 315-326.

Chugani, H. T., Phelps, M. E., & Mazziotta, J. C. (1987). Positron emission tomography study of human brain functional development. Annals of Neurology, 22, 487-497.

Cohen, L. B., & Caputo, N. F. (1978, May). Instructing infants to respond to perceptual categories. Paper presented at the meeting of the Midwestern Psychological Association Convention, Chicago, IL.

Cohen, L. B., & Strauss, M. (1979). Concept acquisition in the human infant. Child Development, 50, 419-424.

Cruikshank, R. M. (1941). The development of visual size constancy in early infancy. The Journal of Genetic Psychology, 58, 327-351.

Day, R. H. (1987). Visual size constancy in infancy. In B. E. McKenzie & R. H. Day (Eds.), Perceptual development in early infancy: Problems and issues. Hillsdale, NJ: Erlbaum.

Day, R. H., & McKenzie, B. E. (1981). Infant perception of the invariant size of approaching and receding objects. Developmental Psychology, 17, 670-677.

Diamond, A. (1985). Development of the ability to use recall to guide action, as indicated by infants' performance on A not B. Child Development, 56, 868-883.

Diamond, A. (1988). Abilities and neural mechanisms underlying A not B performance. Child Development, 59, 523-527.

Diamond, A. (1991). Neuropsychological insights into the meaning of object concept development. In S. Carey & R. Gelman (Eds.), The epigenesis of mind: Essays on biology and cognition. (pp. 67-110). Hillsdale, NJ: Erlbaum.

Diamond, A., Cruttenden, L., & Neiderman, D. (1994). A not B with multiple wells: 1. Why are multiple wells sometimes easier than two wells? 2. Memory or memory + inhibition? Developmental Psychology, 30, 192-205.

Diamond, A., & Doar, B. (1989). The performance of human infants on a measure of frontal cortex function, the delayed response task. Developmental Psychobiology, 22, 271-294.

Diamond, A., & Goldman-Rakic, P. S. (1983). Comparison of performance on a Piagetian object permanence task in human infants and rhesus monkeys: Evidence for involvement of the prefrontal cortex. Society for Neuroscience Abstracts, 9, 641.

Diamond, A., & Goldman-Rakic, P. S. (1985). Evidence that maturation of the frontal cortex underlies behavioral changes during the first year of life: 1. The A not B task. 2. Object retrieval. Society for Research in Child Development Abstracts, 5, 85.

Diamond, A., & Goldman-Rakic, P. S. (1986). Comparative development in human infants and infants rhesus monkeys of cognitive functions that depend on prefrontal cortex. Neuroscience Abstracts, 12, 742.

Diamond, A., & Goldman-Rakic, P. S. (1989). Comparison of human infants and rhesus monkeys on Piaget's A not B task: Evidence for dependence on the dorsolateral prefrontal cortex. Experimental Brain Research, 74, 24-40.

Doré, F. Y., & Dumas, C. (1987). Psychology of animal cognition: Piagetian studies. Psychological Bulletin, 102, 219-233.

Dumas, C. (1985). Sensorimotor and object permanence development in domestic cats. Unpublished doctoral dissertation, Laval University, Quebec, Canada.

Dumas, C., & Doré, F. Y. (1985, October). Cross-sectional and longitudinal studies of object permanence in domestic cats. Paper presented at the annual meeting of the Quebec Society for Research in Psychology, Montreal, Quebec, Canada.

Etienne, A. S. (1973). Searching behavior towards a disappearing prey in the domestic chick as affected by preliminary experience. Animal Behavior, 21, 749-761.

Fantz, R. L., & Fagan, J. F. (1975). Visual attention to size and number of pattern details by term and preterm infants during the first six months. Child Development, 46, 3-18.

Fantz, R. L., & Nevis, S. (1967). Pattern preferences and perceptual-cognitive development in early infancy. Merrill-Palmer Quarterly, 13, 77-108.

Field, J. (1975, May). The adjustment of reaching behavior to object distance in early infancy. Paper presented at the Second Experimental Psychology Conference, Sydney.

Flechsig, P. (1896). Gehirn und seele. Leipzig: von Veit.

Flechsig, P. (1920). Anotomie des menschlichen und rückenmarks auf myelogenetischer grundlage. Leipzig: Thieme.

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. Trends in Neurosciences, 15, 20-25.

Goodale, M. A., Milner, A. D., Jakobson, L. S., & Carey, D. P. (1991). A neurological dissociation between perceiving objects and grasping them. Nature, 349, 154-156.

Granrud, C. E. (1987). Size constancy in newborn human infants. Investigative Ophthalmology and Visual Science, 28, (Supplement), 5.

Granrud, C. E., Haake, R. J., and Yonas, A. (1985). Infants' sensitivity to familiar size: The effect of memory on spatial perception. Perception and Psychophysics, 37, 459-466.

Gratch, G. (1975). Recent studies based on Piaget's view of object concept development. In L. B. Cohen & P. Salapatek (Eds.), Infant perception: From sensation to cognition (Vol. 2, pp. 51-99). New York: Academic Press.

Gratch, G. (1977). Review of Piagetian infancy research: Object concept development. In W. F. Overton & J. M. Gallagher (Eds.), Knowledge and development: Advances in research and theory (Vol. 1, pp. 59-91). New York: Plenum Press.

Gratch, G. (1982). Responses to hidden persons and things by 5-, 9-, and 16-month-old infants in a visual tracking situation. Developmental Psychology, 18, 232-237.

Gruber, H. E., Girgus, J. S., Banuazizi, A. (1971). The development of object permanence in the cat. Developmental Psychology, 4, 9-15.

Hagger, C., Bachevalier, J., Macko, K., Kennedy, C., Sokoloff, L., & Mishkin, M. (1988). Functional maturation of inferior temporal cortex in infant rhesus monkeys. Society for Neuroscience Abstracts, 14, 2.

Harris, P. L. (1987). The development of search. In P. Salapatek & L. B. Cohen (Eds.), Handbook of infant perception (Vol. 2, pp. 155-208). New York: Academic Press.

Hirsch, E. (1982). The concept of identity. Oxford University Press, New York.

Lawson, K. R., & Ruff, H. A. (1984). Infants' visual following: Effects of size and sound. Developmental Psychology, 20, 427-434.

LeCompte, G. K., & Gratch, G. (1972). Violation of a rule as a method of diagnosing infants' levels of object concept. Child Development, 43, 385-396.

Lockman, J. J, & Ashmead, D. H. (1983). Asynchronies in the development of manual behavior. In L. P. Lipsitt (Ed.), Advances in infancy research (Vol. 2, pp. 113-136). Norwood, NJ: Ablex.

Macnamara, J. (1987). A border dispute: The place of logic in psychology. Cambridge, MA: MIT Press.

Mandler, J. M. (1988). How to build a baby: On the development of an accessible representational system. Cognitive Development, 3, 113-136.

Mandler, J. M., & Bauer, P. J. (1988). The cradle of categorization: Is the basic level basic? Cognitive Development, 3, 247-264.

Mandler, J. M., Bauer, P. J., & McDonough L. (1991). Separating the sheep from the goats: Differentiating global categories. Cognitive Psychology, 23, 263-298.

Mandler, J. M., Fivush, R., & Reznick, J. S. (1987). The development of conceptual categories. Cognitive Development, 2, 339-354.

Mathieu, M. (1983). Object permanence. Unpublished manuscript.

Mathieu, M., Bouchard, M. A., Granger, L., & Herscovitch, J. (1976). Piagetian object-permanence in *Cebus capucinus*, *Lagothrica flavicauda* and *Pan troglodytes*. Animal Behavior, 24, 585-588.

Mayer, D. L., & Dobson, V. (1982). Visual acuity development in infants young children, as assessed by operant preferential looking. Vision Research, 22, 1141-1151.

McKenzie, B. E. (1972). Visual discrimination in early infancy. Unpublished doctoral dissertation, Monash University.

McKenzie, B. E., & Day, R. H. (1972). Object distance as a determinant of visual fixation in early infancy. Science, 178, 1108-1110.

McKenzie, B. E., & Day, R. H. (1976). Infants' attention to stationary and moving objects at different distances. Australian Journal of Psychology, 28, 45-51.

McKenzie, B. E., Tootell, H. E., & Day, R. H. (1980). Development of visual size constancy during the first year of human infancy. Developmental Psychology, 16, 163-174.

Meicler, M., & Gratch, G. (1980). Do 5-month-olds show object conception in Piaget's sense? Infant Behavior and Development, 3, 265-282.

Miranda, J. B., & Fantz, R. L. (1971). Distribution of visual attention of newborn infants among patterns varying in size and number of details. Proceedings of the American Psychological Association, Washington, D. C.

Mishkin, M., Ungerleider, L. G., & Macko, K. A. (1983). Object vision and spatial vision: two cortical pathways. Trends in Neurosciences, 71, 414-417.

Misumi, J. (1951). Experimental studies of the development of visual constancy in early infancy. Bulletin of the Faculty of Literature, Kyushu University, 1, 91-116.

Moscovitch, M. (1982). Multiple dissociations of function in amnesia. In L. S. Cermak (Ed.), Human memory and amnesia (pp. 337-378). Hillsdale, NJ: Erlbaum.

Muller, A. A., & Aslin, R. N. (1978). Visual tracking as an index of the object concept. Infant Behavior and Development, 1, 309-319.

Náñez, J. E. (1988). Perception of impending collision in 3- to 6-week-old human infants. Infant Behavior and Development, 11, 447-463.

Norcia, A. M., & Tyler, C. W. (1985). Spatial frequency sweep VEP: Visual acuity during the first year of life. Vision Research, 25, 1399-1408.

Olsen, G., & Sherman, T. (1983). Attention, learning, and memory in infants. In P. H. Mussen (Ed.), Handbook of Child Psychology (4th ed). NY: Wiley.

Parker, S. T. (1977). Piaget's sensorimotor series in an infant macaque: A model for comparing unstereotyped behavior and intelligence in human and nonhuman primates. In S. Chevalier-Skolnikoff & F. E. Poirier (Eds.), Primate bio-social development: Biological, social, and ecological determinants (pp. 43-112). New York: Garland.

Parkinson, J., Murray, M., & Mishkin, M. (1988). A selective mnemonic role for the hippocampus in monkeys: Memory for the location of object. The Journal of Neuroscience, 8, 4159-4167.

Piaget, J. (1952). The origins of intelligence in children. New York: International University Press.

Piaget, J. (1954). The construction of reality in the child. New York: Basic Books.

Piaget, J., & Inhelder, B. (1969). Psychology of the child. New York: Basic Books.

Pinker, S. (1984). Language learnability and language development. Cambridge, MA: Harvard University Press.

Quinn, P. C., Eimas, P. D., & Rosenkrantz, S. L. (1993). Evidence for representations of perceptually similar natural categories by 3-month-old and 4-month-old infants. Perception, 22, 463-475.

Rabinowitz, T. (1967). Quantitative appraisal of the cerebral cortex of the premature infant of 8 months. In A. Minkowski (Ed.), Regional development of the brain early in life. Oxford: Blackwell Scientific Publications.

Redshaw, M. (1978). Cognitive development in human and gorilla infants. Journal of Human Evolution, 7, 133-141.

Roberts, K., & Horowitz, F. D. (1986). Basic level categorization in seven- and nine-month-old infants. Journal of Child Language, 13, 191-208.

Rodman, H., Skelly, J., & Gross, C. (1991). Stimulus selectivity and state dependence of activity in inferior temporal cortex of infant monkeys. Proceedings from the National Academy of Sciences, 88, 7572-7575.

Ross, G. S. (1980). Categorization in 1- to 2-year-olds. Developmental Psychology, 16, 391-396.

Rosser, R. A., Narter, D. B. (1997). Infants' differentiation of physical entities on the basis of ontological kind: Objects and aggregates. Manuscript in preparation.

Rosser, R. A., Narter, D. B., & Paullette, K. M. (1995, April). Ontological kind, object identity, and infants' sensitivity to violations of the continuity constraint. Poster presented at the meeting of the Society for Research in Child Development, Indianapolis, IN.

Rosser, R. A., Narter, D. B., & VanWyhe, R. (1996). Infants' sensitivity to changes in ontological kind. Infant Behavior and Development, 19, 717.

Rovee-Collier, C. K., & Hayne, H. (1987). Reactivation of infant memory: Implications for cognitive development. In H. W. Reese (Ed.), Advances in child development and behavior (Vol. 20, pp. 185-219). New York: Academic Press.

Ruff, H. A., & Turkewitz, G. (1979). Changing role of stimulus intensity as a determinant of infants' attention. Perceptual and Motor Skills, 48, 815-826.

Schacter, D. L., Moscovitch, M., Tulving, E., McLachlan, D. R., & Freedman, M. (1986). Mnemonic precedence in amnesic patients: An analog of the A not B error in infants? Child Development, 57, 816-823.

Schiff, W. (1965). Perception of impending collision: A study of visually directed avoidant behavior. Psychological Monographs: General and Applied, 79, 1-26.

Schiff, W., Caviness, J. A., & Gibson, J. J. (1962). Persistent fear responses in rhesus monkeys to the optical stimulus of "looming". Science, 136, 982-983.

Schuberth, R. E. (1983). The infant's search for objects: Alternatives to Piaget's theory of the concept development. In L. P. Lipsitt (Ed.), Advances in infancy research (Vol. 2, pp. 137-182). Norwood, NJ: Ablex.

Slater, A., Mattock, A., & Brown, E. (1990). Size constancy at birth: Newborn infants' responses to retinal and real size. Journal of Experimental Child Psychology, 49, 314-322.

Sophian, C. (1985). Perseveration and infants' search: A comparison of two- and three-location tasks. Developmental Psychology, 21, 187-194.

Spelke, E. S. (1985). Perception of unity, persistence, and identity: Thoughts on Infants' conception of objects. In J. Mehler & R. Fox (Eds.), Neonate cognition: Beyond the blooming buzzing confusion. Hillsdale, NJ: Erlbaum.

Spelke, E. S. (1988). The origins of physical knowledge. In L. Weiskrantz (Ed.), Thought without language (pp. 168-184). Oxford, England: Clarendon Press.

Spelke, E. S. (1990). Principles of object perception. Cognitive Science, 14, 29-56.

Spelke, E. S., & Kestenbaum, R. (1986). Les origines du concept d'objet. Psychologie Francaise, 31, 67-72.

Squire, L. R., & Zola-Morgan, S. (1983). The neurobiology of memory: The case for correspondence between the findings for human and nonhuman primates. In J. A. Deutsch (Ed.), The physiological basis of memory (pp. 200-268). New York: Academic Press.

Triana, E., & Pasnak, R. (1981). Object permanence in cats and dogs. Animal Learning and Behavior, 9, 135-139.

Uzgiris, I. C. (1973). Patterns of cognitive development in infancy. Merrill-Palmer Quarterly, 19, 181-204.

Ungerleider, L., & Mishkin, M. (1982). Two cortical visual systems. In D. J. Ingle, M. A. Goodale, & R. J. W. Mansfield (Eds.). Analysis of visual behavior. Cambridge: MIT Press.

Vaughter, R. M., Smotherman, W., & Ordy, J. M. (1972). Development of object permanence in the infant squirrel monkey. Developmental Psychology, 7, 34-38.

Volkmann, F. C., & Dobson, M. V. (1976). Infant responses of ocular fixation of moving visual stimuli. Journal of Experimental Child Psychology, 22, 86-99.

Walk, R. D. (1966). The development of depth perception in animals and human infants. Monographs of the Society for Research in Child Development, 31, 82-108.

Wilcox, T. (1997, April). 4.5- and 7.5-month-old infants' use of shape, color, and size when reasoning about object identity. Poster presented at the biennial meeting of the Society for Research in Child Development, Washington, DC.

Wilcox, T., & Baillargeon, R. (1996a, April). Infants' reasoning about object identity in moving events with static endpoints: The nature of the mapping problem. Infant Behavior and Development, 19, 820.

Wilcox, T., & Baillargeon, R. (1996b, April). Infants' use of featural information in reasoning about object identity: Reconciling contradictory results. Infant Behavior and Development, 19, 821.

Wilcox, T., & Baillargeon, R. (1997). Object individuation in infancy: The use of featural information in reasoning about occlusion events. Manuscript submitted for publication.

Wilcox, T., & Nadel, L. (1993, March). Location memory in infants 2.5-6.5 months of age. Poster presented at the meeting of the Society for Research in Child Development, New Orleans, LA.

Wilcox, T., Nadel, L., & Rosser, R. (1996). Location memory in healthy preterm and full-term infants. Infant Behavior and Development, 19, 309-323.

Wilcox, T., Rosser, R., & Nadel, L. (1994). Representation of object location in 6.5-month-old infants. Cognitive Development, 9, 193-209.

Wise, K. L., Wise, L. A., & Zimmerman, R. R. (1974). Piagetian object permanence in the infant rhesus monkey. Developmental Psychology, 10, 429-437.

Wood, S., Moriarity, K. M., Gardner, B. T., & Gardner, R. A. (1980). Object permanence in child and chimpanzee. Animal Learning and Behavior, 8, 3-9.

Yonas, A., Bechtold, A. G., Frankel, D., Gordon, F. R., McRoberts, G., Norcia, A., & Sternfels, S. (1977). Development of sensitivity to information for impending collision. Perception and Psychophysics, 21, 97-104.

Yonas, A., Pettersen, L., & Lockman, J. J. (1979). Young infants' sensitivity to optical information for collision. Canadian Journal of Psychology, 33, 268-276.

Xu, F., & Carey, S. (1996). Infants' metaphysics: The case of numerical identity. Cognitive Psychology, 30, 111-153.

Xu, F., Carey, S., Raphaelidis, K., & Ginzbursky, A. (1996). Twelve-month-old infants represent sortal concepts more specific than object: Further evidence from reaching. Infant Behavior and Development, 19, 832.