Means-end Search for Hidden Objects by 6.5-month-old

Infants: Examination of an Experiential Limitation Hypothesis

by

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Author's Declaration for Electronic Submission of a Thesis

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Abstract

Three experiments were conducted to investigate the hypothesis that young infants' failures to search for occluded objects arises, not from deficiencies in their object representations, but from limitations in experience with the physical world. Successful means-end search is typically found at 8 months of age and is traditionally taken as the hallmark of object permanence. However, recent evidence suggests that infants much younger than 8 months of age are able to represent and reason about objects that are no longer visible. In Experiment 1, successful means-end search was found for 8.5-, but not 6.5-month-old infants in a traditional task, but younger infants showed successful search ability when the task was made familiar to them in Experiment 2 (i.e., when the toy and occluder are first presented as a single composite object), and when they were given the opportunity to watch a demonstration of the solution to the task in Experiment 3. These results are taken as evidence for the 'experiential limitation' hypothesis and suggest that young infants are more apt at solving manual search tasks than previously acknowledged.

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Dedication

To my son Jake, never let others stop you from realizing your dreams.

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INTRODUCTION

In the study of infant cognition, an important and unresolved issue concerns the fact that infants younger than 8 months of age typically fail to search for objects when hidden by an occluder. The ability to search for occluded objects has traditionally been taken as a hallmark of object permanence, a developmental landmark in infants' ability to maintain a representation of an object when the object is not visually present. However, failures to search for occluded objects may not always be caused by deficient representations, and over the past 50 years there has been little agreement about the possible reasons for such failures, and thus, over the validity of the claim that infants younger than 8 months of age do not possess an understanding of object permanence (e.g., Piaget, 1954).

Jean Piaget (1954) was the first researcher to investigate this issue, and he believed that infants do not hold a complete understanding of object permanence until 18 to 24 months of age. In fact, Piaget suggested that a rudimentary understanding of object permanence only emerges at 8 to 9 months of age and that it is not until this age that infants understand the basic principle that objects continue to exist in the physical world even though they may not be visually present. Piaget based this conclusion on his quasi-experimental examination of how infants searched for hidden objects. In his tasks, a toy was hidden behind a screen (i.e., an occluder) and infants were given the opportunity to search for it. Using these 'means-end' search tasks, Piaget found that infants younger than 8 months of age made no attempt to grasp and remove the occluder (i.e., the means) to retrieve the toy (i.e., the desired end), or did so for reasons other than retrieving the toy, such as to play with the occluder. He concluded that infants younger than 8 months of age failed at this task because they were unable to represent the object once it was no longer visible. These classic observations of young infants' performance in means-end search tasks are robust, having been replicated numerous times over the years (e.g., Bower & Wishart, 1972; Diamond, 1993; Gratch & Landers, 1971; Uzgiris, 1973; Willatts, 1984) and the conclusion that infants younger than 8 months of age do not understand object permanence is currently accepted by many researchers (e.g., Bogartz, Shinskey, & Speaker, 1997; Haith, 1998; Meltzoff & Moore, 1998; Shinskey, Bogartz, & Poirier, 2000).

Other contemporary researchers, however, have suggested that the traditional means-end search task is too conservative as a measure of infants' understanding of the continued existence of occluded objects (e.g., Baillargeon, 1987; Spelke, Breinlinger, Macomber, & Jacobson, 1992), primarily because such a measure is heavily dependent on infants' motor abilities. Indeed, the results of recent research, utilizing methods that are not constrained by the motoric demands of a typical means-end search task, suggest that infants much younger than 8 months of age are able to represent and reason about objects that are no longer visible (e.g., Aguiar & Baillargeon, 1999; Baillargeon, 1987; Baillargeon & Graber, 1987; Baillargeon, Spelke, & Wasserman, 1985; Spelke, 1991; Wilcox, Nadel, & Rosser, 1996; Wynn, 1992, 2000).

Baillargeon (1987), for example, compared infants' reactions to an expected versus an unexpected event to examine whether 4.5-month-old infants could represent an object that became temporarily hidden. In both events, a box was situated on the apparatus floor, and an occluder, originally lying flat at the base of the box, rotated backwards in the manner of a drawbridge, thereby occluding the box. In the expected event, the occluder stopped rotating when it reached the top of the box. In the unexpected event, the occluder rotated through a full 180-degree arc until it rested on the floor of the apparatus, thus appearing to have "passed through” the box. Baillargeon found that the infants looked at the unexpected event reliably longer than at the expected event. A control condition, in which the occluder rotated in the same manner as in the expected and unexpected events described above, with the exception that no box was present, produced equal looking times, suggesting that the infants did not simply prefer to look at the longer occluder-rotation. Baillargeon took these results as evidence that the infants were surprised when their expectation had been violated in the unexpected event (i.e., that the occluder did not stop rotating when it reached the box), and that this indicated that the 4.5-month-old infants must have represented the existence of the box when it was behind the occluder in order to generate this expectation.

More recently, Aguiar and Baillargeon (1999) examined whether infants as young as 2.5 months of age were able to determine whether an object should remain hidden, or become temporarily visible, as it passed behind different occluders. As in Baillargeon’s (1987) previous studies, infants viewed both an expected and an unexpected event. In the expected event, infants watched a toy mouse move across the floor of an apparatus and pass behind a occluder. The occluder had a central window extending down from its upper edge, but the toy mouse was shorter than the window’s lower edge and was thus never visible when it passed behind the occluder. The unexpected event was similar to the expected event, except that there were two separate occluders positioned a few inches apart from each other on the apparatus floor. In this event, the toy mouse moved and disappeared behind the first occluder and reappeared from behind the second occluder, but without appearing in the space between the occluders. Aguiar and Baillargeon (1999) found that 2.5-month-old infants looked significantly longer at this unexpected event than at the expected event, suggesting that the infants were surprised when the toy mouse did not appear in the gap between the two occluders. This finding was therefore taken as evidence that the 2.5-month-old infants were able to represent the presence and trajectory of the toy mouse even when it was not visible. The ‘trick’ in the unexpected condition was that the experimenter was actually using two mice; one that initially moved behind the first occluder and another that moved out from behind the second occluder. Thus, the fact that there was no difference in infants’ looking times between the two conditions when the occluders were first lowered in a control condition to reveal two mice, one behind each of the two occluders (‘unexpected’ control) or one behind each edge of the single occluder (‘expected’ control), suggests that preferential looking in the unexpected condition did not occur when information to explain why the toy mouse passed behind the two occluders without appearing in the gap is readily available. The results of the control condition also provided converging evidence that the 2.5-month-old infants looked longer at the unexpected event, not because they had a preference for two separate occluders, but rather because they had expected the toy mouse to appear between the two occluders.

Findings from experiments such as the rotating-occluder (Baillargeon, 1997) and the toy mouse experiments (Aguiar & Baillargeon, 1999) suggest that infants much younger than 8 months of age are able to represent hidden objects. Such evidence underscores the need to understand why such infants fail to search for a hidden object in Piaget’s (1954) traditional means-end search task. The extant literature provides three prevailing explanations for such means-end search task failures: biological immaturity (e.g., Diamond, 1991), lack of understanding of causal relationships (e.g., Willatts, 1984), and limitations in representational quality (e.g., Munakata, et al., 1997). In contrast to these, the results of the research I report here suggest an alternative explanation that is based on infants’ experiential limitations. To understand the rationale for the experiential limitation hypothesis, and the predictions that follow from it, it is useful to first consider the three prevailing explanations.

Biological immaturity: Motor deficits

The motor skills that are necessary for successfully completing a means-end search task include the ability to reach for, grasp, and manipulate an object. Infants are able to reach and grasp for objects by 3 or 4 months of age (Spencer & Thelen, 2000). Several studies have shown that infants, well before 6 months of age, use visually guided reaches to grasp objects (e.g., von Hofsten, 1979; Robin, Berthier, & Clifton, 1996). As a specific example, it has been shown that infants are able to adjust their reach by 4 months of age to contact moving objects (von Hofsten & Lindhagen, 1979). Furthermore, 5-month-old infants have been shown to successfully reach and contact stationary objects with and without the use of vision (i.e., in the dark; McCarty & Ashmead, 1999).

Infants are typically able to master fine finger movements, such as a pincer grasp used to pick up and manipulate tiny objects, by their first birthday. Precise manual behaviours such as these are present at 6 months and continue to be refined until 12 months of age (von Hofsten, 1993). However, even infants that are only 3-4 months of age are able to grasp and manipulate objects, they simply use less precise finger movements. Young infants tend to explore an object with one hand while holding on to the object with the other hand (Rochat, 1989). Taken together, the existing evidence regarding motor development suggests that infants have the basic motor skills necessary for solving a means-end search task well before 8 months of age.

Although infants younger than 8 months of age may possess each of the basic motor skills necessary for solving a means-end search task, Diamond (1993) suggests that the immaturity of the prefrontal cortex (PFC) in infants younger than 7 months of age may prevent them from organizing their basic motor skills into effective sequences. According to Diamond, the apparent paradox created by infants' failure at solving a means-end search task, but success at visual attention tasks, may be explained by the fact that reaching to remove an occluder to reveal a desired object is more complicated than the response needed in a visual attention task (i.e., where infants only need to look toward an object). According to this view, infants between 5 and 7 months of age understand the concept that an object continues to exist when hidden, but are unable to demonstrate this understanding in means-end search tasks because the lack of maturation of the supplementary motor area of the PFC yields imperfect sequencing of arm and hand movements. Indeed, it has been shown that infants who are successful at an object retrieval task show an increase in Electroencephalogram (EEG) activity in the prefrontal cortex not observed among infants who are unsuccessful at the same task (Bell & Fox, 1997). Diamond and others argue that such dissociations between action and knowledge systems are produced by neurologically and psychologically distinct networks (Diamond, 1991, 1993, 2000; Goodale & Milner, 1992). Accordingly, knowledge systems may be fully functional, while action systems remain underdeveloped or impaired.

Brain lesion studies involving both human adults and primates provide converging evidence for Diamond's (1993) biological immaturity explanation, with lesions in the supplementary motor area producing difficulty in sequencing two motor skills needed to obtain a desired object, and causing errors in aiming reaches in monkeys and humans; individuals become "stuck" on the initial action in the behavioral sequence. A monkey with PFC damage, for example, may attempt to reach around a barrier to obtain an object, and will continue to reach instead of halting their action at the barrier. By continuing with the first action and failing to switch to the second action, the animal ultimately reaches beyond the desired object. Diamond (1991) suggests that such behavior parallels that of 5- to 7-month-old infants attempting to solve manual search tasks. Lack of maturity in the supplementary motor area of infants at this age may thus yield similar difficulty in sequencing motor skills needed in manual search tasks. By 7 to 9 months of age, maturation of the PFC has progressed to the point of allowing for proper organization of movements so that infants are able to sequence the actions necessary to succeed at a manual search task.

Means-end Reasoning

Willatts (1984) proposes a similar explanation, with the addendum that infants younger than 8 months of age do not search for hidden objects and are unable to perform means-end action sequences because they are unable to reason about *causal* sequences. In this regard, his argument that: "infants' difficulty at producing a means-end sequence derives from their lack of knowledge of the appropriate actions for efficiently solving the problem" (p. 666, Willatts, 1997) parallels Piaget. Indeed, some of Piaget's observations support this view; for example, his report that young infants' inability to retrieve objects was not limited to situations in which the object was hidden, but extended to other situations in which the desired object was in full view. Piaget found that infants younger than 8 months of age made no attempt to pull a cloth to bring a toy within reach when it was placed beyond reach on the far end of a cloth. Such failures by young infants' in such tasks have thus been taken as evidence that infants younger than 8 months of age lack an understanding of causal relationships. Specifically, infants do not understand that a means-end action sequence, such as pulling the cloth (the means), would cause the toy to move within their reach (the end). Infants' demonstrated ability to reach for objects concealed only by darkness appears to support this conclusion (Bower & Wishart, 1972; Clifton, Rochat, Litovsky, & Perris, 1991; Hood & Willatts, 1986). Reaching for an object in the dark only requires a one-step direct reach, whereas reaching in a search task for an object occluded by a barrier, rather than darkness, requires a two-step means-end sequence (i.e., first reaching for and removing an occluder before reaching for the object).

However, research using the violation-of-expectation paradigm suggests that infants much younger than 8 months of age are able to recognize appropriate means-end sequences. Baillargeon, Graber, DeVos, and Black (1990), for example, demonstrated a means-end sequence to 5.5-month-old infants in both an expected and an unexpected visual event. In the expected event, the means-end action sequence that infants were shown was a sequence of events that were probable in the physical world. A toy bear was first placed on the left side of a cup. An occluder was then brought up which occluded the toy and cup. Finally, a hand reached behind the occluder from the right and retrieved the toy. The unexpected event was similar to the expected event, except that the infants were shown an impossible means-end sequence. In this event, the toy was placed under the cup, the occluder was brought up, and a hand reached directly behind the occluder and retrieved the toy, without first appearing to lift or remove the cup. The hand action in this event was identical to the hand action in the expected event, and yet the 5.5-month-old infants looked reliably longer at the unexpected event than the expected event. Baillargeon and colleagues took this finding as evidence that these infants were aware that a sole direct reach in the unexpected event was insufficient to retrieve the toy, suggesting that infants younger than 8 months of age are indeed able to recognize appropriate means-end sequences. These results suggest that infants do understand what action sequences are necessary for retrieving an occluded object. Why then are they not implementing this knowledge in order to search for hidden objects?

Representational Deficits

The theory that infants' ability to successfully search for a hidden objects is related to the strength of the representation the infants holds for the object when it is no longer visible (e.g., Munakata, 1997) stands in contrast to that put forth by Diamond (1991). Diamond (1991) explains the seemingly contrary findings of young infants' apparent memory for hidden objects in visual and manual search tasks not in terms of representational strength, but as being due to dissociations between action and thoughts. That is, young infants are able to hold hidden objects in memory, but the systems for acting on such representations are not yet developed before 8 months of age (Baillargeon, et al., 1990, Diamond, 1991; Bell & Fox, 1997).

In contrast, Munakata et al. (1997) has argued that young infants fail at manual search tasks because, once the object is no longer in view, infants' representation of the hidden object weakens. According to this account, infants' representation of the object loses its intensity over time and becomes degraded. Infants' representations of hidden objects become stronger with maturation. Failure in manual search tasks is, by this account, due to weak representations of the hidden objects that would allow infants to recognize an unexpected event in a visual task, but would not suffice in directing the reach for the hidden objects. This graded representation account offers an explanation of findings that show young infants between 5 and 7 months of age are successful at searching for a toy hidden by darkness (Clifton, Perris, & Bullinger, 1991). Such results have been explained as infants' fragile representations of hidden objects can withstand the darkness of a room, but not the direct interference from an occluder in traditional search tasks (Munakata et al., 1997; Shinskey & Munakata, 2003).

Experiential Limitation Hypothesis

Given the evidence that infants are sensitive to hidden objects long before 8 months of age, it remains unclear why they have difficulty searching for objects hidden by occluders. Violation-of-expectation experiments, such as the rotating occluder (Baillargeon, 1987), the toy mouse experiment (Aguiar & Baillargeon, 1999), and the toy bear experiment (Baillargeon et al., 1990), indicate that infants younger than 8 months of age possess the conceptual knowledge necessary to solve means-end search tasks, that they are able to represent hidden objects, and are able to understand what action sequences are appropriate to solve means-end tasks. Despite this, infants at this young age fail at traditional search tasks. I address this issue in the present studies and propose that the discrepancy between the negative findings obtained by Piaget in the means-end search task and the positive findings found in the violation-of expectation experiments (e.g., Aguiar & Baillargeon, 1999; Baillargeon, 1987; Baillargeon et al., 1990), are due to infants' *experiential limitations*. According to this experiential limitation hypothesis, young infants fail to search because such tasks require acting on one object as a means to achieve a goal involving another object, and young infants simply have little experience with such tasks. Because infants younger than 8 months of age are unfamiliar with problems involving acting on one object as a means to retrieve a second object, the solution to such problems does not spontaneously occur to them. The experiential limitation hypothesis differs from Piaget's work in an important way; namely, that search behavior is an index of infants' ability to use one object as a means of achieving a goal involving a second object, not just an index of infants' understanding about the permanence of occluded objects (see also, Baillargeon, 1993).

The primary assumption of this hypothesis is that infants younger than 8 months have limited, if any, experience dealing with two objects. This assumption is supported by research described in the object manipulation and play literatures. For example, that infants have a tendency to explore only one object, manually or orally, until 7 to 8 months of age, and only after this age does activity with one object decrease to be replaced by activity in which two objects are manipulated simultaneously (e.g., Fenson, Kagan, Kearsley, & Zelzo, 1976; McCall, 1974). Even then, infants initially appear to put objects together in an unrelated manner (e.g., banging two random and unrelated toys), failing to combine objects in a related manner (e.g., putting a ball into a cup) until approximately 9 months of age (Belskey & Most, 1981). Moreover, it is not until 7 or 8 months of age that infants become independently mobile and begin crawling or creeping. Such independence affords more opportunity for exploration of their physical world and corresponds to the age when infants are able to solve means-end search tasks.

The experiential limitation hypothesis suggests that young infants faced with a means-end search task are in the same position as children and adults who fail to solve a problem for which they possess the conceptual knowledge, but for which they have no previous experience solving. In this situation, children and adults often benefit if the novel problem is made familiar to them (e.g., Brown, Kane, & Long, 1989; Gick & Holyoak, 1983), or if they are given a demonstration of the solution (e.g., Brown, 1990; Meltzoff, 1995). Indeed, the research reported here is an extension to search tasks of one previous set of studies conducted by Aguiar, Menard, Kolstad, and Baillargeon (2001) who demonstrated that 6.5-month-old infants may succeed in means-end *support* tasks (i.e., using a cloth to bring a toy, sitting on the far end of the cloth, within reach) if the task is first made familiar to them, or if they are first given a demonstration of the solution. That is, young infants' performance in such tasks is facilitated when they are able to overcome their experiential limitations.

In Aguiar and her colleague's (2001) first experiment, the means-end support tasks were videotaped. The experimenter drew the infant's attention to a toy and a cloth, placed the cloth flat on the table, near end within the infant's reach, and then placed the toy on the far end of the cloth. Infants were given a total of four such tasks and two independent coders categorized each infant's behavior on each task as exhibiting either a *means-end* solution (i.e., the infant pulled the cloth as a means to obtain the toy) or a *non-means-end* solution (i.e., the infant clearly did not pull the cloth as a means to obtain the toy). It was found that the 8-, but not the 6.5-month-old infants, pulled the cloth as a means to attain the toy, thereby replicating Piaget's (1952) original observations. The behavioral coding confirmed that the 8-month-old infants produced significantly more means-end solutions to the problem than the 6.5-month-old infants. Detailed frame-by-frame analyses of the test trials also revealed that those infants exhibiting means-end solutions were significantly faster at attaining the toy, spent significantly more time focused on the toy (as opposed to the cloth or the experimental room), and engaged in more behaviors relevant to retrieving the toy than infants exhibiting non-means-end solutions.

In a second experiment, Aguiar and her colleagues (2001) examined whether 6.5-month-old infants would reliably pull a cloth to bring a toy within reach if the problem was transformed into a familiar one. This experiment was similar to the first experiment, except that the infants were first shown that the toy and the cloth were *attached* to each other. That is, at the start of the experiment and before each test trial, the experimenter held the toy up so that infants could see the cloth dangling from it. Presumably, infants would thereafter view the toy and the attached cloth as a *single* composite object (i.e., a single object with two distinct parts). Because infants should have considerable means-end experience with composite objects (e.g., grasping a nursing bottle to bring the nipple to the mouth) by 6 months of age, they should have less difficulty in determining what action to perform with the composite object to retrieve the toy. Indeed, the results supported this hypothesis, showing, in contrast to the first experiment, that the 6.5-month-old infants produced significantly more means-end than non-means-end solutions to the support problem.

In a third experiment, Aguiar and her colleagues (2001) found that 6.5-month-old infants were also successful at pulling a cloth to attain a distant toy when first given the opportunity to watch an experimenter demonstrate the solution to the problem. In this study, the experimenter placed the toy on the far end of the cloth and then demonstrated the action sequence of pulling the cloth and then grasping the toy once it was within reach. Importantly, 6.5-month-old infants were *not* successful at retrieving the toy when the experimenter placed the toy next to her, rather than on the cloth, before demonstrating the action sequence of pulling the cloth and grasping the toy. In this control condition, the action of pulling the cloth was no longer a means to retrieve the toy. Taken together, these findings suggest that the 6.5-month-old infants succeeded after seeing the experimenter solve the means-end support task, not because they simply imitated the experimenter's actions, but rather, because they interpreted these actions as a means to retrieve the toy. When young infants are able to link a problem to previous experience or acquire experience through a familiarization process they may overcome experiential limitations and succeed in means-end support tasks. If this is the case, then overcoming experiential limitations may also be the key for young infants to succeed in traditional means-end *search* tasks.

The primary goal of the three experiments reported here was to examine and provide an empirical test of the experiential limitation hypothesis with respect to means-end search tasks. Experiment 1 was designed to validate the basic paradigm by examining whether 8.5-, but not 6.5-month-old infants, are able to solve a traditional means-end search task. Experiment 2 examined whether 6.5-month-old infants are more likely to search for a hidden toy when the task is made familiar to them (i.e., the toy and occluder are first presented as a single composite object). Experiment 3 examined whether 6.5-month-old infants are able to solve a traditional means-end search task after being given the opportunity to watch an experimenter demonstrate the solution to the task.

A secondary goal of the present research is to provide a more detailed analysis of infants' behavior in means-end search tasks. Failure to solve such a problem does not necessarily mean that infants younger than 8 months are not able to act on the occluder. In fact, beginning at 6 months of age, infants often do act on the occluder, although their actions are typically not judged to be a means to an end (e.g., Willatts, 1984, 1989; Piaget 1954). Successful means-end solutions require that problem-solvers evaluate an initial problem and take action to reduce the difference between the problem and their ultimate goal (DeLoache, Miller, & Pierroutsakos, 1997). It is often difficult, given the absence of language in infants to determine whether the problem solvers' actions reflect behaviors that are intentionally directed at achieving the goal. Systematic analysis of behavior in means-end search tasks may, however, provide a basis from which intentionality can be inferred.

Piaget (1954) proposed three phases for the development of means-end search, culminating at approximately 9 months of age: (1) an initial phase in which the infant makes no attempt to search; (2) a transitional phase in which the infant removes the occluder but is unaware of the hidden object (i.e., fails to look at the object when it becomes visible or is surprised to find the object); and, (3) an intentional phase in which the infant is aware of the object and removes the occluder to find it. According to Piaget, these phases of search behavior reflect infants' developing understanding of object permanence. Specifically, intentional search behavior is indicative of an infant's recognition that an object continues to exist when hidden, whereas transitional or no search behavior is indicative of a deficiency in an infant's understanding of object permanence.

Piaget's (1954) phases of search behavior indicate that the manner in which the infants are searching may be used as a marker of a successful means-end solution. In particular, the work of Piaget, Willatts (1984, 1999), and Aguiar et al. (2002), therefore, suggest several behaviours that can be used as indicators of success means-end search. First, infants producing behaviors representing means-end searches should be more efficient at retrieving a hidden object. More efficient responses should thus translate into shorter delays to retrieve the toy, more visual focus on the occluder and the toy (as opposed to elsewhere in the experimental room), and more behaviours relevant to attaining the goal, such as reaching for, grasping and removing the occluder, as opposed to irrelevant behaviors such as banging the experimental table (e.g., Aguiar et al., 2001, Willatts, 1984, 1999). Second, infants producing means-end searches should anticipate the appearance of the object becoming visible once the occluder is removed. According to Piaget (1954) and Willatts (1984), such behavior is perhaps the most important indication of deliberate search. To measure infants' anticipation of the toy becoming visible the latency time between when the toy first becomes visible and the infant's first look at the toy can be examined. In contrast, infants producing behaviors representing non-means-end searches should be unaware of the consequences of pulling the occluder and thus should be more likely to focus on elements other than the location where the toy will become visible.

EXPERIMENT 1

The purpose of this experiment was to validate the procedures used in the subsequent experiments by replicating Piaget's original observations that only infants older than 8 months of age will search for an object once it is hidden behind an occluder. The resulting observations should also provide a basis to establish the behavioral characteristics of clearly successful means-end search solutions. According to Piaget (1954), 8.5-month-old infants should be aware of the location of the hidden object and remove the occluder for the purpose of retrieving the toy and thus produce behaviours representing means-end search. In contrast, 6.5-month-old infants should fail to remove the occluder, or else remove the occluder without being aware that it will reveal the toy, and thus produce behaviours representing non-means-end search. As such, reviewing infants' actions on the occluder should determine whether these actions represented a deliberate attempt to retrieve the toy (means-end search) or were produced for reasons other than retrieving the toy, such as playing with the occluder or accidentally bumping it (non-means-end search).

In this experiment, 8.5-month-old infants were predicted to be more deliberate, relative to the 6.5-month-old infants, in their actions of attaining a toy placed behind the occluder. The older infants should therefore produce more behaviors that represent means-end searches and have more test trials categorized as means-end than the younger infants. Furthermore, the efficiency of retrieving the hidden object should correspond to behaviours that represent means-end searches, such that infants that deliberately retrieve the toy should show shorter delays to get the toy, display more visual focus on the occluder and the toy, and have a higher proportion of behaviours that are relevant to attaining the goal, (i.e., reaching for, grasping and removing the occluder). Anticipation of the appearance of the object becoming visible once the occluder is removed should be reflected in shorter latencies between the point at which the toy first becomes visible and the point when the infant first looks at the toy.

Method

Participants

Thirty-one healthy term infants were tested and coded for Experiment 1; 16 8.5-month-old infants (8 male and 8 female), ranging in age from 253 to 272 days (M = 262.19, SD = 5.4) and 15 6.5-month-old infants (8 male and 7 female), ranging in age from 186 to 209 days (M = 195.8, SD = 7.4). An additional 6 infants were tested and eliminated from the experiment because they failed to complete four valid test trials: 4 due to lack of interest in the toy and 2 due to fussiness.

The names of the infants tested in this and the following experiments were obtained from birth announcements in a local newspaper. Parents were contacted by letter and follow-up phone calls. Parents were not compensated for their participation, but were given a certificate and a small toy for their infant.

Apparatus and Materials

The means-end search tasks were presented at a table with a light blue Formica top measuring 122 cm in width and 117 cm in length (see Figure 1). There was an opening along the front edge of the table, 34 cm deep and 30.5 cm wide into which the infant was placed. Parents held their infants on their lap while sitting on a desk chair with wheels and adjustable height. The toys used included a colorful plastic toy dog that was 10.5 cm wide, 3.5 cm thick, and 12 cm high, and a colorful plastic butterfly measuring 17.5 cm wide, 4 cm thick and14 cm high. The toy dog produced a barking and/or laughing sound when pressure was applied to a button on its front, and had a small bell tied around its neck that jingled when it was shaken. The toy butterfly had a transparent center containing a black and white ball that rattled when it

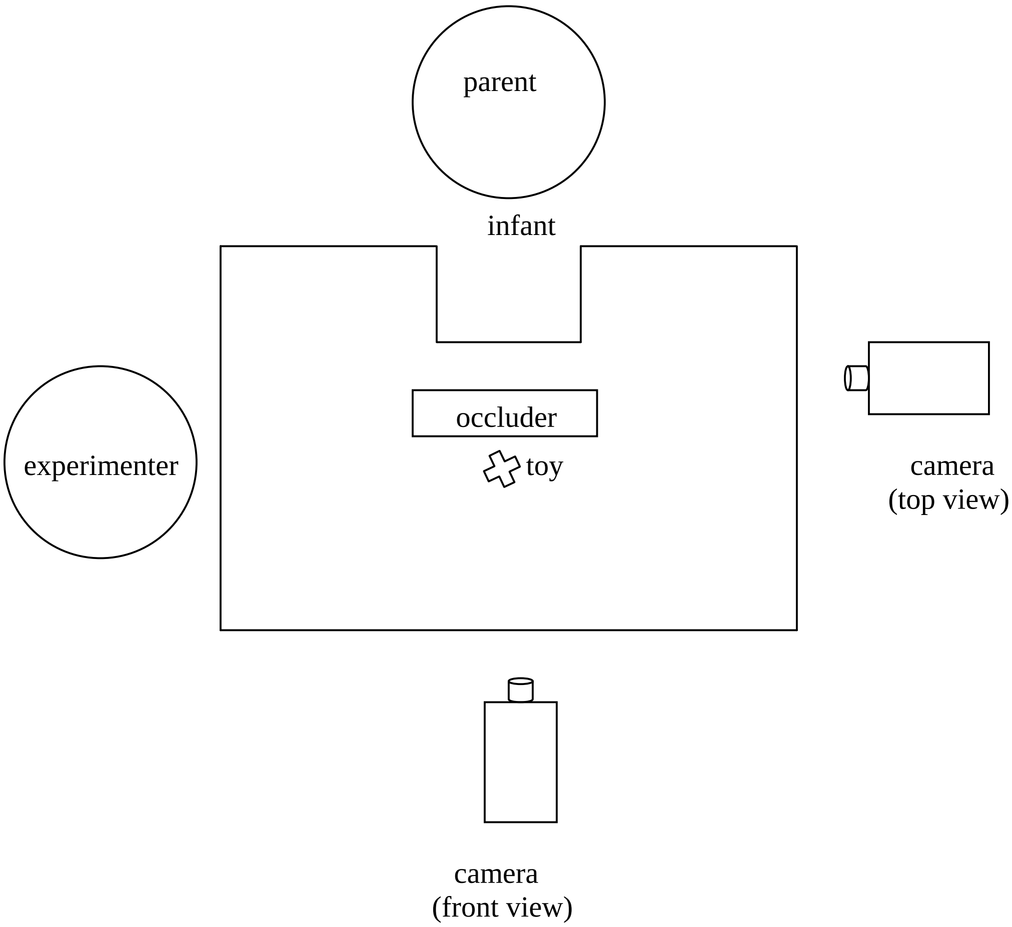

Figure 1. Depiction of experimental room set-up.

was shaken. To allow each toy to stand upright, they were mounted on a white rectangular plastic base measuring 8 cm wide, 10 cm deep and 0.6 cm thick.

A freestanding L-shaped occluder, 25 cm wide and 18 cm high, made of metal netting covered with grey felt cloth was used to occlude the toy during the experiment. The occluder had a horizontal rectangular base on one side, measuring 22.5 cm wide and 12 cm deep, on which the toy was placed during the experiment. On the side opposite to this base were three semi-circle handles made from grey felt cloth; one measuring 13 cm wide and 12 cm long was sewn to the top edge of the occluder, and the others, measuring 4 cm wide and 7 cm long, were sewn to each side of the occluder, 3 cm above its base. The handles were used to bring the occluder down and to turn it to reveal the toy that had been positioned its base.

Procedure

At the start of the testing session, parents were asked to roll their chair forward so that the infant sitting in their lap would face the front of the testing table, and be positioned in the table recess, surrounded by the table surface. Parents were instructed to neither interact with their infants, nor react to their infants' actions during the experiment. The majority of parents who participated complied with these instructions. In those instances in which parents interacted with their infants during the testing session, a gentle reminder from the experimenter was sufficient to gain compliance. The experimenter sat on a chair to the infant's right side. Each infant received a familiarization trial, three practice trials, and then four test trials. At the start of each trial, the experimenter held the occluder and the toy side-by-side, centered at the baby's eye-line (approximately 20 cm above the table). The experimenter held the occluder in her left hand and the toy in her right hand. The experimenter then directed the infants' attention to the occluder and the toy by shaking each of these items, and saying “Look at the cover.” and “Look at the toy”.

Familiarization Trial. In the familiarization trial, the experimenter placed the occluder and the toy on the table at the infant’s midline and within the infant’s reach. The infant was allowed to play with the occluder and the toy for approximately 30 seconds. The familiarization trial was designed to ensure that the infant was interested in the toy.

Practice Trials. The practice trials were designed as an opportunity for the experimenter to establish a rapport with the infant and for the infant to become comfortable with the experimental setting and task. In the first of three practice trials, the experimenter placed the occluder on the table (approximately 20 cm from the edge of the table), with the base of the occluder facing the infant, but beyond the infant’s reach. Next, the experimenter placed the toy on the base of the occluder, and then moved the occluder and toy within the infant’s reach (approximately 10 cm from the edge of the table). The infant was then encouraged to retrieve the toy (e.g., “Can you get it?”). If the infant retrieved the toy he/she received a positive verbal reinforcement (e.g., “Good for you, you got it!”), and was allowed to play with the toy for approximately 30 seconds. If the infant failed to act on the occluder and looked away for more than 2 seconds, the experimenter redirected the infant’s attention by tapping the toy. The second practice trial was similar to the first, except that before moving the occluder and toy within the infant’s reach, the experimenter turned the occluder 90 degrees clockwise, so that the toy and occluder were facing to the left of the infant. In the third practice trial, the occluder was turned 90 degrees counter-clockwise, so that the toy and occluder were facing to the right of the infant.

Test Trials. At the start of each test trial, the experimenter placed the occluder on the table (approximately 20 cm from the edge of the table), with the base of the occluder facing the infant, but beyond the infant's reach. Next, ensuring that the infant was watching, the experimenter placed the toy on the base of the occluder and turned it clockwise until the toy was completely hidden, and then moved the occluder and toy within the infant's reach (approximately 10 cm from the edge of the table). The infant was then encouraged to retrieve the toy (e.g., "Can you get it?"). If the infant retrieved the toy he/she received a positive verbal reinforcement (e.g., "Good for you, you got it!"), and was allowed to play with the toy for approximately 30 seconds. If the infant failed to act on the occluder and looked away for several seconds, the experimenter attempted to redirect the infant's attention by tapping the top of the occluder or snapping her fingers in front of the occluder. If the infant failed to retrieve the toy after 30 s the experimenter terminated the trial by removing the occluder and the toy from the table.

The infants' actions during both the familiarization and test trials were videotaped using two cameras. One video camera was directed at the infant's face to record the direction of the infant's eye gaze and the infant's hand actions on the occluder and toy. The second video camera was placed on the ceiling and directed down onto the experimental table to record the infant's head movements and hand actions on the occluder and toy that were not visible from the perspective of the first camera.

Data Scoring

Toy interest rating of familiarization trials. A coder independently viewed the videotaped test trials of each infant and rated how interested in the toy the infant was during the familiarization trial using a scale of 1 (low interest) to 5 (high interest). Coders were instructed to look at the infants' behaviors with the toy and the occluder and to consider infants' interest in the toy based on their actions and facial expressions. Coders were instructed to consider infants who spent the majority of the familiarization trial playing with the toy to be interested in the toy and to rate the infant's interest as a 4 or 5. For infants who spent a majority of the familiarization trail playing with the occluder, coders were instructed to rate the level of interest in the toy as a 1 or 2.

Means-end rating of test trials. Two coders, one of whom was naïve to the purpose of the research, independently viewed the videotaped test trials of each infant and rated how clearly the infant appeared to be acting on the occluder as a means to retrieve the toy. The coders used a scale from 1 (clearly not means-end) to 5 (clearly means-end). Coders were instructed to view the videotaped trials twice, first in normal speed and then in slow motion. Following the second viewing of the trial, means-end ratings were assigned. Coders were given no specific criteria regarding which behaviors were to be considered means-end and which were to be considered non-means-end, with the exception that trials in which the infants pulled the occluder and brought the occluder to their mouths were to be coded as 1 (clearly not means-end).

Trials that received a score of 4 or 5 by both coders were categorized as *means-end*, and trials that received a score of 1 or 2 by both coders were categorized as *non-means-end*. Trials that received a score of 3 by both coders were considered ambiguous and were excluded from the analyses. Trials in which the coders were in disagreement regarding the means-end categorization were viewed and scored by a third coder, also naïve to the purposes of the research. Any trials that received a score of 3 (unable to code) by the third coder were not categorized and excluded from the analyses.

Coding of manual and visual responses. A fourth coder, also naïve to the purpose of the research, used Observer-Pro 4.0 software (Noldus, Trienes, Hendriksen, Jansen, & Jansen, 2000) to view and code the test trials of each infant frame-by-frame to record the duration of each trial, as well as the frequency and duration of every hand action and change in eye-gaze direction. To assess reliability of this coding, a fifth coder conducted the same recording of behaviors for 25% of the infants in each age group (i.e., 4 out of the 16 infants in each age group).Each trial began when the occluder was turned around and the toy completely hidden from the infant. Each trial ended when the toy was touched directly by the infant, or after 30 s had elapsed. The recording of the infants' manual and visual response time recordings was precise to one-hundredth of a second.

The detailed analyses obtained from the coding of the video tapes were used to examine the differences between the search behaviors of the 8.5-month-old infants and those of the 6.5-month-old infants and between test trials in which the infants' behaviors were categorized as means-end and those trials in which the infants' behaviors were categorized as non-means-end. Behavioral measures were examined in two categories: 1) efficiency at retrieving a hidden object; and 2) anticipation of revealing a hidden object. To evaluate infants' efficiency at retrieving a hidden object, three behavioral measures were analyzed: the latency between the beginning of the test trial and infants' first touch of the toy (i.e., trial duration); the proportion of visual attention spent focused goal-oriented (i.e., toy and occluder) and non-goal oriented (i.e., parent, experimenter and other elements in the experimental room) elements; and, the proportion of manual behaviors spent executing goal-oriented (i.e., reaching and touching the occluder, touching the toy) versus non-goal-oriented (i.e., no action, playing with the occluder by swinging it in the air). The behavioral measure analyzed to evaluate infants' anticipation of the hidden object becoming visible was the latency between the toy becoming visible and the infants' first look at the toy.

Results and Discussion

The first two coders were in disagreement about the means-end categorization of 8 of the 64 (12.5%) test trials for the 8.5-month-old infants and 11 of the 60 trials (18.3 %) for the 6.5-month-old infants. The third coder reviewed and rated these 19 trials and, as a result, 3 trials for the 8.5-month-old infants and 4 trials for the 6.5-month-old infants were excluded from further analysis because of their ambiguity. The analyses of Experiment 1 therefore, included 62 trials by 8.5-month-old infants and 56 trials by 6.5-month-old infants. The two coders of the video tapes were reliable within 0.18 s of all behaviours, and 0.05 for 80 % of the behaviours.

Differences between 8.5- and 6.5-month-old infants

The means-end ratings revealed, as predicted, that the 8.5-month-old infants produced reliably more test trials reflecting means-end search behavior than the 6.5-month-old infants (see Table 1). The magnitude of this difference was quite large, with 83.9 % (52/62) means-end trials produced by 8.5-month-old infants, and only 14.3 % (8/56) means-end trials produced by the 6.5-month-old infants, (Fischer's exact test, $p < .0001$). A repeated measures analysis of variance (ANOVA) was conducted to assess whether the ratings of infants' search behavior changed over successive trials. Analyses revealed that the means-end ratings were not affected by trial for either the 8.5-month-old infants, F (3, 45) = 1.13, *MSE* = 1.94, p = *n.s.*, or the 6.5-month-old infants, $F < 1$, *MSE* = .96. (See Table 2 for the breakdown of means-end categorization by trial). Additionally, the 8.5-month-old group produced more means-end trials per infant (M = 3.19, SD = 0.91) than the 6.5-month-old group (M = .53, SD = 1.06), F (1, 29)

Table 1. Percentage of Means-end (ME) and Non-means-end Searches (NME) in All Experiments.

	Condition	# of infants	# of trials categorized	# of ME searches (%)
Experiment 1	8.5-month-olds	16	62	52 (83.9 %)
	6.5-month-olds	15	56	8 (14.3 %)
Experiment 2	Toy-attached	15	58	31 (53.4 %)
Experiment 3	Means-end demonstration	16	62	34 (54.8 %)
	Non-means-end demonstration	16	64	17 (26.6 %)

Table 2. Frequency and Percentage of Means-end Categorizations per Trial.

	Condition	Trial 1 *N (%)*	Trial 2 *N (%)*	Trial 3 *N (%)*	Trial 4 *N (%)*
Experiment 1	8.5-month-olds	12 (75.0 %)	11 (73.3 %)	15 (93.8%)	13 (81.3 %)
	6.5-month-olds	2 (14.3 %)	2 (14.3 %)	1 (6.7 %)	3 (23.1 %)
Experiment 2	Toy-attached	6 (40.0 %)	9 (60.0 %)	7 (53.8 %)	9 (60.0 %)
Experiment 3	Means-end demonstration	7 (43.8 %)	10 (62.5 %)	9 (56.3 %)	8 (50.0 %)
	Non-means-end demonstration	3 (18.8 %)	4 (25.0 %)	5 (31.3 %)	5 (31.3 %)

= 56.14, *MSE* = 0.97, $p < .001$. Therefore, at both the group and individual level, 8.5-month-old infants appear to be more likely to act on the occluder as a means to retrieve the toy than 6.5-month-old infants. These results replicate Piaget's (1954) original observations and offer validation of the procedure used in subsequent experiments.

Efficiency at retrieving a hidden object

For each of the three measures examined in this section (trial duration, visual attention, and manual goal actions), 2 X 4 (age X trial) mixed analysis of variances (ANOVAs), with age as the between-subjects variable and trial as the within-subjects variable, were conducted to examine the effects of trial and age. These analyses revealed no significant main effects of trial or any significant trial by age interactions for any of the above measures. As expected, main effects of age were found for all three measures, with 8.5-month-old infants having shorter trial durations, and a greater proportion of their time spent engaged in goal-oriented visual attention and behaviour. See Table 3 for the results of these 3 mixed ANOVAs. For ease of presentation, these data were collapsed across trial for all subsequent analyses.

To provide converging evidence that behaviors measuring efficiency at retrieving a hidden object reflect means-end behaviors, these behaviors were directly compared for trials categorized as means-end and those considered non-means-end. Only 8.5-month-old infants were included in this comparison to avoid any confounding effects of age. Analysis of latency between the beginning of the test trial and the infants' first touch of the toy revealed that trials categorized as means-end were indeed significantly shorter in duration (*M* = 7.23 s, *SD* = 4.79 s) than trials categorized as non-means-end (*M* = 21.69 s, *SD* = 11.01 s), $F(1, 60) = 46.52$, *MSE* = 37.68, $p < .001$. Over the course of the trial, infants producing behaviors categorized as means-end spent a greater proportion of time focused on elements deemed to be goal-oriented

(*M* = .85, *SD* = .20) on those trials than on trials categorized as non-means-end (*M* = .46, *SD* = .22), F (1, 60) = 28.80, *MSE* = .04, $p < .001$. In contrast, on trials categorized as means-end, infants spent a greater proportion of time executing behaviors deemed to be goal-oriented (*M* = .64, *SD* = .25) than on those trials categorized as non-means-end (*M* = .30, *SD* = .34), F (1, 60) = 14.12, *MSE* = .07, $p < .001$ (see Figure 2). The above results confirm the predictions that infants producing means-end searches are more efficient in their behaviors, even among older infants with high overall levels of means-end search performance, than infants of the same age producing non-means-end searches.

Anticipation of revealing the hidden object

For the measure of anticipation (latency between the toy becoming visible and the infants' first look at the toy) a 2 X 4 (age X trial) mixed analysis of variance (ANOVA) was conducted, with age as the between-subjects variable and trial as the within-subjects variable, to test for effects of trial and age. This analysis revealed that neither the main effect of trial, nor any significant interaction involving trial for any of the anticipation measure. As expected, however, there was a main effect of age, with 8.5-month-old infants having shorter latency between the toy becoming visible and their first look to the toy, relative to the 6.5 month-old infants. See Table 3 for the results of this mixed ANOVA. For ease of presentation, these data were collapsed across trial for all subsequent analyses.

To provide converging evidence that anticipation behavior reflects means-end behaviors, the anticipation measure was directly compared for trials categorized as means-end and those considered non-means-end. As above, only 8.5-month-old infants were included in this comparison to avoid any confounding effects of age. An analysis of the latency between the toy becoming visible and the infants' first look at it revealed that trials categorized as

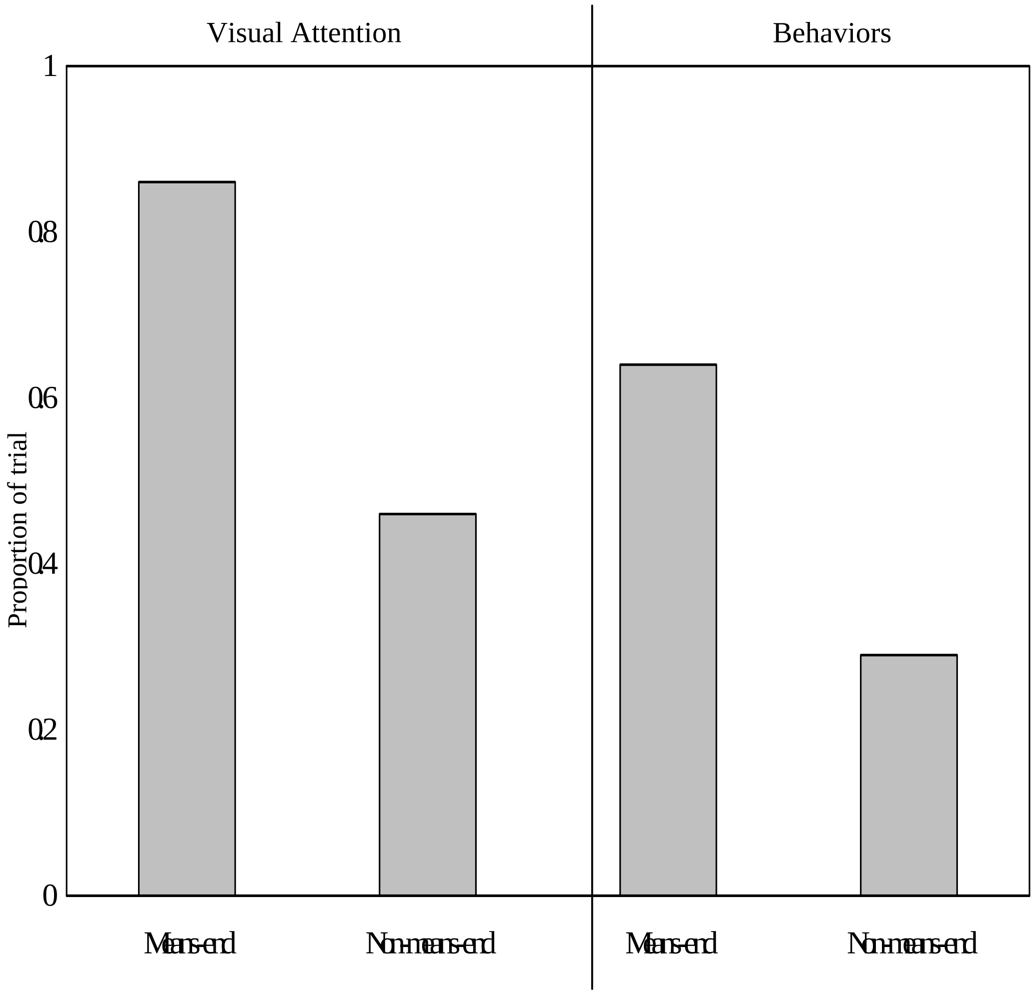

Figure 2. Proportion of test trials spent on goal-oriented behaviors and attention in means-end and non-means-end trials for 8.5-month-old-infants in Experiment 1.

Table 3. Mixed 2 X 4 ANOVA (Age X Trial) Results From Experiment 1.

Measure	6.5-month-old infants *M (SE)*	8.5-month-old infants *M (SE)*	Age	Trial	Age by trial
Trial duration	15.68 (1.83)	9.61 (1.64)	F (1,25) = 6.04 p = .021	F < 1	F < 1
Goal-oriented behaviour	.357 (.054)	.578 (.053)	F (1,29) = 8.53 p = .007	F (3, 87) = 1.25 p = *n.s.*	F (1,87)[a] = 3.41 p = *n.s.*
Goal-oriented visual attention	.548 (.043)	.785 (.043)	F (1,29) = 15.57 p < .001	F < 1	F (1,87)[b] = 3.59 p = *n.s.*
Latency between toy visible and infants' look at toy	2.51 (.48)	0.48 (.52)	F (1,15) = 5.50 p = .033	F (3, 45) = 1.34 p = *n.s.*	F (3, 45) = 1.63 p = *n.s.*

Note. [a] Epsilon adjustment, Machley's W = ..830, *df* = 5, *p* = .39.
[b] Epsilon adjustment, Machley's W = .771, *df* = 5, *p* = .21.

means-end had latencies that were significantly shorter in duration (*M* = .33 s, *SD* = .79 s) than those trials categorized as non-means-end (*M* = 1.89 s, *SD* = 1.01 s), F (1, 116) = 25.66, *MSE* = .85, $p < .001$ (see Figure 3). This result confirms the prediction that infants producing means-end searches would show more anticipation toward the location in which the toy was due to appear and, thus quickly direct their eye gaze to that location while removing the occluder. The contrast observed in the non-means-end search trials suggests that infants may sometimes be unaware of the consequences of pulling the occluder, and therefore be more likely to focus on elements other than the location where the toy will become visible. The anticipation results provide crucial validation that the coding scheme employed to measure these behaviors provides a close reflection of means-end search performance.

The fact that the majority of searches deemed to reflect the 8.5-month-old infants performed means-end behaviors is consistent with Piaget's (1954) classic observations. Accordingly, the search related characteristics established by the detailed behavioral analysis in this experiment provide a basis to identify behavior patterns that reflect deliberate searches, and may thus, be used as a benchmark for evaluating search behaviors in younger infants. If the behavioral patterns found in the 8.5-month-old infants in Experiment 1 emerge in the 6.5-month-old infants in Experiments 2 and 3, this would indicate that such infants are indeed searching deliberately, and not executing behaviors reflective of more transitional search.

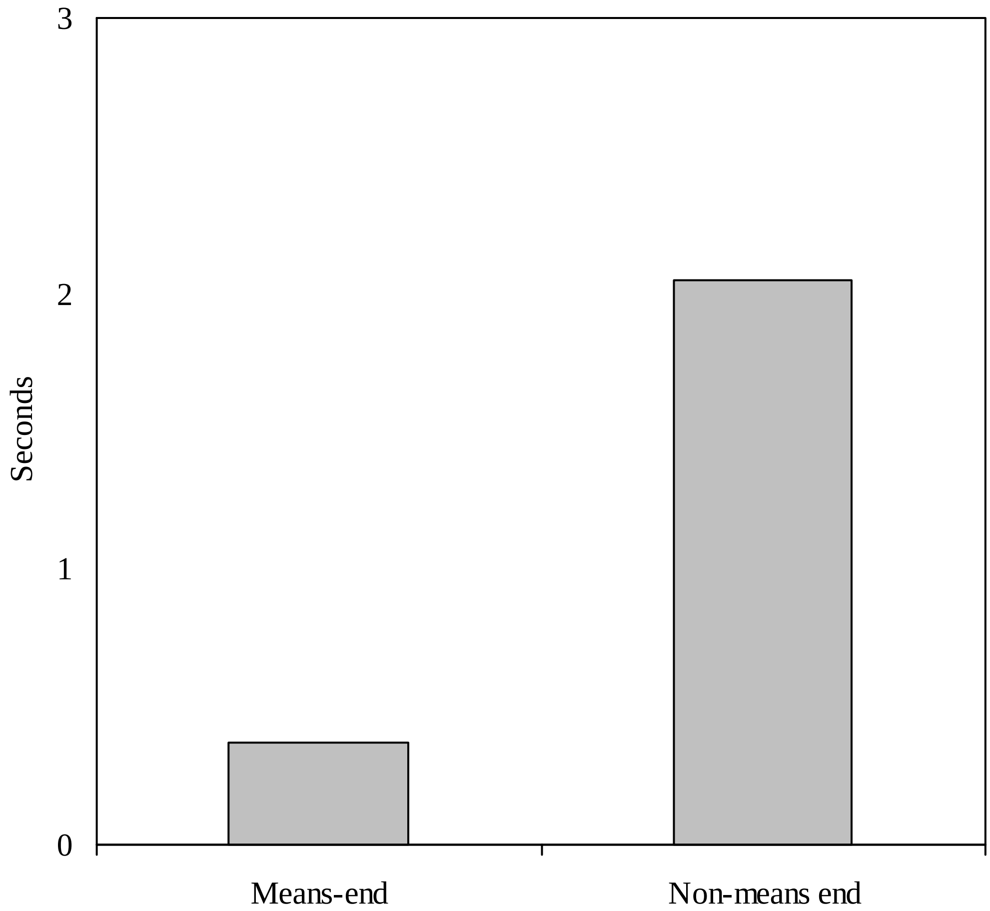

Figure 3. Latency between the toy becoming visible and the infants' first look at the toy in means-end and non-means-end trials for Experiment 1.

EXPERIMENT 2

The purpose of Experiment 2 was to assess whether 6.5-month-old infants succeed at a means-end search task if the task is transformed from a problem that they have little or no experience with to one that is familiar. The experiential limitation hypothesis suggests that when the toy and the occluder are separate, as in Piaget's (1954) original task, the solution of using the occluder as a means to retrieve the toy does not readily occur to young infants because it is not yet part of their experience with the physical world. However, when the toy and the occluder are attached, infants may be more likely to view them as a single composite object, something that infants younger than 8 months of age expect to move as a whole (e.g., Needham, 1999; Needham, Baillargeon, & Kaufman, 1997; Spelke, Breinlinger, Jacobson, & Phillips, 1993). Given this, and the fact that 6.5-month-old infants have experience playing and manipulating one object, they should have no difficulty in determining what action to perform on the occluder to retrieve the toy attached to it (Aguiar et al., 2002). Thus, attaching the toy to the occluder should transform the traditional means-end search task into one that 6.5-month-old infants have experience with, and thus, facilitate their ability to act on the occluder as a means to reveal the toy.

The prediction that 6.5-month-old infants in Experiment 2 will deliberately act on the occluder to retrieve the toy more than those of the same age from Experiment 1 would be confirmed if the infants in Experiment 2 produced more behaviors representing means-end searches, both as a group and individually, than those who received the traditional means-end search task in Experiment 1. The pattern of differences in the duration and latency of visual and manual responses between means-end searches and non-means-end searches should also reflect goal-oriented behavior and therefore have similar behavior characteristics as the corresponding trials in Experiment 1. Thus, as in Experiment 1, infants should be more efficient at retrieving the hidden object when producing behaviors representing means-end searches (i.e., shorter delays to retrieve the toy, more visual focus on the occluder and the toy, and more behaviors relevant to attaining the goal, such as reaching for, grasping, and removing the occluder), and anticipate the appearance of the object becoming visible once the occluder is removed (i.e., shorter latency between when the toy first becomes visible and the infant's first look at the toy and shorter latency between the infant's first look at the toy and his or her first touch of it).

Method

Participants

Fifteen healthy term 6.5-month-old infants (7 male and 8 female), ranging in age from 188 days to 212 days (*M* = 200.87 days, *SD* = 8.49 days) were tested and coded. An additional 3 infants were tested and eliminated from the experiment because they failed to complete four valid test trials: 1 due to lack of interest in the toy, and 2 due to fussiness.

Apparatus and Materials

The apparatus and materials were similar to those used for Experiment 1, with the exception that the toy was attached to the base and back of the occluder to form a single composite object.

Procedure

The procedure used was similar to that used in Experiment 1, except that the experimenter held up the occluder in her left hand, prior to the beginning of each trial to allow the infant to see that the toy was attached to the occluder. The experimenter directed the infants' attention to the occluder and the toy by shaking the occluder, causing the toy to produce a noise.

Data Scoring

The same rating scales and procedures for scoring toy interest and means-end categorization were used in this experiment as in Experiment 1, as was the coding of manual and visual responses.

Results and Discussion

In this experiment, the two coders were in disagreement about the means-end categorization in 10 of the 60 (16.67 %) test trials. A third coder reviewed and rated these 10 trials. With this additional rating, 2 trials remained ambiguous and were, thus, excluded from the analyses. Therefore, the analyses of Experiment 2 include 58 of the possible 60 test trials. The two coders of the video tapes were reliable within 0.15 s of all behaviours, and 0.02 for 80 % of the behaviours.

Performance of the 6.5-month-old infants

As predicted, the means-end ratings revealed that the 6.5-month-old infants in the toy-attached condition of Experiment 2 produced reliably more test trials categorized as means-end search than the same age group in Experiment 1 who performed in the traditional search task (see Table 1). In Experiment 2, 53.4% (31/58) of the trials produced by the 6.5-month-old infants were categorized as means-end, a greater than three-fold increase over that (14.3%) produced by the same age infants in Experiment 1 (Fischer's exact test, $p < .001$). As in Experiment 1, the means-end ratings did not change across successive trials, F (3, 42) < 1 (see Table 2 for the breakdown of means-end categorization by trial). Additionally, compared to the 6.5-month-old infants in Experiment 1, those in Experiment 2 had more trials per infant categorized as means-end (*M* = 2.07, *SD* = 1.16 for Experiment 2 and *M* = .53, *SD* = 1.06 for Experiment 1), *F* (1, 28) = 14.24, *MSE* = 1.24, *p* = .001. Therefore, as a group and individually, the 6.5-month-old infants who received the toy-attached means-end search task appeared to be acting on the occluder as a means to retrieve the toy more often than same age infants who received a traditional two-object search task.

Efficiency at retrieving a hidden object

To evaluate these young infants' efficiency at retrieving a hidden object, three behavioral measures were analyzed: the latency between the beginning of the test trial and infants' first touch of the toy; the proportion of visual attention spent focused on elements related to the task versus elements not related to the task; and, the proportion of manual behaviors spent executing goal-oriented versus non-goal-oriented actions. For each of the above measures, a repeated-measures ANOVA was conducted to examine if any effect of trial was present. No main effect of trial was found for any of the above measures; therefore data were collapsed across test trial for the following analyses. See Table 4 for a breakdown of these results.

Analysis of latency between the beginning of the test trial and infants' first touch of the toy revealed that trials categorized as means-end had latencies that were significantly shorter in duration (*M* = 9.48 s, *SD* = 5.43 s) than those trials categorized as non-means-end (*M* = 21.96 s, *SD* = 8.30 s), *F* (1, 58) = 49.09, *MSE* = 47.11, *p* < .001. Over the course of the trial, infants that produced behaviors categorized as means-end spent a greater proportion of time focused on elements that were deemed to be goal-oriented (i.e., the occluder or toy) (*M* = .88, *SD* = .15) than those trials categorized as non-means-end (*M* = .62, *SD* = .29), *F* (1, 58) = 19.65, *MSE* = .05, *p* < .001. Infants producing behaviors categorized as means-end spent a greater proportion

Table 4. ANOVA Results of Trial From Experiment 2

Measure	Trial 1 *M (SD)*	Trial 2 *M (SD)*	Trial 3 *M (SD)*	Trial 4 *M (SD)*	Trial
Trial duration	15.95 (10.78)	16.38 (9.73)	15.56 (9.89)	12.11 (6.75)	F (3,36) = 1.32 p = *n.s.*
Goal-oriented behaviour	.504 (.305)	.458 (.297)	.502 (.267)	.534 (.264)	$F < 1$
Goal-oriented visual attention	.739 (.259)	.759 (.251)	.689 (.320)	.889 (.155)	F (3,36) = 1.92 p = *n.s.*
Latency between toy visible and infants' look at toy	1.09 (2.33)	0.87 (1.09)	0.83 (1.35)	0.14 (0.18)	$F < 1$

of time executing behaviors deemed to be goal-oriented (i.e., reaching and touching the occluder, touching the toy) (*M* = .64, *SD* = .22) than infants producing behaviors categorized as non-means-end (*M* = .32, *SD* = .23), F (1, 58) = 29.76, *MSE* = .05, $p < .001$. The above results confirm the predictions that infants producing means-end searches were more efficient in their behaviors than infants producing non-means-end searches (see Figure 4). In fact, the findings for the trials categorized means-end produced by the 6.5-month-old infants in Experiment 2 did not differ from those of the trials categorized means-end produced by the 8.5-month-old infants in Experiment 2. See Table 5 for a breakdown of the results.

Anticipation of revealing the hidden object

To evaluate the infants' anticipation of the hidden object becoming visible, the latency between the toy becoming visible and the infants' first look at the toy was analyzed. A repeated measure ANOVA was conducted to examine if any effect of trial. No main effect of trial was found for the anticipation measure; therefore, these data were collapsed across test trial (see Table 4).

An analysis of the latency between the toy becoming visible and the infants' first look at the toy revealed that trials categorized as means-end had latencies that were significantly shorter in duration (*M* = .17 s, *SD* = .16 s) than those trials categorized as non-means-end (*M* = 1.17 s, *SD* = 1.83 s), F (1,51) = 9.73, *MSE* = 1.27, $p = .003$ (see Figure 5). These results confirm the prediction that infants producing means-end searches anticipated the location in which the toy was due to appear and thus, while removing the occluder, directed their eye gaze to that location. Further, when this latency measure of the trials categorized as means-end produced by the 6.5-month-old infants in Experiment 2 was compared with the trials

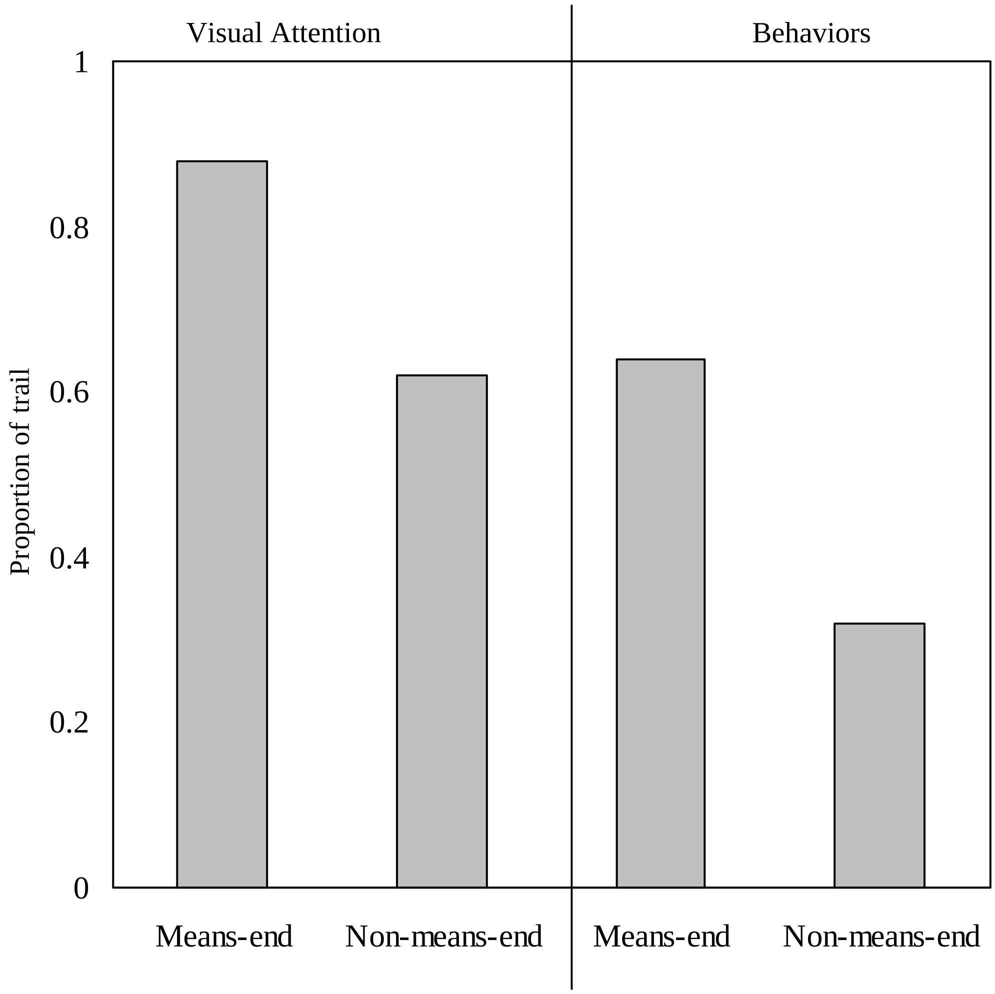

Figure 4. Proportion of test trials spent on goal-oriented behaviors and attention in means-end and non-means-end trials for in Experiment 2.

Table 5. Comparison of means-end trials produced by 6.5-month-old infants in Experiment 2 and 8.5-month-old infants in Experiment 1

Measure	6.5-month-old infants (Exp. 2) *M (SD)*	8.5-month-old infants (Exp. 1) *M (SD)*	Condition
Trial duration	9.48 (5.43)	7.23 (4.79)	F (1,83) = 4.00 p = *n.s.*
Goal-oriented behaviour	.644 (.223)	.640 (.246)	$F < 1$
Goal-oriented visual attention	.879 (.155)	.845 (.201)	$F < 1$
Latency between toy visible and infants' look at toy	.171 (.161)	.367 (.431)	F (1,82) = 6.19 p = .015

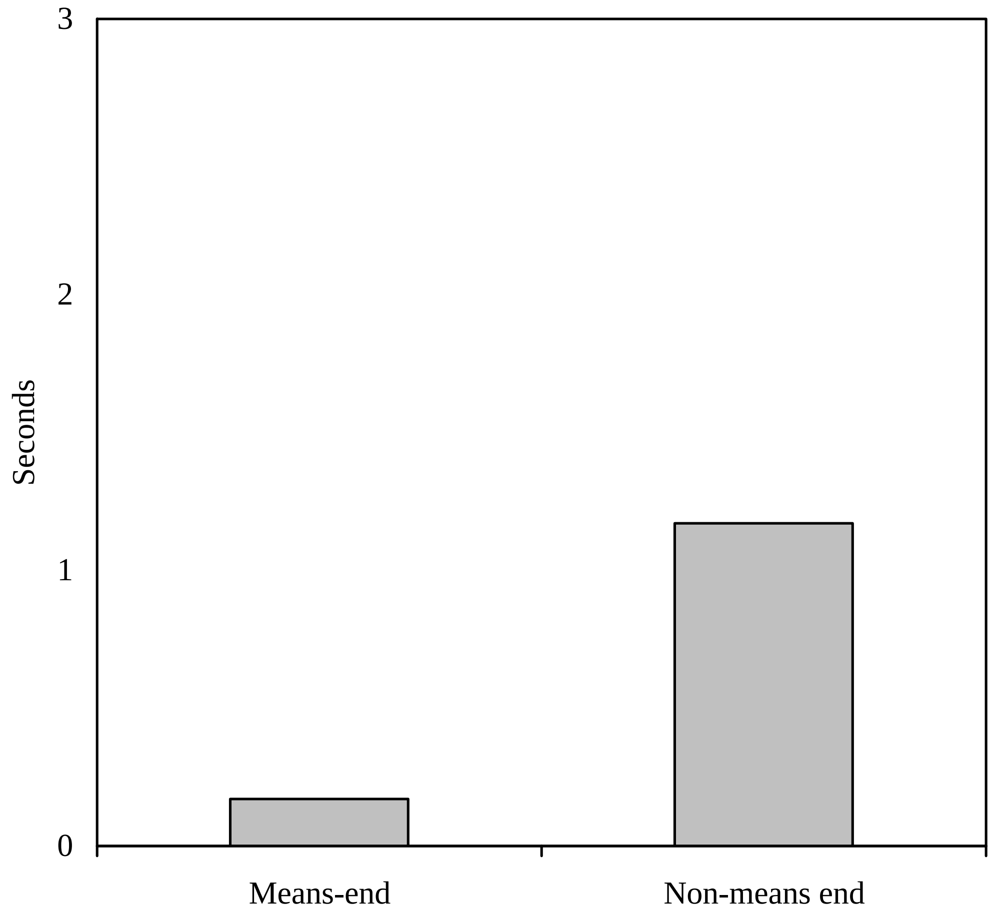

Figure 5. Latency between the toy becoming visible and the infants' first look at the toy in means-end and non-means-end trials for Experiment 2.

categorized as means-end produced by the 8.5-month-old infants in Experiment 1, it was found that the younger infants were faster to look toward the toy once it became visible (see Table 5).Thus, taken together, the results of this experiment suggest that when the means-end search task is modified to fit within age-appropriate experiences, infants as young as 6.5-month-old are able to deliberately and efficiently search for a hidden object.

EXPERIMENT 3

Experiment 3 addressed the question of whether 6.5-month-old infants are able to solve a means-end search task, involving two objects (as in Piaget's original task), when they are first shown a demonstration of the solution. It is a well-established finding that infants as young as a few hours old will imitate an adult's actions (Meltzoff & Moore, 1977). By reproducing another's behaviors, infants gain knowledge about themselves, and their own capacity for action (Rochat, 2001). Infants can use adults as a source of information about what to do with objects and their behaviors can be guided by the particular nature of the acts of the adults (Meltzoff, 1995). Following this rationale, in this experiment infants were given an opportunity to watch an experimenter demonstrate the solution to the search task (means-end demonstration) before they were given an opportunity to search. To ensure that the 6.5-month-old infants were not simply imitating the action of pulling the occluder, without realizing the means-end relationship between pulling the occluder and retrieving the toy, an additional group of infants was tested. This second group of infants first viewed a similar demonstration involving the pulling of the occluder, except that now pulling the occluder was no longer a means to reveal the toy (non-means-end demonstration), but would instead reveal a beige divider.

Infants who view the means-end demonstration are expected to produce more behaviors representing means-end searches, as a group and as individuals, than infants who view the non-means-end demonstration. As in the first two experiments, the differences between behaviors representing means-end searches and those representing non-means-end searches should differ.

Method

Participants

Sixteen healthy term 6.5-month-old infants, (8 male and 8 female), ranging in age from 189 days to 217 days (*M* = 201.3 days, *SD* = 7.0 days) were tested and coded in the means-end demonstration condition. Sixteen healthy term 6.5-month-old infants, (8 male and 8 female), ranging in age from 188 days to 209 days (*M* = 201.6 days, *SD* = 6.3 days) were tested and coded in the non-means-end demonstration condition. An additional 7 infants were tested and eliminated from the experiment because they failed to complete four valid test trials: 4 due to lack of interest in the toy, and 3 due to fussiness.

Apparatus and Materials

The apparatus and materials were identical to those used for Experiment 1 with the addition of a beige divider, 12 cm wide, and 18 cm high, which was placed on the far end of the table during the non-means-end demonstration task.

Procedure

The procedure was similar to that used for Experiment 1 except that the experimenter provided either a means-end demonstration or a non-means-end demonstration three times before the first test trial and once before each subsequent test trial. In the means-end demonstration, the experimenter (1) placed the occluder on the table; (2) placed the toy on the base of the occluder; (3) turned the occluder clockwise, hiding the toy; (4) grabbed the large handle of the occluder; (5) pulled the handle down to reveal the toy; and, finally, (6) retrieved the toy. In the non-means-end demonstration, the experimenter (1) placed the toy behind the beige divider, hiding it; (2) placed the occluder on the table in front of the beige divider, hiding it; (3) turned the occluder clockwise; (4) grabbed the large handle of the occluder; (5) pulled the handle of the occluder handle down to reveal the divider; and, finally (6) retrieved the toy from the behind the divider. It is important to note that the non-means-end demonstration was similar to the means-end demonstration in that the experimenter pulled the occluder and retrieved the toy; however, the action of pulling the occluder is no longer a means to reveal the toy because the toy was hidden behind the beige divider.

Data Scoring

The rating scales and procedure used for Experiment 1 for scoring toy interest and means-end categorization were employed for this experiment. Similarly, the coding of manual and visual responses was completed as in the previous experiments.

Results and Discussion

It was found that the two coders were in disagreement about the means-end categorization in 7 of the 64 (10.09%) test trials for the means-end demonstration condition and 12 of the 64 trials (18.75 %) for the non-means-end demonstration condition. A third coder reviewed and rated these 19 trials and as a result 2 trials for the means-end demonstration condition and no trial for the non-means-end demonstration condition remained ambiguous and were, thus, excluded from the analyses. Therefore, the analyses of Experiment 2 include 62 trials for the means-end demonstration condition and 64 trials for the non-means-end demonstration condition. The two coders of the videotapes were reliable within 0.45 s of all behaviours, and 0.05 for 80 % of the behaviours.

Differences between the means-end and non-means-end conditions

As predicted, the means-end ratings revealed that the infants who viewed the means-end demonstration produced reliably more test trials in which their behaviours were considered reflective of means-end searches than the infants who viewed the non-means-end demonstration (see Table 1). Of the 62 trials produced by the infants in the means-end demonstration condition, 34 were categorized as means-end, whereas only 17 of the 64 trials produced by the infants in the non-means-end demonstration condition were categorized as means-end (Fischer's exact test, $p = .002$). The means-end ratings were not affected by trial for the means-end demonstration condition, F (3, 45) < 1, nor the non-means-end demonstration condition, F (3, 45) < 1. See Table 2 for the breakdown of means-end categorization by trial. Additionally, compared to non-means-end demonstration condition, the infants in the means-end demonstration condition had more trials per infant categorized as means-end ($M = 2.13$, $SD = 1.30$) for the means-end demonstration condition and ($M = 1.06$, $SD = 1.29$) for the non-means-end demonstration condition, F (1, 30) = 5.80, $MSE = 1.56$, $p = .022$. Therefore, as a group and individually, the 6.5-month-old infants who viewed the means-end demonstration appeared to be acting on the occluder as a means to retrieve the toy more often than the same infants who viewed the non-means-end demonstration.

Efficiency at retrieving a hidden object

For each of the three behavioural measures, a 2 X 4 (condition X trial) mixed ANOVA, with condition as the between-subjects variable and trial as the within-subjects variable was conducted to examine if any effect of trial or condition was present. No significant main effects of trial or condition, nor any interaction of trial by condition, were found for any of the efficiency measures; therefore, data were collapsed across test trial and condition for the following analyses. See Table 6 for a breakdown of these mixed ANOVA findings.

Analysis of latency between the beginning of the test trial and infants' first touch of the toy revealed that trials categorized as means-end had latencies that were significantly shorter in duration ($M = 9.02$ s, $SD = 4.55$ s) than those trials categorized as non-means-end ($M = 17.86$ s, $SD = 9.14$ s), F (1,123) = 40.77, $MSE = 58.02$, $p < .001$. Over the course of the trial, infants

Table 6. Mixed 2 X 4 ANOVA (Condition X Trial) Results From Experiment 3.

Measure	Means-end Condition *M (SE)*	Non-means-end Condtion *M (SE)*	Condition	Trial	Condition by trial
Trial duration	12.98 (1.46)	15.41 (1.37)	F (3, 84) = 1.27 p = *n.s.*	F (3, 84) = 1.26 p = *n.s.*	F (1, 28) = 1.47 p = *n.s.*
Goal-oriented behaviour	.593 (.054)	.594 (.051)	F < 1	F < 1	F < 1
Goal-oriented visual attention	.765 (.036)	.739 (.034)	F < 1	F (3, 84) = 1.11 p = *n.s.*	F < 1
Latency between toy visible and infants' look at toy	.706 (.213)	.597 (.243)	F < 1	F < 1	F < 1

producing behaviors categorized as means-end spent a greater proportion of time focused on elements deemed to be goal-oriented (i.e., the occluder or toy) (*M* = .87, *SD* = .14) than trials categorized as non-means-end (*M* = .67, *SD* = .20), F (1, 124) = 46.38, *MSE* = .03, $p < .001$ (see Figure 6). Infants producing trials categorized as means-end spent a greater proportion of time executing behaviors deemed to be goal-oriented (i.e., reaching and touching the occluder, touching the toy) (*M* = .67, *SD* = .24) than infants producing trials categorized as non-means-end (*M* = .53, *SD* = .29), F (1,124) = 9.00, *MSE* = .08, $p = .004$. These results provide support for the hypothesis that infants producing means-end searches are more efficient in their behaviors than infants producing non-means-end searches.

Anticipation of revealing the hidden object

For the latency measure examining anticipation of revealing the hidden object, a 2 X 4 (condition X trial) mixed ANOVA, with age as the between-subjects variable and trial as the within-subjects variable was conducted to examine if any effect of trial or condition was present. No significant main effects of trial or condition, or any interaction of trial by condition were found for the above measure; therefore, data were collapsed across test trial and condition. See Table 6 for a breakdown of these mixed ANOVA findings.

First, analysis of the latency between the toy becoming visible and the infants' first look at the toy revealed that trials categorized as means-end had latencies that were significantly shorter in duration (*M* = .34 s, *SD* = .54 s) than those trials categorized as non-means-end (*M* = .89 s, *SD* = 1.57 s), F (1,11) = 5.64, *MSE* = 1.5, $p = .019$.

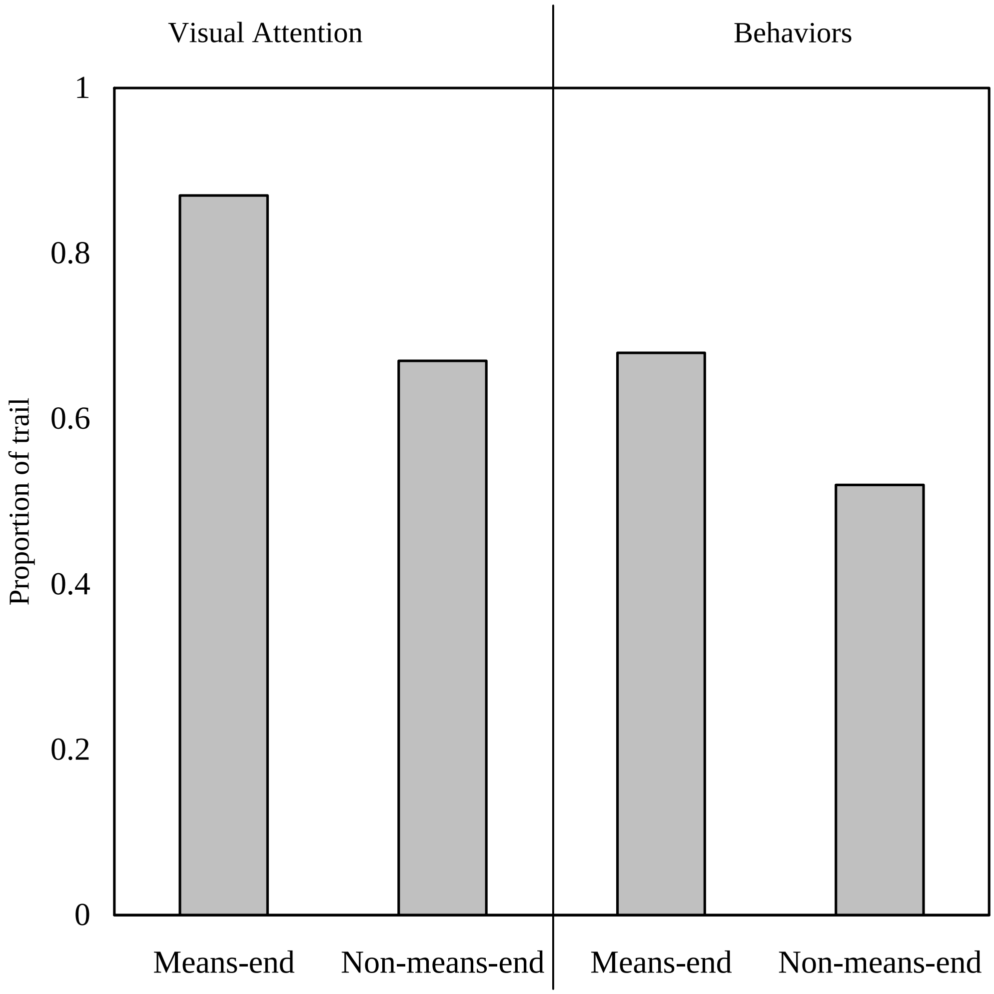

Figure 6. Proportion of test trials spent on goal-oriented behaviors and attention in means-end and non-means-end trials for in Experiment 3.

See Figure 7. This result suggests that 6.5-month-old infants benefited from viewing general demonstrations of means-end search (i.e., either the means-end or non-means-end condition) and produced means-end searches in which they anticipated the location in which the toy will appear and thus, while removing the occluder, directed their eye gaze and motor responses to that location.

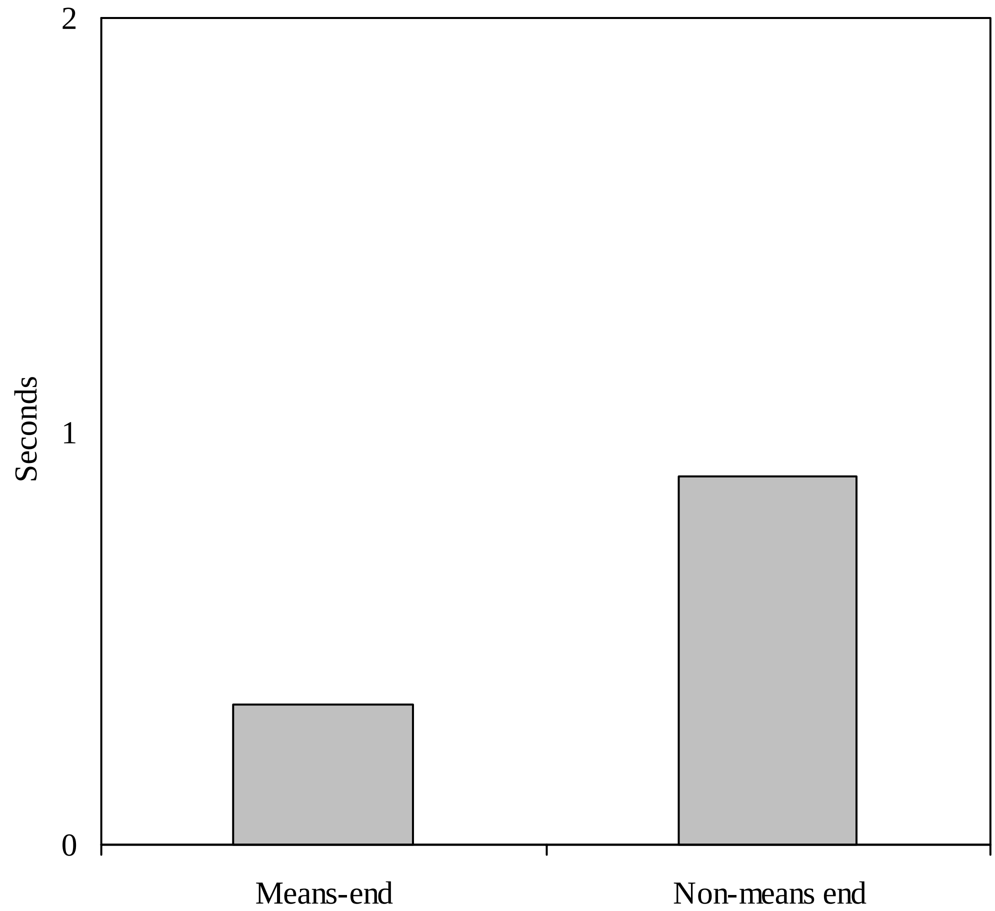

Figure 7. Latency between the toy becoming visible and the infants' first look at the toy in means-end and non-means-end trials for Experiment 3.

GENERAL DISCUSSION

The research presented here was designed to examine the experiential limitation hypothesis. The corresponding proposal addresses the discrepancy that exists between Piaget's (1954) observation that infants younger than 8 months of age fail to search for an object that becomes hidden by an occluder, and the research findings obtained using the violation-of expectation paradigm (e.g., Aguiar & Baillargeon, 1999; Baillargeon, 1987; Baillargeon et al., 1990), which suggest that infants much younger than 8 months of age possess the conceptual and motor abilities needed to perform means-end tasks. According to this experiential limitation hypothesis, young infants fail to search because such a task requires acting on one object as a means to achieve a goal involving a second object, and young infants typically have little experience with such a task. Infants younger than 8 months of age are unfamiliar with problems involving acting on one object as a means to retrieve a second object; thus, the solution to such problems does not spontaneously occur to them. The theoretical implications of the experiential limitation hypothesis differ from those of Piaget's work in an important way. The proposed experiential limitation hypothesis holds the fundamental assumption that search behavior is an index of infants' ability to use one object as a means of achieving a goal involving a second object, and is not only an index of infants' understanding about the permanence of occluded objects (see also, Baillargeon, 1993).

Taken together, the results of three experiments provide strong support for the experiential limitation hypothesis. The first experiment provided a replication of the classic observation that 8.5-month-old, but not 6.5-month-old, infants were able to successfully search for an occluded object on a majority of test trials. In Experiment 2, using the same basic procedure, 6.5-month-old-infants were able to retrieve a toy hidden behind an occluder when the task was transformed to one they had experience solving (i.e., the occluder and toy were transformed into one composite object), and were similar in their behaviors as the older infants of Experiment 1. In Experiment 3, 6.5-month-old-infants were able to successfully complete the means-end search tasks after viewing a demonstration using the occluder to retrieve the toy. Furthermore, in Experiments 2 and 3, the 6.5-month-old-infants were able to retrieve the toy in a manner that demonstrated an understanding both of how to solve a manual search task, and of the fact that the toy was still present even when hidden by the occluder.

Converging evidence that young infants' search performance improved when their experiential limitations are overcome was provided by the results of objective measures of 6.5-month-old infants' behaviours. The behaviors of the 6.5-month-old infants who successfully retrieved the toys (i.e., produced test trials that were categorized as means-end) were similar to those found in means-end searches by older 8.5-month-old-infants in Experiment 1. Specially, the 6.5-month-old-infants who successfully retrieved the toy from behind the occluder in Experiment 2 had more efficient responses (i.e., shorter duration between the start of the test trial and their first touch of the toy). Such efficient responses were characterized by the production of more goal-relevant behaviours (i.e., reaching for, grasping and removing the occluder), and a greater proportion of their attention focused on goal-oriented objects (i.e., the toy and occluder) during toy retrieval than test trials in which the infants had been unsuccessful in retrieving the toy. Furthermore, 6.5-month-old-infants demonstrated higher levels of anticipation regarding the appearance of the toy once they removed the occluder. This increased anticipation was marked by shorter latencies between the appearance of the toy and their first look at the toy. The significance of these quantitative behavioral results are reflected in Piaget's (1954) and Willatts' (1984) suggestions that such behaviors are perhaps the most important indications of deliberate search.

It is interesting to note that while the specific of Experiment 3 had a reliable effect on the proportion of means-end search behaviours in 6.5-month-old infants; it did not yield significant differences in the objective measures of search efficiency and anticipation. In consideration of this, it seems that the novel application of the experience gained by the demonstrations in this experiment, though successful overall, may require additional practice before by the infant displaying the more direct behaviors of search efficiency and anticipation. The 6.5-month-old infants in Experiment 2 were led to utilize the occluder in a manner with which they were presumed to already have adequate experience. In contrast, the same-age infants in Experiment 3 were led to act on the occluder through a demonstration of an action-sequence with which they were presumed to have very little experience. Therefore, just as a young child is still hesitant and shaky during the first successful attempts at riding a bicycle, the infants in Experiment 3 may have required more practice or additional demonstrations before coming to execute means-end searches in that task with the same confidence and efficiency that is typically associated (and shown in Experiments 1 and 2) with means-end behaviors. While future research is needed to directly address this possibility, the failure to find reliable differences in the converging measures of search efficiency and anticipation does not detract from the finding of primary importance in Experiment 3; namely, that 6.5-month-old infants are able to perform significantly more successful means-end searches when provided with experience regarding how to complete the search.

The present results cannot be accounted for by an explanation that focuses on biological immaturity (e.g., Diamond, 1991; 1997). According to this view, infants between 5 and 7 months of age understand the concept that an object continues to exist when hidden, but are unable to utilize this understanding in means-end search tasks because the lack of maturation of the supplementary motor area of the PFC yields imperfect sequencing of arm and hand movements. However, if such a hypothesis were correct, then the 6.5-month-old-infants would not have benefited from simply watching a demonstration of the solution in Experiment 3. It would be quite a feat; indeed, if any deficit that is due to gross immaturity of a brain region could be overcome by a few trials of learning. That infants required very little experience with the solution to perform successful search is, thus, quite dramatic in light of the biological immaturity argument, as one would expect that young infants' inability to solve the task would be quite resistant to change until the onset of critical period of maturations. Accordingly, just as monkeys with PFC lesions show little ability to learn action sequences they were previously familiar with (Diamond, 1993), so should infants show little change in their ability to quickly learn action sequences if they have immature prefrontal cortices. The present results suggest, instead, that 6.5 month-old infants' ability to successfully perform means-end search is not limited by PFC immaturity, because once infants at this young age are provided with a little experience with the steps necessary to successfully retrieve an occluded object, they produce the means-end sequencing that is necessary to solve the task.

The present results are also difficult to reconcile with theoretical accounts based on the notion that infants younger than 8 months of age do not search for hidden objects and are unable to perform means-end action sequences because they are unable to reason about causal sequences (e.g., Piaget, 1954; Willatts, 1984). The successful means-end search performance of 6.5-month-old infants in Experiment 2, for example, suggested that these infants understood means-end sequences and manipulated the occluder portion of the composite object attain the interesting part of the object (i.e., the toy). It is important to emphasize that the primary difference between the experimental method in Experiment 2, where 6.5-month-old infants were successful at retrieving the occluded object, and in Experiment 1 where infants of the same age were unsuccessful at retrieving the occluded object, is the fact that in Experiment 1 infants were shown the toy and occluder as two separate objects.

One could argue that these results suggest that young infants are able to reason about causal sequences, but only when they are dealing with a single object. However, if the ability to solve means-end search tasks involving two objects is dependent on reaching yet another cognitive stage in development, then young infants should not have benefited from viewing the demonstrations in Experiment 3. Both conditions provided opportunity for 6.5-month-old infants to alter their behavior through simple imitation, and were differentiated only as to whether the demonstrated actions provided a causal link to retrieval of the toy. The fact that the infants in the means-end demonstration produced more trails that were categorized as means-end suggest that such a demonstration of the causal link between the occluder and the toy provided the infants with the experience with the task they needed in order to solve the search task. Such a finding is similar to the toy-attached condition of Experiment 2, which allowed infants' access to crucial experience when the task was transformed to one that infants of that age have had previous experience solving.

The compelling finding of the means-end demonstration condition of Experiment 3 was the fact that such a small amount of experience (i.e., exposure to a demonstration) with the solution resulted in successful search in a greater number of 6.5-month-old-infants. Future research is needed to explore the extent to which infants at this age are able to apply this existing knowledge, perhaps through the imposition of a time delay between the point when infants view the demonstration of the solution and when they are given the opportunity to solve the task. Thus, while the present results cannot speak to young infants' ability to apply their experience over delays or to generalize their knowledge to other occluders and toys, it is clear that young infants are able to perform causal reasoning when they are provided with situations that they have had previous experience with, or are provided experience through demonstrations of potential solutions.

As discussed above, the results of the experiments here are problematic for accounts of young infants' failures at traditional means-end search tasks that are based on biological immaturity or cognitive development of casual sequence reasoning. But what do they mean for Munakata and her colleague's (1997) theory that infants' ability to successfully search for a hidden object is related to the strength of the representation the infants holds for the object when it is no longer visible? This theory holds that young infants fail at manual search tasks because the representation of a hidden object becomes graded as soon as the object is no longer in view, and continually loses its intensity over time. Moreover, the rate of representational loss is thought impact the nature of the events that follow the object's disappearance from view. For example, young infants' success at searching for toys hidden by darkness (Clifton, Perris, & Bullinger, 1991) is thought to result from the fact that the fragile representations of hidden objects held by infants between 5 and 7 months of age can withstand the darkness of a room, but not the direct interference from an occluder in traditional search tasks (Munakata et al., 1997; Shinskey & Munakata, 2003).

The results of the toy-attached condition in Experiment 2 are consistent with Munakata and colleague's (1997) graded representation view to the extent that the representation of the toy may have been strengthened by the demonstration that it and the occluder acted as a single object. Accordingly, the occluder in such a situation might not be in direct competition with the representation of the toy, so the infant maybe able to better represent the composite object and track the interesting portion of it (i.e., the toy). While the interference of a graded representation of the toy may have been reduced in Experiment 2 by attaching the toy to the occluder, the same cannot be said for Experiment 3, where the toy and occluder remained unattached as two separate objects.

Infants' means-end search success in the means-end demonstration of Experiment 3, accompanied by failure in the non-means-end demonstration, is more difficult to explain from a graded representation perspective. If the original representation depends on the amount of exposure to the toy, then the strength of the representation should have been similar in the means-end and non-means-end demonstration conditions, because of infants' equal exposure to the toy in each condition. Similarly, the amount of interference provided by the occluder was also the same in the means-end and non-means-end demonstration conditions of Experiment 3, as was the outcome for Experiment 3 (i.e., successful retrieval of the toy). In fact, the only difference between the two conditions was that the experience associated with the means-end condition included a direct causal link between the demonstrated action of pulling the occluder and retrieval of the toy. Accordingly, the only obvious way in which the strength of the representation of the toy could have differed between the means-end and non-means-end demonstration conditions was through internal activation via knowledge about the causal link provided by viewing the means-end demonstration. Ultimately, while graded representation theories may allow for influences to accumulate over time, they rest on the basic assumption that search failures reflect the operation of an underdeveloped system, one that, again, should not show such large changes following only a few demonstration trials. In contrast, an explanation based on experiential limitations suggests that failures are not due to lack of development, but rather to lack of experience.

One assumption of the experiential limitation hypothesis is that infants younger than 8 months possess the basic knowledge necessary to solve a manual search task, including the understanding that objects continue to exist when they are no longer visible. Indeed, the studies based on this assumption (e.g., Aguiar & Baillargeon, 1999; Baillargeon, 1987; 1993; Baillargeon, & Graber, 1987) have come under criticism in recent years (e.g., Bogartz, Shinskey, & Speaker, 1997; Cashon & Cohen, 2000; Haith, 1988). Critics suggest that the findings from such visual based experiments are not indicative of high-level cognitive understanding or reasoning by infants, but rather indicative only of perceptual processing. For example, it has been suggested that researchers using visual based experiments to measure infants' ability to represent hidden objects are, perhaps, simply detecting infants' preferential response to novelty (e.g., Bogartz, Shinskey, & Speaker, 1997), or that infants are developing an expectation of what would happen to the objects while the objects are visible (Haith, 1998).

Although young infants' understanding of the existence of hidden objects was not explicitly tested, there is some evidence to support the idea that young infants hold some understanding that objects continue to exist when no longer visible. This was evident in the findings that 6.5-month-old-infants in the toy-attached and means-end demonstration conditions produced behaviours suggestive of their anticipation that the toy would appear at a specific location when they pulled the occluder down or around. These infants did not produce many behaviors that one might expect to be indicative of a lack of expectation and object permanence, such as making leisurely movements toward the toy when it became visible or not noticing the toy at all when it became visible. Instead, these 6.5-month-old infants produced actions consistent with abilities reflecting object permanence and indicating anticipation (i.e., short latency times of looking to the toy) that echoed that of the older 8.5-month-old-infants.

One could argue that above results could be explained within the framework of dynamic systems theory. Dynamic systems theorists, such as Esther Thelen and her colleagues, suggest that behavior is merely the emergent property of the interaction between all forms of input, including those immediately present and from one's recent past (e.g., Spencer & Schöner, 2003; Thelen & Smith, 1994). To this end, incorporating experience as a concept integral in understanding young infants' performance on manual search tasks works well within a dynamic systems framework. A key element of modelling behavior within the framework of dynamic system theories, however, is the specification and determination of the weight of the various input sources. However, the elements considered crucial in young infants' success in means-end search tasks are still highly underspecified, and thus, it is difficult to estimate the appropriate weights to assign to these elements with any precision. Indeed, few areas of psychological research are sufficiently well specified to properly apply a dynamical systems approach (Eliasmith, 1997).

The proposed experiential limitation hypothesis therefore provides a highly parsimonious and comprehensive explanation of the discrepancy between young infants' performance on visual and manual search tasks than other leading explanations that have been proposed previously. These explanations are unable to fully account for the findings of the three experiments reported here. The experiential limitation hypothesis suggests that infants as young as 6 months of age are more sophisticated in their general abilities than many contemporary developmental psychologists would acknowledge (e.g., Bogart, Shinskey, & Speaker, 1997; Haith, 1998; Willatts, 1997). The above empirical support provided for the experiential limitation hypothesis demonstrates that young infants not only understand *how* to solve means-end search tasks but also are *able* to use that knowledge to solve the task.

Increased experience with the physical world provides a means for advancement in infants' cognitive abilities, practically through the onset of independent mobility (Bai & Bertenthal, 1992; Campos et al., 2000). The onset of crawling signifies the commencement of major changes in the psychology of the infant (e.g., referential gestural communication, and improved spatial search performance; Campos et al., 2000). Bai and Bertenthal (1992), for example, examined the search behavior of same age infants of varying crawling abilities (i.e., pre-crawling, creeping, and crawling). Consistent with the experiential hypothesis, they found that increases in locomotor status were related to successful search performance. This finding suggests that as infants become more independent through increases in their mobility, they are increasingly able to explore and experience the world in a way that is conducive to specific application of existing knowledge structures. By the age of 8 months, infants are not only crawling, but also are successful in freely retrieving hidden objects in manual search tasks, a co-occurrence that should not go unmentioned.

In summary, the research presented here addresses an important and previously unresolved issue in the study of infant cognition regarding the fact that infants younger than 8 months of age typically fail to search for objects when hidden by an occluder. The result of this research suggests that the ability to search for occluded objects, which has traditionally been taken as a hallmark of object permanence, may not be caused by deficiencies in young infants' representations, but may instead be due to limitations in their experiences with the physical world which prevent them from applying their existing knowledge structures, including object permanence.

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