Available online at www.sciencedirect.com
ScienceDirect
Infant Behavior & Development 31 (2008) 168–180
Infant Behavior & Development

Factors affecting infants' manual search for occluded objects and the genesis of object permanence

M. Keith Moore*, Andrew N. Meltzoff*

Institute for Learning & Brain Sciences, Box 357920, University of Washington, Seattle WA 98195, United States

Received 4 August 2007; received in revised form 27 September 2007; accepted 12 October 2007

Abstract

Two experiments systematically examined factors that influence infants' manual search for hidden objects ($N = 96$). Experiment 1 used a new procedure to assess infants' search for partially versus totally occluded objects. Results showed that 8.75-month-old infants solved partial occlusions by removing the occluder and uncovering the object, but these same infants failed to use this skill on total occlusions. Experiment 2 used sound-producing objects to provide a perceptual clue to the objects' hidden location. Sound clues significantly increased the success rate on total occlusions for 10-month-olds, but not for 8.75-month-olds. An identity development account is offered for why infants succeed on partial occlusions earlier than total occlusions and why sound helps only the older infants. We propose a mechanism for how infants use object identity as a basis for developing a notion of permanence. Implications are drawn for understanding the dissociation between looking time and search assessments of object permanence.

Keywords: Object permanence; Identity; Manual search; Spatial cognition; Development; Representation

When an occluder moves in front of an object, adults understand that the occluder blocks visual access to it. They believe that the object exists constantly for every moment it is occluded, and that it exists independent of human perception or action in a specific location in the world (even if they do not recall where exactly at the moment). Our shorthand for this belief is that objects are permanent over occlusion events, or even more briefly: Adults have 'object permanence.'

Three principal behaviors have been used to assess infants' notion of object permanence: (a) total looking time devoted to events that contradict permanence, (b) anticipatory reaching for moving objects as they emerge from behind a stationary occluder, and (c) manual search for stationary objects hidden by movement of an occluder. The looking-time approach capitalizes on the fact that infants increase their looking when an unexpected event occurs. The finding is that infants as young as 2.5 months of age discriminate unexpected events that contradict permanence for adults from events consistent with permanence (Aguiar & Baillargeon, 2002; Spelke, Breinlinger, Macomber, & Jacobson, 1992; see Baillargeon, 2004b, for a review). These findings are argued to imply innate understanding of object permanence (Baillargeon, 2004a; Spelke, 1994).

The second approach capitalizes on anticipatory reaching behavior, based on the fact that 6-month-olds can 'catch' a moving object when it comes within reach (von Hofsten, Vishton, Spelke, Feng, & Rosander, 1998). The test of

* Corresponding authors. Tel.: +1 206 685 2045; fax: +1 206 221 6475.
E-mail addresses: mkmoore@u.washington.edu (M.K. Moore), meltzoff@u.washington.edu (A.N. Meltzoff).

0163-6383/$ – see front matter
doi:10.1016/j.infbeh.2007.10.006

object permanence: Will infants catch an object that is briefly occluded (<1 s) behind a screen before moving into reaching distance, just as they catch it if the object is not occluded? Studies found that 6-month-olds do *not* reach out to catch the object as it emerges from behind the screen (Jonsson & von Hofsten, 2003; Spelke & von Hofsten, 2001), but that older infants do so—9.5-month-olds (Berthier et al., 2001) and 11-month-olds (van der Meer, van der Weel, & Lee, 1994). This failure of young infants who have the requisite reaching skills has sparked new debate about the development of object permanence in young infants (e.g., Munakata & Stedron, 2002; Spelke & Hespos, 2001).

The third major approach uses manual search for stationary objects that are hidden by movement of an occluder. This allows the infant to actively uncover the object's hidden location. Longitudinal and cross-sectional studies have consistently reported an age-related progression of manual search tasks, from solving partial occlusions, to total occlusions, to invisible displacements (e.g., Kramer, Hill, & Cohen, 1975; Piaget, 1954; Uzgiris & Hunt, 1975). Numerous follow-up studies confirm that infants first recover a totally occluded object between 8 and 10 months of age depending on the precise procedure used (for a review, see Marcovitch & Zelazo, 1999). The puzzle is why infants who respond in accord with permanence on the looking-time measures in the first months of life do not manually recover a stationary occluded object or 'catch' a briefly hidden moving one until around 9 months of age. This dilemma has not been fully resolved and motivates the current research on manual search.

We note that the weaknesses of the looking time and manual search/catching measures are mirror images of each other: Looking time is easy for infants to exhibit and experimenters to measure but requires complex chains of inference to bear on infants' understanding of permanence (for fuller exposition, see Bremner, 2000; Bremner & Mareschal, 2004; Cohen & Cashon, 2006; Hood, 2004). Manual responses are more complex for infants to perform and may underestimate competence, but allow relatively direct inferences about permanence when infants succeed (because they search in a particular place for the object *while it is still invisible*). This suggests that if the manual search tasks could be made easier, infants might succeed on tasks they would ordinarily fail, and shed light on the infancy literature's attempts to reconcile the discrepant findings obtained by the two measures (for reviews, see Cohen & Cashon, 2006; Meltzoff & Moore, 1998; Newcombe & Huttenlocher, 2006). Three hypotheses about the sources of infants' manual search difficulties guided the present work.

First, in order to recover a totally occluded object, infants must be motorically able to grasp and move the occluder and also coordinate this act with the goal act of obtaining the object—a coordination of means and ends (see Shinskey & Munakata, 2003, for a review of the means–ends literature). We devised a new assessment to address these components of successful search. In a longitudinal pilot study, infants were found to recover partially occluded objects in two distinct ways. When infants began to solve partial occlusions they usually grasped the visible part of the object protruding from the occluder; later, they often recovered the object by removing the occluder, then grasping the object. This second means of recovery has not been reported in the literature, probably because most assessments were done with the visible part, often the head of a toy, protruding toward the infants so it was attractive and easy to grasp (e.g., Miller, Cohen, & Hill, 1970; Uzgiris & Hunt, 1975). If infants solve partial hidings simply by pulling on the visible portion, the motor and means–ends skills for recovering the partially hidden object are different and easier than for recovering the totally hidden one. But a procedure can be devised to equate the skills needed. In the present study: (a) the visible part protruded laterally from the occluder and thus the visible part was not closer to the infant than the occluder, and (b) the attractive part of the object (e.g., the head) was hidden. If infants now remove the occluder as a means of recovering the invisible part, their lifting or displacing of the occluder demonstrates the same motor skills and means–ends coordination needed to remove that occluder on total occlusions. Previous studies of the means–ends factor have either trained infants on a new means of recovery (e.g., pushing a button to obtain an occluded object; Munakata, McClelland, Johnson, & Siegler, 1997) or used a specialized occlusion not requiring occluder removal (e.g., Shinskey, 2002). The results with these methods suggest that means–ends coordination is not the source of young infants' difficulty with total occlusions. Our new procedure provides a check on this inference with the potential advantage that the means of recovery were the untrained, natural responses infants use with ordinary occlusions (e.g., lifting the cloth covering an object). Can infants who succeed on partial hidings in this way also succeed on total hidings?

A second factor that might affect manual search is the spatial relationship between the occluder and the occluded object. From a perceptual perspective, Bower (1982) predicted that when a perceptible distance separates an object and its occluding vertical screen, the object is perceived as 'behind' the occluder in 3D space. However, if the object shares boundaries with its occluder (e.g., 'under' cloths and 'inside' cups), the search task is made more difficult, because the occluder can be perceived as replacing the object rather than hiding it. Manual search tests of these predictions yielded mixed support (Dunst, Brooks, & Doxsey, 1982; Lucas & Uzgiris, 1977; Wishart & Bower, 1984); but Baillargeon and colleagues found evidence for the predicted developmental order using looking-time measures: Understanding ‘occlusion’ (behind) precedes ‘covering’ (under) and ‘containment’ (inside) (Hespos & Baillargeon, 2001; Wang, Baillargeon, & Paterson, 2005). The present studies systematically compared the behind and under spatial relations using manual search.

Third, previous work has suggested that memory limitations may contribute to infants’ manual search failures with totally occluded objects (Diamond, 1985; Harris, 1987). Infants may forget the object or they may forget where it was hidden. Experiment 2 attempted to ameliorate memory demands by hiding a continuously sounding object—thus reducing memory load by offering a perceptual clue to the object’s existence and location. The few studies directly comparing search for silent versus sounding objects on the same tasks have raised a possible distinction: when a cloth occluder was used, infants’ performance was improved by the sound (Bigelow, 1983; Ginsburg & Wong, 1973); however, with a solid upright occluder, there was no improvement (Legerstee, 1994). The inferences that can be drawn from this collection of studies are unclear because they confound spatial relations with the sound-transmission qualities of the occluder used (‘behind’ solid vertical screens versus ‘under’ horizontal cloth occluders). We used the same material horizontally and vertically by creating a vertical cloth occluder—a washcloth stretched over an open frame—and hid both sounding and silent objects. This allowed us to disentangle the relevant factors (behind-sounding, behind-silent, under-sounding, under-silent) to assess the effects of sound versus spatial relations.

Two experiments were conducted and, taken together, they provide new information allowing us to: (a) explain why understanding partial occlusions is a necessary precursor to developing a notion of object permanence and (b) specify a mechanism of change that could lead to permanence. The heart of this view is that infants maintain the identity of an object over occlusion events at an earlier age than they maintain its permanence; when they can construe the disappearances–reappearances of an object as involving a single individual object, they use experience with these events to develop a new interpretation of occlusions—the object continues to exist in the place hidden by the occluder.

1. Experiment 1: partial versus total occlusions

This experiment tested infants’ manual search for partially versus totally occluded objects at 8.75 months of age using a rigorous protocol. The partial occlusion served as a control for whether infants had the means–ends coordination and motor skills needed to remove the occluder in the total occlusion task. Vertical and horizontal occluders were used to gauge the relative difficulty of the ‘behind’ and ‘under’ spatial relations.

Based on previous research, two procedural safeguards were instituted on both the total and partial occlusions. First, the occlusion events occurred with the infants out of reach of the objects. Thus, infants were ‘out-of-action’ until after the occlusion was complete and could not launch their reach on the basis of a still-visible object. This safeguard is used in some recent publications (e.g., Moore & Meltzoff, 1999; Riviere & Lécuyer, 2003) but not in the older studies of partial occlusion. Second, since young infants’ attention and manual action can be drawn to an occluder by virtue of the fact that an experimenter ‘touched it last,’ rather than because the infant is searching for the occluded object (Diamond, Cruttenden, & Neiderman, 1994; Smith, Thelen, Titzer, & McLin, 1999), infants in this study saw the experimenter touch both occluders before search was allowed.

1.1. Method

1.1.1. Participants

The participants were 32 8.75-month-old infants, all tested within ±5 days of the target age of 38 weeks ($M = 38$ weeks, S.D. = 0.30 weeks). Half of the participants were female. They were recruited by telephone from the University’s computerized participant pool. Pre-established criteria for admission into the experiment were that infants be of normal birth weight (2.5–4.5 kg), normal length of gestation (40 ± 3 weeks), and have no known visual, motor or mental handicaps. Direct measures of socioeconomic status were not obtained; but based on previous analyses of the same participant pool, the sample was primarily middle- to upper-middle class. According to parental report, 27 of the participants were White; 3 were Asian; 1 was Black; and 1 was of Hispanic ethnicity. All of the participants came to the laboratory without siblings to avoid distractions. Four additional infants were tested but dropped from the study due to: crying (3) and refusing to watch a hiding event (1).

1.1.2. Test environment, materials and apparatus

Testing took place within a three-sided chamber. The walls and ceiling of the chamber were lined with gray paper. The rear wall of the chamber had a small hole for videotaping. Infants sat on their parents' lap across a table from the experimenter and facing the rear wall. The table's top was 125 cm wide × 90 cm deep and provided a black background for the objects. In the middle of the infants' side, a 25 cm wide by 20 cm deep 'notch' was cut so infants could slide into the notch and be enclosed on three sides when sitting at the table (see Moore & Meltzoff, 1999). Two cameras videotaped the experiment: one focused on the infants, the tabletop and occluders; the other focused on a close-up of the infants' face and body.

Both horizontal cloths and vertical screens were used as occluders. The cloths were made of white Terry cloth (30 cm × 25 cm), and the vertical screens were made of gray plastic (16 cm × 16 cm) with a 2.5 cm base flange. The occluders were situated on the table in a left–right arrangement such that the nearest inside edges were 25 cm apart. The objects hidden were: a pink-colored rubber baby (10 cm × 5 cm × 4 cm); a salmon-colored, plastic, hammer-shaped rattle (10 cm × 5.7 cm × 2.3 cm); a white-rubber squeak toy with a bear face atop a cylindrical shaft (13 cm × 6.7 cm × 4 cm); and a brown plastic articulated horse (10.2 cm × 9.5 cm × 2.5 cm).

1.1.3. Design

Each infant was presented with two hiding tasks, a partial occlusion and a total occlusion, with each infant serving as his/her own control. For each infant, the occluder (horizontal or vertical) was the same for both tasks. The locations of the hiding (left or right) and the objects hidden were changed between trials. Infants were randomly assigned to conditions, counterbalancing for: task order (partial/total), occluder (horizontal/vertical), side of the first hiding, and sex of the infant.

1.1.4. Procedure

1.1.4.1. Pre-assessment. Upon arriving at the laboratory, infants were brought to a waiting room and allowed to acclimate for about 10–15 min. The parents then carried their infants into the test chamber and sat at the table with the infants on their lap. The parents' chair enabled them to roll away from the table, or toward it until the infant's stomach touched the innermost edge of the notch.

In the warm-up period, the experimenter played with colored rings while the infant was rolled away from the table; then, he would say 'It's your turn,' leave the rings on the table, and the infant would be rolled forward to play with them. The experimenter would then say, 'Watch,' take the rings back, and repeat the process. 'Watch' and 'It's your turn' were signals to the parent to roll away from the table and forward to it, respectively. This pre-assessment practice was effective in establishing a turn-taking game and teaching infants to wait until they were rolled to the table before reaching for the objects. The occluders were then introduced for exploration and play. The object to be hidden (the toy) was placed between the occluders on the experimenter's side of the table, while the infant was focused elsewhere. When the infant noticed the toy, it was pushed within reach. For the occlusion events, the toy was placed on the table so that its nearest edge was about 3 cm inside the infant's reach space.

1.1.4.2. Assessment. For both hiding tasks, the following procedures were identical. The infants were rolled back 20 cm from the table and held under the arms by the parent so they could not lunge forward before the object disappeared. The parent was not signaled to roll forward until after the hiding was finished and the experimenter's empty hand had returned to the center of the table. The response period was a fixed interval and electronically timed; it started from the moment the infant's stomach touched the table edge after rolling forward and ended when the object was fully revealed or 20 s had elapsed. If infants recovered the object, they were allowed to pick up the object and play with it. If they were unsuccessful, the experimenter uncovered it in its place of disappearance, and infants were then allowed to pick-up and play with it. After approximately 30 s, the toy for the second hiding was put on the table as the first had been. When the infants had seen both toys together, the first one was removed from the table.

1.1.4.2.1. Partial occlusion. A stationary object was partially hidden by movement of an occluder. The endpoint of the occlusion was that 50% of the object, including the entire head, was hidden under (horizontal) or behind (vertical) the occluder. To begin, the object was laid flat on the table between the occluders, and the infants' attention attracted to it. For the horizontal occluders, the experimenter folded one cloth laterally in half, grasped the end of the object, and pushed it halfway into the place on the table exposed by folding the cloth. The object was then partially occluded by slowly folding the cloth back to its original position. For the vertical occluders, the experimenter grasped the end of the object and pushed it halfway into the area of the table in front of the screen. The object was then partially occluded by lifting the screen from behind the object and slowly lowering it onto the table between the infants and the object (approximately 3 cm from the object). After the partial occlusion, the experimenter's transport hand returned to the center of the table, palm up, and his non-transport hand touched the other occluder (to ensure that the infants had noticed it). After the infants had looked at the other occluder and at the centered, empty hand, the experimenter said, 'It's your turn,' and the parents rolled the infants to the table.

1.1.4.2.2. Total occlusion. A stationary object was completely hidden by movement of an occluder. The total occlusion task was administered in exactly the same way as the partial occlusion with one exception: the object was pushed fully into the place on the table exposed by folding the cloth, or fully into the area of the table in front of the screen. After the occlusion, the result was that 100% of the object was hidden under or behind an occluder.

1.1.4.3. Scoring procedures. The scorer was naïve to both the purpose of the experiment and the hypotheses, and the tapes were scored without listening to the sound track. The video records of all 64 trials (32 infants × 2 trials) were scored in a random order, with the restriction that trials from the same infant had to be more than four trials apart. The scorer viewed the video segments in real time or frame by frame as needed to achieve accuracy.

Willatts (1984) and others have pointed out the need to distinguish 'playing with the occluder' from removing the occluder in order to uncover the hidden object—which he called 'intentional' search. The chief criterion of intentional search is that infants expect their search action to reveal the object (Moore & Meltzoff, 1999; Willatts, 1984). Following this previous work, *successful search* was operationally defined as infants manually displacing the correct occluder while maintaining visual fixation on the disocclusion event until the object (or its invisible part) reappeared. Maintaining fixation required continuous focus without being distracted by the moving occluder or hand. In order to count as occluder displacement, the occluder had to be moved to reveal at least half of the previously occluded table surface or half of the previously invisible part. The scorer assigned a 'yes/no' score to each trial based on the first occluder displaced by the infant. A 'yes' was scored if the correct occluder was successfully removed (as defined above); a 'no' was scored if the occluder was not successfully removed or the wrong occluder was displaced. For infants who received a 'no,' a further score was assigned in the partial-occlusion condition. If infants grasped the visible part and pulled on it so that the object was fully revealed, this was scored as *pulling out*.

Scoring agreement was assessed by re-scoring a randomly selected 25% of the trials by both the principal and a second scorer (who was similarly naïve to the experimental purposes). Intra- and inter-scorer agreements were assessed using Cohen's kappa, and all were excellent. The intra- and inter-scorer kappas for successful search and pulling out were, respectively, 1.0, 1.0; and 0.91, 0.91.

1.2. Results and discussion

Each infant was given both the partial and the total occlusion task. Each infant either solved: Both the partial and the total occlusion tasks, neither task, or one task but not the other. Such within-subject data are appropriately analyzed using the McNemar test for change (Siegel, 1956). The critical cells of the McNemar test for task differentiation fall on the diagonal in Table 1. If the partial occlusion task is easier than the total occlusion task, there should be more infants who solve partial occlusion and fail total occlusion than the converse. There was a significant difference in infants' success on the two tasks. In the critical diagonal cells, 15 infants succeeded on the partial occlusion but not the total occlusion versus 1 infant who did the converse, as shown in bold in Table 1 ($p < 0.001$, McNemar test). This differentiation obtained regardless of the spatial relation between object and occluder: For infants who saw the object disappear 'under' a horizontal occluder, the relevant diagonal data were 6 versus 1; and for infants who saw it disappear

Table 1
Experiment 1: number of infants searching successfully by removing the occluder as a function of both partial and total occlusions

Partial occlusion	Total occlusion	
	No	Yes
Yes	**15**	1
No	15	**1**

Note: 11 of the 16 infants, who did not successfully remove the occluder on the partial occlusion (bottom row), pulled out the object to recover it.

'behind' a vertical occluder, the diagonal data were 9 versus 0. The same task differentiation between partial and total occlusions was also found using the first trial data alone. The number of infants succeeding on the partial occlusion in their first trial was 7 of 16 versus 1 of 16 on the total occlusion ($p < 0.02$, Fisher's exact test).

These results go beyond the normative studies reporting that partial hidings are solved before total hidings (Kramer et al., 1975; Miller et al., 1970; Piaget, 1954; Uzgiris & Hunt, 1975). No previous study of partial occlusions: (a) had the tasks independently scored from video records by observers who were not present at testing, (b) used test periods of fixed duration rather than clinical judgments about what constituted a trial, (c) ensured that infants were out of action until the occlusion was complete (so they could not initiate search while the object was still fully visible), (d) adopted a task-administration procedure ensuring that infants could not 'succeed' by simply moving the occluder 'last touched' by the experimenter, and (e) tested whether the results were due to learning within the study (the significant first-trial effects reported here). All of these procedural safeguards were incorporated in the current experiments. The results comport with the findings in the literature but are now established under laboratory-controlled conditions.

The results show that 16 of the infants solved partial hidings by removing the occluder to uncover the object on the table. This requires the same motor skills and means–ends coordination needed to uncover the object after a total occlusion by that same occluder, yet only two infants did that. This new control confirms and extends previous reports that difficulty with means–ends and motor skills are not the source of manual search failure on total occlusion (see Shinskey & Munakata, 2003). The extension provided by the current work stems from the fact that the infants' search responses were untrained removals of ordinary occluders rather than trained responses and/or specialized occlusions (e.g., Munakata et al., 1997; Shinskey, 2002). The fact that multiple methods converge on the same answer helps solidify and sharpen the inference that the difficulties young infants have with total occlusions are not due to means–ends problems: Infants can have the means—as shown when *uncovering* a partially occluded object—but not use those means for the end of *uncovering* a totally occluded object. In Section 3 we consider the differences between these two occlusion events, the reasons for the (nearly) invariant developmental ordering and a proposed mechanism of developmental change.

2. Experiment 2: a developmental study

Experiment 2 was designed to explore developmental changes in manual search and whether a sound clue from a hidden object (sounding vs. silent) might differentially help younger (8.75-month-old) versus older (10-month-old) infants on the total occlusion task. In Experiment 1, Bower's (1982) prediction that the spatial relation 'behind' is easier than 'under' could not be evaluated on total occlusions because only two infants were successful. Therefore, both spatial relations were presented to the infants with and without sound in this experiment. The current study also sought to improve the video imaging procedures used in Experiment 1 to determine whether, as the occluder was removed, infants visually *anticipated* the place where the object should reappear before it was visible. Such anticipation would help indicate where infants understood the object to be *while invisible* and thereby capitalize more fully on the advantages of manual search suggested by Bremner (2000), Harris (1987), and Hood (2001).

2.1. Method

2.1.1. Participants

The participants were 64 infants: half were 8.75-month-olds ($M = 37.96$ weeks, S.D. = 0.39 weeks), and half were 10-month-olds ($M = 43.64$ weeks, S.D. = 0.33 weeks). All infants were tested within ±5 days of their target age. Half of the participants at each age were female. The recruitment procedure and pre-established criteria for admission into the study were the same as in Experiment 1. According to parental report, 59 of the infants were White, 1 was Asian/Pacific Islander, 3 were other (e.g., two or more racial groups), and 1 was of Hispanic ethnicity. Four additional infants were tested but dropped from the study due to: crying (3) and experimenter error (1).

2.1.2. Test environment and materials

The test environment and video recording procedures were the same as in Experiment 1. The horizontal occluders were the Terry cloth occluders used in Experiment 1. The vertical occluders were made by stretching Terry cloth over a plastic frame (16 cm × 16 cm) with 2.5 cm flanges to hold them upright. Two objects were used: a white, disc-shaped, wind up music box (3.8 cm thick × 7 cm in diameter; from 'Mobile Musical Dinos' by DAKIN); and a blue-plastic toy radio that played music (10.8 cm × 12 cm × 5 cm, Hasbro's 'Kid Clips' player).

2.1.3. Design

Each infant was presented with two total occlusion trials, one with a silent and the other with a sounding object. For each infant, the occluders (vertical or horizontal) remained the same across the two trials, but the object (music box or radio) and side of hiding (left or right) changed between trials. Infants were randomly assigned to groups such that there was counterbalancing within age for the occluder used, whether the first object was silent or sounding, the side of the first hiding, and the object first hidden.

2.1.4. Procedure

The pre-assessment and test procedures were the same as in Experiment 1. During warm-up play with the objects, the experimenter demonstrated their sounds and how they were turned on and off. To begin a trial, the infants' attention was attracted by activating the object's sound. When they had visually fixated on it for approximately 3 s, the experimenter either turned off the sound (silent condition), or left it on (sounding condition), for the duration of the hiding and subsequent response period.

2.1.4.1. Scoring procedures. The scorer was blind to the hypotheses and scored the videotapes without sound. The video records of all 128 trials (64 infants × 2 trials) were scored in a random order following the procedures of Experiment 1. In order to code the infants' visual behavior, one camera was focused on the infant's face at approximately eye level with a field of view from the top of the head to the immediate foreground. This enabled coders to relate eye movements to objects and events in the visual field and score spatially directed anticipatory looking (defined below).

The first occluder displacement was scored. It was classified as *successful search* if the infant displaced the correct occluder while anticipatorily looking at the object's spatial locus until it reappeared. In order to count as occluder displacement, the occluder had to be manually moved from its initial location to reveal at least half of the previously occluded table surface. Anticipatory looking was defined as looking to the object's locus of reappearance simultaneously with the start of occluder displacement and maintaining fixation there until the infant saw the object. Looking was considered 'simultaneous' if it occurred in the interval starting with the occluder's displacement and ending when either: (a) the infant could see the object or (b) the previously occluded table surface was physically half uncovered. The principal and a second scorer re-coded a randomly selected 25% of the trials to assess scoring agreement. Both intra- and inter-scorer agreements were high. The intra- and inter-scorer kappas for successful search were, respectively, 0.93 and 0.85.

2.2. Results and discussion

The experiment was counterbalanced for occluder, object first hidden, sound order, and side of the first hiding. A preliminary analysis found no significant main effects or interactions for these factors ($F < 1.4$ and $p > 0.24$); they were collapsed for the main analyses.

Infants were given two total occlusion trials, and therefore received a score that ranged from 0 to 2 depending on the number of trials passed successfully. As expected, the older infants were more successful than the younger ones (Mann–Whitney $U = 256.50$, $p < 0.001$). This was true in both the silent and the sounding-object conditions. For the sounding condition, 21 of 32 (65.6%) 10-month-olds succeeded versus 5 of 32 (15.6%) 8.75-month-olds ($\chi^2(1, N = 64) = 14.58$, $p < 0.001$). For the silent condition, 9 of 32 (28.1%) 10-month-olds were successful versus 2 of 32 (6.3%) 8.75-month-olds ($\chi^2(1, N = 64) = 3.95$, $p < 0.05$). Additionally, more of the older (9 of 32) than the younger infants (0 of 32) succeeded on *both* the sounding and silent object tasks ($p < 0.002$, Fisher's exact test).

As shown in Table 2, the 10-month-old infants profited from the sound: 12 infants succeeded with a sounding object, but not with a silent object, versus 0 infants who did the converse ($p < 0.001$, McNemar test). For 8.75-month-olds, the sound had no significant impact on infants' success: five infants succeeded with a sounding object but not with a silent object versus two infants who did the converse ($p > 0.45$, McNemar test). This age-related effect of sound also held for the first-trial data. For 10-month-olds, the number of infants succeeding with sounding objects (10 of 16) was significantly greater than those succeeding with silent objects (3 of 16) ($\chi^2(1, N = 32) = 4.66$, $p < 0.03$). For 8.75-month-olds, the number of infants succeeding with sounding objects (4 of 16) was not significantly different from the number succeeding with silent objects (2 of 16) ($p > 0.65$), Fisher's exact test.

Table 2
Experiment 2: number of infants succeeding/failing on total occlusions as a function object sound and age

Sounding object	Silent object			
	8.75 months old		10 months old	
	Fail	Succeed	Fail	Succeed
Succeed	5	0	12	9
Fail	25	2	11	0

Infants were no more successful on total occlusions when the object's spatial relation was 'behind' vertical occluders than when it was 'under' horizontal occluders (Mann–Whitney $U = 450.00$, $p = 0.35$). On the first trial, 7 of 16 10-month-olds succeeded with the horizontal occluders versus 6 of 16 with the vertical occluders.

In sum, the results replicate the finding of Experiment 1 that 8.75-month-olds did not search successfully for a silent, stationary object totally hidden by an occluder. However, Experiment 2 shows a developmental change: The 10-month-olds successfully searched for stationary objects under these conditions, and they did so with spatially directed anticipatory looking to the object's locus of reappearance. Moreover, the introduction of sound helped the older but not the younger infants, and the spatial relations (behind/under) made no difference at either age. This provides a rich data set for theory construction.

3. General discussion

Two experiments investigated infants' manual search for partially and totally occluded objects. In Experiment 1, 16 of the 8.75-month-olds successfully removed the occluder on the partial-occlusion task but only 2 infants used this ability to remove the same occluder on the total-occlusion task. Experiment 2 showed that the sounding object led to significant improvement in success for 10-month-olds but not for 8.75-month-olds.

These findings raise several issues: (a) why did infants with the ability to remove an occluder after a partial occlusion fail to do so after a total occlusion, (b) what develops between 8.75 and 10 months of age that led to success with total occlusions, and (c) why does sound aid search for the older but not the younger infants?

Two accounts can be offered to explain why motorically skilled infants might not use those skills on total occlusions: (a) memory limitations and (b) spatial relations between object and occluder. First, the memory demands posed by the total occlusion task might be too great, causing infants to forget the object. However, in Experiment 2, the object emitted a continuous sound, presumably preventing infants from simply forgetting the object. Even with this potential memory aid, 8.75-month-olds did not search significantly more for the sounding object, which suggests that a limited memory span was not the sole impediment to success. Second, Bower (1982) argued that search for an object hidden 'behind' an occluder should be easier than 'under' one. However, there were no significant differences in infants' success as a function of the behind versus under spatial relations at either age. The difficulty in searching for totally occluded objects, then, is not reducible to infants' particular difficulty with the spatial relationship 'under' between an object and its occluder.

These failures to search are puzzling, and all the more so because younger infants will reach toward objects that have disappeared in other ways. For example, 5-month-olds will reach toward an invisible, silent object after the room lights have been turned off (Bower & Wishart, 1972; Hood & Willatts, 1986). This phenomenon is impressive because the reaching is not based on auditory localization of a sounding object in darkness as is more commonly studied (e.g., Perris & Clifton, 1988). However, we would argue that such reaching in the dark is not based on the same representational underpinning that infants use to search for a totally occluded object. All disappearances are not the same. Disappearances caused by darkness and those caused by occluding an object differ in significant ways. Psychophysical work with both adults and infants underscores this. Michotte (1962) found that adults perceived an abrupt, whole field disappearance (turning off the lights) as maintaining a short-lived phenomenal persistence of the world, and occlusions defined as gradual, local, and perspectival (like the ones used here) were perceived as maintaining such phenomenal persistence for an occluded object. These Michottean psychophysical parameters also differentiate the behavioral reactions of 8-week-olds (Bower, 1967, which he termed 'existence constancy') and the EEG responses of 6-month-olds (Kaufman, Csibra, & Johnson, 2005, which they termed 'neural correlates of representational persistence'). Michotte (1962) argued that these psychophysical parameters undergird a *short-term* perceptual process that serves to maintain the phenomenal stability of the visual world in the face of change (e.g., head turns, eye closures, rapid disappearance and reappearance events; see also Gibson, 1979). It is intriguing to speculate that turning out the lights is like freezing the perceptual frame, and reaching in the dark is a targeted means of exploring this phenomenon. Turning off the lights is similar to a sustained eye closure. Visual input is suspended, and no further input occurs to change the infants' last view of the external world. In this case, infants' 'freeze frame' representation of their once visible surroundings (including the target object) would continue over some short-term decay function.

Could such representations support search for an object hidden by darkness? Apparently not at first: Hood and Willatts (1986) conducted a microanalysis and reported that first reaches were random (p. 61), which is not consistent with intentional search for a permanent object residing in an invisible location. It would also be interesting to check whether infants reached out with an open hand and closed it around the spatial locus where the object was expected to be. Such hand-shaping and grasping measures were not taken; rather, Hood and Willatts found a change in the distribution of arm extensions—reaches in the direction of the object's last seen position increased and those in the alternative direction decreased. This leads to the speculation that infants' last visual input before the 'freeze frame' might have biased their attentional focus and exploratory reaching activity towards the nearest section of the represented surround (which would be towards the object, given the experimental layout). These ideas can be tested. The most powerful test would be to assess infants' goal-directed grasping at the locus of the invisible object (as if expecting to find an object there).

In contrast to turning off the lights, a total *occlusion* involves a gradual, local invisibility of part of the visual world. Where there was an object, there is 'gradual deletion at an edge' leaving only an occluder in view. Updating of the representation is required as the object disappears—a 'freeze frame' will not do. In this case, visual input from the world continues, the spatial arrangement of the infants' surroundings is directly perceived, and only the object and its location are transformed to invisibility. The pre-occlusion perception and post-occlusion representation of object and surroundings are nearly identical for whole field disappearances caused by turning off the lights (the 'freeze-frame') versus object occlusions where they are markedly different. This pre- to post-occlusion change may be a fundamental source of infants' difficulty in interpreting the disappearing and reappearing object as the numerically identical individual, with important implications for infants' notion of permanence (see identity discussion below). For these reasons, we suggest that search for an occluded object and reaching in the dark, at least as currently tested, may tap different representational processes. Reaching in the dark seems to be a special case. The more general case in the real world, and certainly the more usual case, is one object occluding another object. The basic question is whether, after observing an object's gradual occlusion, the infant thinks it continues to reside in a specific, invisible location in the physical world while it is still hidden. The current studies were designed to bear on this question.

3.1. An identity-based account of the genesis of permanence

We favor a developmental account for the pattern of age-related changes observed in our data. Our hypothesis has two interwoven parts. First, infants' understanding of partial occlusions is a necessary precursor to locating stationary objects that are totally occluded. Second, infant's spatial criterion for identifying the same individual object over disappearances and reappearances (thus preserving numerical identity) underlies their understanding of occlusion events and the genesis of permanence.

Regarding the first point, where is the object when it is out of sight? In this case, the location of the occluded object can be specified by its relationship to another object, the table. The *place* where the object resides after it is hidden is a portion of the table's surface that is now also hidden; however, the entire surface of the table is only partially hidden. If infants first understand partial occlusions by representing the invisible part of an object in relation to its visible part (the invisible part is physically located/attached at its boundary with the visible part), then the invisible part of the occluded object can be put into relationship with the invisible part of the table—both parts are hidden by the same occluder. Experiences of occluder displacement would reveal the two invisible pieces as co-located, which offers infants an alternative interpretation of subsequent partial occlusion events. Such representational coordination presumably underlies infants' removing the occluder rather than always pulling on the visible part of a partially hidden object. Consider now the total occlusion of an object for an infant who understands the partial occlusion of the table surface. The occluded place on the partially occluded table continues to exist after occlusion and provides an invisible location for the totally occluded object to reside while it is out of sight. Thus, infants could understand that there is somewhere for the totally occluded object to be. We suggest that this development in spatial cognition is a critical factor accounting, at least in part, for why success on partial occlusions is a precursor to success on total occlusions.

The second interwoven point is that this occluded place on the table's surface could play a role in re-identifying a reappearing object as 'the same one again' (a numerical identity) based on spatial parameters. That is, studies of occlusion have found that featurally identical objects disappearing and reappearing in *different places* are treated as different objects by infants 10 months of age or younger, whereas featurally different objects disappearing and reappearing in the *same place* are not differentiated until 12 months of age (Newcombe, Huttenlocher, & Learmonth, 1999; Van de Walle, Carey, & Prevor, 2000; Xu & Carey, 1996). Thus, the spatial parameter of 'place' appears to serve as an identity criterion for infants in the age range tested in these experiments. If infants can identify the reappearing object as the same one that disappeared because it is in the same place (spatial identity criterion), this would enable them to generate a more comprehensive interpretation from their experience with disappearances and reappearances. A finding from the current experiments is compatible with this notion: There was no difference in infants' success on hidings 'under' versus 'behind' occluders. This makes sense because the place on the table is the same spatial location regardless of how it is occluded or disoccluded. Occluders simply block the view to that *place*.

The hypothesized developmental logic then is as follows. For infants to discover through everyday experience that an object continues to exist in a particular hidden location, the object's disappearance and reappearance in that location must be construed as involving one and the same object, a numerical identity. Unless this identity can be established, appearing objects are new and different ones, rather than reappearances of the *same* one. And, if new and different objects are popping into view after occlusions, the question of what happens to a single object between appearances never arises, and the answer cannot be learned. However, infants who understand partial occlusions are developmentally poised to discover how to understand total occlusions from experience. They can construe the locus of disappearance and reappearance as the same continuously existing *place* on the *partially occluded table top*, and therefore the object appearing there is the same individual again according to the spatial identity criterion. This, in turn, gives infants the opportunity to interpret the disappearance event as preserving the object: The self-same object continues to reside at that invisible place and is simply hidden between encounters (for further discussion of this identity account of the development of permanence, see Meltzoff & Moore, 1998; Moore, Borton, & Darby, 1978; Moore & Meltzoff, 1999, 2004).

Why did sound from the object aid search by the older but not the younger infants? Once infants have a framework for identifying disappearing and reappearing objects as one and the same, sound could provide valuable information about how to interpret an object's disappearance. Consider what the older infants understand about this situation: They remember the object and where it disappeared; they would expect a stationary object to reappear in the place it disappeared (Newcombe et al., 1999); they are just beginning to understand total occlusions (since only 9 of the 32 succeeded with silent objects); and, by our earlier account, at some point they should begin to apply their understanding of partially occluded objects to the partially occluded table surface. In our view, permanence takes the character of an *interpretation* placed on observed physical events, such as the disappearances and reappearances of an object. Thus, sound from the hidden object, localized as coming from the partially occluded surface, might help catalyze a reinterpretation: the unseen object that is the source of this sound remains on that partially occluded surface. Such an interpretative event is argued to account for why more of the older infants uncover the sounding object than they do the silent one or than the younger infants do with or without sound.

3.2. Reconsidering the dissociation between manual search and looking-time assessments of object permanence

In order to force infants to act off of their representation of the occluded object, infants in the present studies observed the object's occlusion while it was out of reach. They were thus prevented from initiating a reach until after the occlusion was complete (and they had been brought back within reach, see Section 1.1.4). From that point on, any action taken toward the hidden object would have to be governed by their representation of it. Under these conditions, spatially correct search with anticipatory looking to the object's reappearance locus implies that the occluded object is represented as residing at that hidden location *while occluded*. In short, the object was treated as permanent over the occlusion event and infants' prediction of its hidden location guided search.

Looked at in this way, there appears to be a commonality across the kinds of occluded object tasks that are failed by younger infants—namely, tasks that require a prediction of the occluded object's location. In the present studies, infants had to organize their search on the basis of a stationary object's predicted location on the occluded table surface.

In the von Hofsten (Jonsson & von Hofsten, 2003; Spelke & von Hofsten, 2001) and Berthier et al. (2001) studies, infants had to organize their 'catching' act on the basis of a moving object's predicted trajectory as it emerged from behind an occluder. Young infants, even with the requisite reaching skills, were unable to do so. Both our occlusion task and theirs demand that infants interpret the visible disappearance event as bearing on an unseen state of affairs behind the occluder in order to generate a predictive response.

If this account is correct, then it offers a rationale for why looking-time and manual search measures of permanence would diverge. The looking-time measures investigate whether infants can discriminate events whose visible outcomes do not accord with ordinary physics from those that do. That is, most looking time studies present a pre-occlusion visual scene and ask whether the subsequent post-occlusion scene is unexpected (more looking) or expected (less looking). Crucially, in either case the infants are looking at an event outcome in the visible world. In contrast, success on search tasks assesses infants' understanding of the *invisible outcomes* of occlusion events because search can be initiated and directed to the object while it remains hidden. Search acts reflect infants' prediction of where an occluded object is located before reappearance. Another way of saying this is that looking time measures assess infants' *post-diction* of whether the post-occlusion outcome is consistent or inconsistent with the pre-occlusion state of affairs; whereas search measures assess *prediction* (Hood, Carey, & Prasada, 2000; Meltzoff & Moore, 1998).

In sum, the current studies contribute to an emerging view of infant cognition in which early representational ability underlies and relates memory, prediction, and action within a spatial framework. We suggest that environmental feedback from making predictions and taking action in the world contributes to the development of concepts like 'object permanence'—which then are used to interpret events and specify the goals of prospective action in both visible and occluded space (Cohen & Cashon, 2006; Johnson, Amso, & Slemmer, 2003; Meltzoff & Moore, 1998; Munakata & Stedron, 2002; Newcombe & Huttenlocher, 2006; von Hofsten, 2007).

Acknowledgments

This work was supported by a grant from the National Institute for Child Health and Human Development (HD-22514). We are especially appreciative of Geraldine Dawson's contribution to the pilot study enabling this work. We gratefully acknowledge the assistance of Calle Fisher, Craig Harris, and Dawn Kragness and thank Bruce Hood for insightful comments on an earlier version of this paper.

References

Aguiar, A., & Baillargeon, R. (2002). Developments in young infants' reasoning about occluded objects. *Cognitive Psychology*, *45*, 267–336.

Baillargeon, R. (2004a). Infants' physical world. *Current Directions in Psychological Science*, *13*, 89–94.

Baillargeon, R. (2004b). Infants' reasoning about hidden objects: Evidence for event-general and event-specific expectations. *Developmental Science*, *7*, 391–414.

Berthier, N. E., Bertenthal, B. I., Seaks, J. D., Sylvia, M. R., Johnson, R. L., & Clifton, R. K. (2001). Using object knowledge in visual tracking and reaching. *Infancy*, *2*, 257–284.

Bigelow, A. E. (1983). Development of the use of sound in the search behavior of infants. *Developmental Psychology*, *19*, 317–321.

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

Bower, T. G. R. (1982). *Development in infancy* (2nd ed.). San Francisco: Freeman.

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

Bremner, J. G. (2000). Developmental relationships between perception and action in infancy. *Infant Behavior & Development*, *23*, 567–582.

Bremner, A. J., & Mareschal, D. (2004). Reasoning. . .what reasoning? *Developmental Science*, *7*, 419–421.

Cohen, L. B., & Cashon, C. H. (2006). Infant cognition. In D. Kuhn, R. S. Siegler, W. Damon, & R. M. Lerner (Eds.), *Handbook of child psychology* (pp. 214–251). Hoboken, NJ: Wiley.

Diamond, A. (1985). Development of the ability to use recall to guide action, as indicated by infants' performance on A$\bar{\text{B}}$. *Child Development*, *56*, 868–883.

Diamond, A., Cruttenden, L., & Neiderman, D. (1994). A$\bar{\text{B}}$ with multiple wells: 1. Why are multiple wells sometimes easier than two wells? 2. Memory or memory + inhibition? *Developmental Psychology*, *30*, 192–205.

Dunst, C. J., Brooks, P. H., & Doxsey, P. A. (1982). Characteristics of hiding places and the transition to stage IV performance in object permanence tasks. *Developmental Psychology*, *18*, 671–681.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Ginsburg, H. J., & Wong, D. L. (1973). Enhancement of hidden object search in six-month-old infants presented with a continuously sounding hidden object. *Developmental Psychology*, *9*, 142.

Harris, P. L. (1987). The development of search. In P. Salapatek & L. Cohen (Eds.), *Handbook of infant perception* (pp. 155–207). New York: Academic Press.

Hespos, S. J., & Baillargeon, R. (2001). Infants' knowledge about occlusion and containment events: A surprising discrepancy. *Psychological Science*, *12*, 141–147.

Hood, B. (2001). When do infants know about objects? *Perception*, *30*, 1281–1284.

Hood, B. M. (2004). Is looking good enough or does it beggar belief? *Developmental Science*, *7*, 415–417.

Hood, B., Carey, S., & Prasada, S. (2000). Predicting the outcomes of physical events: Two-year-olds fail to reveal knowledge of solidity and support. *Child Development*, *71*, 1540–1554.

Hood, B., & Willatts, P. (1986). Reaching in the dark to an object's remembered position: Evidence for object permanence in 5-month-old infants. *British Journal of Developmental Psychology*, *4*, 57–65.

Johnson, S. P., Amso, D., & Slemmer, J. A. (2003). Development of object concepts in infancy: Evidence for early learning in an eye-tracking paradigm. *Proceedings of the National Academy of Sciences*, *100*, 10568–10573.

Jonsson, B., & von Hofsten, C. (2003). Infants' ability to track and reach for temporarily occluded objects. *Developmental Science*, *6*, 86–99.

Kaufman, J., Csibra, G., & Johnson, M. H. (2005). Oscillatory activity in the infant brain reflects object maintenance. *Proceedings of the National Academy of Sciences*, *102*, 15271–15274.

Kramer, J. A., Hill, K. T., & Cohen, L. B. (1975). Infants' development of object permanence: A refined methodology and new evidence for Piaget's hypothesized ordinality. *Child Development*, *46*, 149–155.

Legerstee, M. (1994). The role of familiarity and sound in the development of person and object permanence. *British Journal of Developmental Psychology*, *12*, 455–468.

Lucas, T. C., & Uzgiris, I. C. (1977). Spatial factors in the development of the object concept. *Developmental Psychology*, *13*, 492–500.

Marcovitch, S., & Zelazo, P. D. (1999). The A-not-B error: Results from a logistic meta-analysis. *Child Development*, *70*, 1297–1313.

Meltzoff, A. N., & Moore, M. K. (1998). Object representation, identity, and the paradox of early permanence: Steps toward a new framework. *Infant Behavior & Development*, *21*, 201–235.

Michotte, A. (1962). *Causalité, permanence, et réalité phénoménales: Études de psychologie expérimentale*. Louvain: Publications Universitaires.

Miller, D. J., Cohen, L. B., & Hill, K. T. (1970). A methodological investigation of Piaget's theory of object concept development in the sensory-motor period. *Journal of Experimental Child Psychology*, *9*, 59–85.

Moore, M. K., Borton, R., & Darby, B. L. (1978). Visual tracking in young infants: Evidence for object identity or object permanence? *Journal of Experimental Child Psychology*, *25*, 183–198.

Moore, M. K., & Meltzoff, A. N. (1999). New findings on object permanence: A developmental difference between two types of occlusion. *British Journal of Developmental Psychology*, *17*, 623–644.

Moore, M. K., & Meltzoff, A. N. (2004). Object permanence after a 24-hr delay and leaving the locale of disappearance: The role of memory, space, and identity. *Developmental Psychology*, *40*, 606–620.

Munakata, Y., McClelland, J. L., Johnson, M. H., & Siegler, R. S. (1997). Rethinking infant knowledge: Toward an adaptive process account of successes and failures in object permanence tasks. *Psychological Review*, *104*, 686–713.

Munakata, Y., & Stedron, J. M. (2002). Memory for hidden objects in early infancy: Behavior, theory, and neural network simulation. In J. Fagen & H. Hayne (Eds.), *Progress in infancy research* (pp. 25–69). Mahwah, NJ: Erlbaum.

Newcombe, N. S., & Huttenlocher, J. (2006). Development of spatial cognition. In D. Kuhn, R. S. Siegler, W. Damon, & R. M. Lerner (Eds.), *Handbook of child psychology* (pp. 734–776). Hoboken, NJ: Wiley.

Newcombe, N., Huttenlocher, J., & Learmonth, A. (1999). Infants' coding of location in continuous space. *Infant Behavior and Development*, *22*, 483–510.

Perris, E. E., & Clifton, R. K. (1988). Reaching in the dark toward sound as a measure of auditory localization in infants. *Infant Behavior & Development*, *11*, 473–491.

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

Riviere, J., & Lécuyer, R. (2003). The C-not-B error: A comparative study. *Cognitive Development*, *18*, 285–297.

Shinskey, J. L. (2002). Infants' object search: Effects of variable object visibility under constant means-ends demands. *Journal of Cognition and Development*, *3*, 119–142.

Shinskey, J. L., & Munakata, Y. (2003). Are infants in the dark about hidden objects? *Developmental Science*, *6*, 273–282.

Siegel, S. (1956). *Nonparametric statistics for the behavioral sciences*. New York: McGraw-Hill.

Smith, L. B., Thelen, E., Titzer, R., & McLin, D. (1999). Knowing in the context of acting: The task dynamics of the A-not-B error. *Psychological Review*, *106*, 235–260.

Spelke, E. S. (1994). Initial knowledge: Six suggestions. *Cognition*, *50*, 431–445.

Spelke, E. S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of knowledge. *Psychological Review*, *99*, 605–632.

Spelke, E., & Hespos, S. (2001). Continuity, competence, and the object concept. In E. Dupoux (Ed.), *Language, brain and cognitive development: Essays in honor of Jacques Mehler* (pp. 325–340). Cambridge: MIT Press.

Spelke, E. S., & von Hofsten, C. (2001). Predictive reaching for occluded objects by 6-month-old infants. *Journal of Cognition and Development*, *2*, 261–281.

Uzgiris, I. C., & Hunt, J. M. (1975). *Assessment in infancy: Ordinal scales of psychological development*. Urbana: University of Illinois Press.

van der Meer, A. L. H., van der Weel, F., & Lee, D. N. (1994). Prospective control in catching in infants. *Perception*, *23*, 287–302.

Van de Walle, G. A., Carey, S., & Prevor, M. (2000). Bases for object individuation in infancy: Evidence from manual search. *Journal of Cognition and Development*, *1*, 249–280.

von Hofsten, C. (2007). Action in development. *Developmental Science*, *10*, 54–60.

von Hofsten, C., Vishton, P., Spelke, E. S., Feng, Q., & Rosander, K. (1998). Predictive action in infancy: Tracking and reaching for moving objects. *Cognition*, *67*, 255–285.

Wang, S.-h., Baillargeon, R., & Paterson, S. (2005). Detecting continuity violations in infancy: A new account and new evidence from covering and tube events. *Cognition*, *95*, 129–173.

Willatts, P. (1984). Stages in the development of intentional search by young infants. *Developmental Psychology*, *20*, 389–396.

Wishart, J. G., & Bower, T. G. R. (1984). Spatial relations and the object concept: A normative study. In L. P. Lipsitt & C. Rovee-Collier (Eds.), *Advances in infancy research* (pp. 57–123). Norwood, NJ: Ablex.

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