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# The Effects of Graded Occlusion on Manual Search and Visual Attention in 5- to 8-Month-Old Infants

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Young infants may be limited in searching for hidden objects because they lack the means–end motor skill to lift occluders from objects. This account was investigated by presenting 5- to 8-month-old infants with objects hidden behind transparent, semitransparent, and opaque curtains. If a means–end deficit explains search limitations, then infants should search no more for an object behind a transparent curtain than for objects behind semitransparent or opaque curtains. However, level of occlusion had a significant effect on manual search and visual attention. Infants retrieved and contacted the object more, contacted the curtain more, and looked away less with the transparent curtain than with the semitransparent or opaque curtains. Adding a time delay before allowing search and presenting a distraction after occlusion further depressed infants' behavior. The findings fail to support the means–end deficit hypothesis, but are consistent with the account that young infants lack object permanence.

When do infants acquire object permanence? Is the acquisition gradual, remaining incomplete until they reach the age of approximately 8 to 10 months (Munakata, 1997; Piaget, 1954)? Or do infants considerably younger than 8 to 10 months have object permanence, but are able to display this knowledge only in certain kinds of tasks (Baillargeon, 1993; Baillargeon, Spelke, & Wasserman, 1985)? More specific, when looking rather than reaching is examined in occlusion events, do infants younger than 8 months old demonstrate object permanence?

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Piaget (1954) concluded that infants do not have object permanence before 8 to 10 months of age, although he reported a gradual progression from 4 to 8 months that revealed increasingly sophisticated knowledge about objects. (The term *object permanence* is contrasted with *object concept:* Infants demonstrate object permanence at 8 to 10 months when they retrieve a completely hidden object, but do not demonstrate the full object concept, according to Piaget, until 18 to 24 months when they retrieve invisibly displaced hidden objects.) From 4 to 8 months, infants visually track falling objects, retrieve hidden objects with which they had tactile contact prior to disappearance, reengage in action with a previously discarded object without external stimulation, retrieve partly visible objects, and remove occluders from their own faces, as in "peek-a-boo" interactions (Piaget). Nevertheless, he observed that it is not until about 8 to 10 months that infants search for a completely hidden object. Piaget's findings are robust because they have been independently replicated (e.g., Appel, as cited in Gratch, 1976; Bower & Wishart, 1972; Bruner, 1970; Gratch & Landers, 1971; Kimball, 1971; Schofield & Užgiris, as cited in Gratch, 1975, 1977; Užgiris & Hunt, as cited in Gratch, 1977; Willatts, 1984). The general interpretation of these findings at the time was that young infants do not manually search for hidden objects because they do not know that hidden objects continue to exist.

This interpretation has been countered with the suggestion that young infants' failure to demonstrate object permanence in manual search tasks may result primarily from motor deficits rather than from lack of conceptual knowledge (e.g., Bower & Wishart, 1972; Diamond, 1993; Rader, Spiro, & Firestone, 1979). That is, infants in Piaget's (1954) reaching task may know that the hidden object continues to exist, but be unable to reveal this knowledge because of motor deficits. The motor sequencing deficit (e.g., Diamond) is one specific motor deficit proposed to account for young infants' search limitations: Infants less than 8 months cannot coordinate multiple reaches to remove the occluder (means) and obtain the object (end), although they know the object exists behind the occluder.

It is arguable whether this deficit is one of enacting the motor sequence or planning the motor sequence. Bower and Wishart (1972) originally presented the problem as one of poor manual skill. Likewise, Rader et al. (1979) referred to the problem as one of undeveloped motor skill. In addition, Diamond (1993) presented the deficit as originating from the immaturity of the supplementary motor area (SMA) of the frontal cortex; as the SMA matures between 5 and 8 months, infants become capable of combining actions together in a sequence. In contrast, Baillargeon (1993) argued that the deficit is not one of performing motor sequences, but one of planning them, which results from poor problem-solving ability. The deficit is presented in this article in terms of a motor skill problem. At least three lines of research address this premise that a means–end motor deficit accounts for young infants' search limitations.

First, several investigators have studied infants in tasks requiring means–end action sequences. Such action sequences require the ability to plan the motor sequence of removing the occluder (means) to get to the hidden object (end). For example, with training, 7-month-old infants learn to pull a cloth to draw into reach a hidden object resting on top of the cloth, and also learn to push a button to make a shelf fall and bring a hidden object into reach (Munakata, McClelland, Johnson, & Siegler, 1997). By 8 months old, infants spontaneously use the means–end action sequence of pulling a cloth to get a hidden toy resting on top of it (Willatts, 1985, 1989). Baillargeon (1993; Baillargeon, DeVos, & Black, as cited in Baillargeon, Graber, DeVos, & Black, 1990; Baillargeon et al., 1990) argued that infants less than 8 months old can distinguish between possible and impossible means–end action sequences, but not perform them, due to limited problem-solving ability. For example, when presented with visual displays of an experimenter performing either correct or incorrect actions to retrieve a hidden object, 5½-month-old infants looked longer at incorrect or impossible actions that resulted in object retrieval than at correct or possible actions (Baillargeon et al., 1990).

Second, it has been argued that if an infant can retrieve an object from a transparent occluder but not from an opaque occluder, then performance may be determined less by a motor deficit than by an object concept deficit. In support of this argument, several investigators have reported that 5- to 7-month-old infants retrieve objects more often from transparent cups, covers, containers, and screens than from opaque ones (Bower & Wishart, 1972; Gratch, 1972; Munakata et al., 1997; Neilson, 1982; Yonas, as cited in Bower & Paterson, 1972). These results suggest that infants have the necessary motor skills to remove an occluder to get to an object, implying that when they fail with opaque occluders, it may be because they do not know the hidden object is there.

The third line of research focuses on infants' looking, rather than reaching, during occlusion tasks. Because infants have control over the visual system sooner than they have control over reaching and grasping, looking may be a more sensitive measure of infants' knowledge regarding occluded objects. Several researchers have claimed that infants between 2 and 8 months of age search for or anticipate the reappearance of an occluded object (e.g., Bower, 1967; Bower, Broughton, & Moore, 1971; Gratch, 1982; Kimball, 1971; Munakata, Jonsson, Spelke, & von Hofsten, 1996; Murai & Nihei, 1983; Nelson, 1974; von Hofsten & Lindhagen, 1982). However, the evidence is not consistent: Other investigators employing similar visual tracking tasks have failed to find evidence of object permanence in infants younger than 8 months of age (e.g., Goldberg, 1976; Meicler & Gratch, 1980; Moore, Borton, & Darby, 1978; Prazdny, 1980; Simoneau & Decarie, 1979).

Looking during occlusion has also been studied using a paradigm of habituation–dishabituation (e.g., Baillargeon, 1993). In this paradigm, the infant is habituated to or familiarized with one event, and then presented with two occlusion events that are featurally similar to the familiarization event, but that differ from each other in an important way: One event is impossible, given the occluded object's continued existence, and the other is possible. Infants between 3½ and 8 months look longer at impossible occlusion events than at possible occlusion events (e.g., Baillargeon, 1986; Baillargeon & DeVos, 1991; Baillargeon & Graber, 1987; Baillargeon et al., 1985), suggesting that they have object permanence. However, other researchers have reported that variables other than the impossibility of the events used in Baillargeon's (1993) design affect infants' looking and that the results are better explained by perceptual mechanisms. For example, in several habituation–dishabituation studies, infants' looking times were better determined by novelty preferences, familiarity preferences, and preferences for more motion than by the possibility or impossibility of the event (e.g., Bogartz, Shinskey, & Schilling, in press; Bogartz, Shinskey, & Speaker, 1997; Cashon & Cohen, in press; Rivera, Wakeley, & Langer, 1999; Schilling, in press).

Another aspect of occlusion tasks related to manual search concerns the type of occluder. Some occluders are easier to manipulate than others. For example, infants less than 8 months old have greater success at retrieving hidden objects from small card covers and vertical screens than from cloth covers (Bower, 1974; Brown, as cited in Dunst, Brooks, & Doxsey, 1982; Rader et al., 1979). Inverted cups and upright boxes are more difficult than screens and cloths for 6-month-old infants but not 10-month-old infants (Dunst et al., 1982).

Concealing an object by turning out the lights rather than hiding it behind or under another object also affects infants' behavior. Infants at 5, 6, and 7 months old are relatively successful in reaching for and retrieving both sounding and silent objects hidden by extinguishing the room lights (Bower & Wishart, 1972; Clifton, Perris, & Bullinger, 1991; Clifton, Rochat, Litovsky, & Perris, 1991; Goubet & Clifton, 1998; Hood & Willatts, 1986; McCall & Clifton, 1996; Munakata, 1997). However, the results of studies that use sounding objects provide less convincing evidence that young infants have object permanence because perceptual cues of the object are still available.

There is some evidence that infants visually anticipate the reappearance of an object hidden by darkness sooner than that of an object hidden by a screen (Munakata et al., 1996). The explanation for this advantage of retrieving objects in the dark may be that infants can reach directly for an object in the dark but must coordinate a means–end sequence of behavior to retrieve an object hidden by a barrier in the light, which requires more cognitive and motor skill. Another explanation is that darkness affects infants' representation of the hidden object less than a visible barrier does (Munakata et al., 1996).

One other aspect of task differences that bears on infants' search for hidden objects has to do with whether infants are less likely to search for no object than for an object. One would not expect an infant with object permanence to search for an object if none had been hidden. Yet, whether an object is hidden or not, 7-month-old infants appear to be just as likely to search when the occluder is opaque, although not when it is transparent (Munakata et al., 1997). Eight-month-old infants also appear to be just as likely to reach in the dark for an occluder behind which no object was hidden as for an occluder behind which an object was hidden (McCall & Clifton, 1996). In other research, by about 8 months old, infants begin to express concern at finding no object after seeing an object hidden (Charlesworth, as cited in Gratch, 1977). Nine-month-old infants do not search under a cover when they see no object hidden, unless they have prior experience finding the object there, but 12 month-old infants do not search when no object is hidden, regardless of prior experience (Appel, as cited in Gratch, 1976, 1977; Appel & Gratch, 1984). Thus, the observation that until 12 months of age infants are as likely to search even when no object has actually been hidden suggests some deficits in object permanence.

## THE EXPERIMENT

We approach the question of whether deficits in searching for a hidden object are more likely due to limited motor skill or to lack of object permanence by continuing investigation of young infants' behavior with transparent occluders as well as opaque occluders. We presented 5- to 8-month-old infants with three occluding curtains of varying levels of transparency: transparent, semitransparent, and opaque (see Figure 1). If young infants rarely retrieve hidden objects primarily because they have limited motor skill, then infants in this experiment should be comparably likely to retrieve the object from the transparent, the semitransparent, and the opaque curtains. On the other hand, if young infants rarely retrieve hidden objects because they lack object permanence, then infants in the experiment should be more likely to retrieve the object from the transparent curtain than from the semitransparent and opaque curtains.

If young infants lack object permanence but have a very brief fading representation of the object, a short delay or distraction may depress their search when an opaque or semitransparent curtain occludes the object. To investigate this issue, on some trials we presented infants with a 3-sec delay before moving the hidden object within reach, and on some trials we presented them with a different distractor object to one side of the target object.

In previous research and in our pilot work for this study, we have repeatedly noticed that young infants quickly look away after an object is occluded. We interpret these rapid looks away as being incompatible with the notion that the infants are confronting a means–ends problem, which they have difficulty solving. These rapid looks away seem more compatible with the hypothesis that out of sight implies out of mind. The infants look away because the object of interest is gone. Therefore, we systematically measured infants' looking in response to the events.

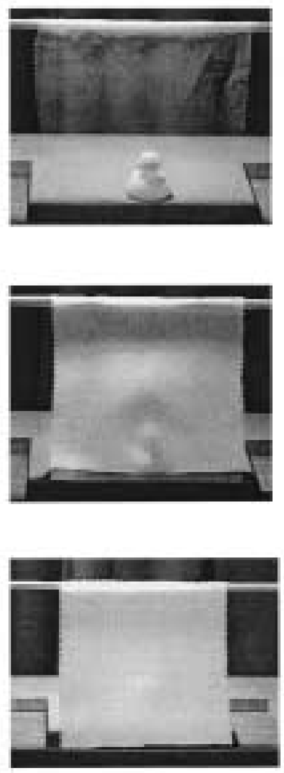

**FIGURE 1** The transparent, semitransparent, and opaque events.

Finally, an infant with object permanence should not search on a trial when no object is hidden because the infant should know that no object exists behind the occluder. However, an infant without object permanence should act no differently on trials when an object is hidden than on trials when no object is hidden. In this experiment, infants received one trial on which no object was presented; yet, an opaque curtain was hung on the apparatus and presented to them. Infants' reaching and looking on this trial was compared with their reaching and looking on the same type of trial in which an object was presented and occluded.

## METHOD

### Participants

Thirty-six full-term infants (20 female, 16 male) from the Amherst, Massachusetts, area participated in the study. Infants ranged in age from 4 months 3 weeks to 8 months 1 week, with a mean age of 6 months 2 weeks. Five additional infants were tested but not included in the sample because of experimenter error (2), lack of reaching (2), and parental interference (1). Participants were recruited from newspaper birth announcements. Parents were contacted by mail and a subsequent telephone call. Parents were not compensated for participation.

## Apparatus

Two chairs were placed at opposite sides of a table (75 cm × 115 cm) located in the center of a brightly lit room (300 cm × 225 cm). A 40-cm tape measure was taped to the edge of the table perpendicular to the infant to allow measurement of the length of the infant's reaches. The apparatus consisted of a 40.5-cm × 40.5-cm square Masonite platform with two vertical poles (2 cm × 2 cm × 41.5 cm) secured to the two front corners. A metal hook was fastened to the back of each pole, approximately 19 cm from the base of the platform. A horizontal curtain dowel (1 cm × 54 cm) rested across these two hooks. The apparatus was painted gray.

Three curtains on separate dowels were used. Each curtain (20 cm × 20 cm) hung on the dowel loosely enough so that it could be moved aside by the infant. The transparent curtain consisted of tulle fabric—a thin netting that revealed all the features of the object behind it (see Figure 1). The semitransparent curtain consisted of a gauzy white fabric that revealed some object features (e.g., color, size, shape) but less clearly than the transparent curtain. The opaque curtain consisted of a thick white polyester fabric that revealed no object features.

## Stimuli

The objects consisted of a variety of small and large rubber toys: a small yellow duck (5 cm × 4.5 cm × 5.5 cm), a large yellow duck (12.5 cm × 8 cm × 12.5 cm), a small green frog (4.5 cm × 4.5 cm × 6 cm), a large green frog (8 cm × 12 cm × 12 cm), a yellow bear (7 cm × 5.5 cm × 4 cm), a Miss Piggy (7.5 cm × 6.5 cm × 5.5 cm), a Winnie the Pooh bear (11 cm × 6.5 cm × 6.5 cm), and a Tigger cat (13.5 cm × 8 cm × 6.5 cm). Except for the ducks, each toy squeaked when squeezed.

## Equipment

A metronome clicked once per second to time each trial. Two video cameras recorded the infant and the event. One camera provided a view of the infant's face. The other was placed directly above the infant, providing an aerial view of the table and the movement of the infant's head, arms, and body. A video mixer recorded the two camera inputs on one videotape, which could be viewed on a monitor in an adjacent room. The aerial view formed the main image on the monitor, and the view of the infant's face served as an insert in the upper left corner of the screen.

## Events

Familiarization consisted of two trials in which the experimenter placed an object in full view on the platform and moved the apparatus toward the infant. There were four experimental events. In the transparent event, the experimenter placed the object in full view on the platform, hung the transparent curtain in front of it, and moved the apparatus toward the infant. The semitransparent and opaque events were identical to the transparent event except for the type of curtain used. Finally, in the opaque–no object event, the experimenter tapped her hand on the platform to get the infant's attention, hung the opaque curtain, and moved the apparatus toward the infant. For each curtain event, except the opaque–no object event, there was either a delay or no delay and a distraction or no distraction. On delay trials, the experimenter delayed moving the apparatus toward the infant for 3 sec after hanging the curtain. On distraction trials, just after the target object was occluded, the experimenter bounced a different toy up and down on the table within view to the right of the infant.

## Design

The basic design was a 3 (age level) × 3 (curtain type) × 2 (delay conditions) × 2 (distraction conditions) factorial design, with age level as a between-subject factor and curtain type, delay condition, and distraction condition as within-subjects factors. Each age group consisted of 12 infants. Infants in the youngest group ranged in age from 4 months 3 weeks to 5 months 3 weeks. Infants in the intermediate group ranged from 6 months 0 weeks to 7 months 0 weeks. Infants in the oldest group ranged from 7 months 1 week to 8 months 1 week.

Each infant experienced each of the three curtain types, combined with both delay and no delay and distraction and no distraction. For each curtain type, there was a trial with a delay and no distraction, a trial with a distraction and no delay, a trial with neither delay nor distraction, and a trial with both delay and distraction. Thus, for each infant, there were 4 transparent trials, 4 semitransparent trials, and 4 opaque trials. Each infant received the first 12 trials as determined by a single randomized Latin square that was used for each age group. For each infant, there was also a 13th trial on which no object was present and the opaque curtain was used (opaque–no object event).

## Procedure

The infant sat on the parent's lap across the table from the experimenter. The parent was instructed not to interact with the infant and to support the infant at the waist so that the infant would be able to reach freely.

The first two trials were familiarization trials. At the start of each trial, the experimenter squeaked the target object above the platform until the infant attended to it. The object was then placed on the platform for 2 sec, and then the experimenter moved the apparatus toward the infant for 3 sec, so that the object was within reaching distance. The infant was given approximately 15 sec to attempt to retrieve the object. If the infant did not attempt to retrieve the object, the experimenter handed it to the infant to explore. If the infant did not retrieve the object on the second familiarization trial, a different object was presented until the infant attempted retrieval.

Following the 2 familiarization trials, 13 curtain trials were presented. Each trial again began with a 2-sec placement of the object on the platform. The experimenter then took 3 sec to hang the curtain in front of the object and an additional 3 sec to move the apparatus toward the infant. On no-delay trials, the apparatus moved toward the infant immediately after the curtain was hung. On delay trials, the experimenter waited for an additional 3 sec after hanging the curtain before moving the apparatus toward the infant. On distraction trials, a different object was bounced up and down, approximately 10 cm to 15 cm to the right of the apparatus from the infant's perspective, for 5 sec immediately after occlusion of the target object (3 sec during which the apparatus was moving and 2 sec after it stopped directly in front of the infant). When the delay and distraction were combined, the distractor was bounced up and down for the 3 sec of the delay and the first 2 sec of the 3-sec period during which the apparatus moved toward the infant. Trial 13 always consisted of the opaque–no object event: The experimenter drew the infant's attention to the empty platform by tapping on it, placed the opaque curtain on the apparatus (3 sec), and moved the apparatus toward the infant (3 sec).

For all trials, once the apparatus stopped moving, the infant had approximately 15 sec to explore it and to attempt to retrieve the target object. If the infant did not retrieve the object, the curtain was removed so that the infant could witness that the object was still there. If the infant appeared to be in the middle of a retrieval attempt when the 15 sec had elapsed, the experimenter let the infant finish the attempt. If the infant made no apparent attempt to retrieve the object after three consecutive trials, the experimenter replaced the target and distractor objects with new objects. Once an infant had the object at the end of a trial, the infant was given several seconds to manipulate and explore the object before the start of the next trial.

With a few exceptions, the yellow bear and Miss Piggy were the target and distractor objects, respectively, for Trials 1 through 6. Winnie the Pooh and Tigger were the target and distractor objects for Trials 7 through 12. Exceptions occurred when the experimenter made an error at Trial 6 or 7, or when the original objects were replaced with new objects because the infant did not appear to be interested in the original objects.

At the end of the experiment, the experimenter explained the purpose of the study to the parent or parents. The experimenter thanked them and offered to mail them a description of the results once the statistical analyses were completed.

## Measures

The measures of manual search were as follows. *Retrieving the object* assessed whether the infant retrieved the object by grasping it and drawing it toward the body. *Revealing the object* was the number of times the infant revealed the object in the semitransparent and opaque events (object already visible in the transparent event) by uncovering it in any way so that it was visible from the infant's perspective while the infant was looking toward the apparatus. *Touching the object* was the number of times the infant contacted the object directly (not through the curtain) with at least one hand or arm while looking toward the apparatus. Both hands had to come off the object in between contacts for the contacts to be scored as separate touches. *Touching the curtain and object* was the number of times the infant contacted the object through the curtain with at least one hand or arm while looking toward the apparatus. Both hands had to come off the object between contacts. *Touching the curtain* was the number of times the infant contacted the curtain alone. Again, both hands had to leave the curtain between contacts. (All contacts that occurred when the infant was looking away from the apparatus were judged to be accidental touches, rather than deliberate search attempts, and were not included in the analyses.) *Number of reaches* was the number of times the infant reached by extending at least one arm toward any part of the apparatus. Finally, *centimeters* represented the number of centimeters the apparatus was from the infant's hand at the start of a reach.

The measures of visual attention were as follows. *Total look-away time* was the total amount of time in seconds the infant looked away from the apparatus, beginning with the moment of occlusion. *Latency to the first look away* was the amount of time in seconds the infant took to make a first look away from the apparatus. *Duration of the first look away* was the amount of time in seconds the infant's first look away from the apparatus lasted. *Direction of head turn* represented to which side of midline (90°) the infant's first head turn was made.

## Interobserver Reliability

Interobserver reliability was calculated for a subset of variables (two looking variables and four reaching variables) from a subset of six infants (two from each age group). For each variable, both observers scored 12 trials per infant. The average interobserver reliability across the six variables was .90.

### Missing Data

Missing scores were estimated using a weighted average of the participant's scores for all the other trials and the scores of all the other participants for that trial. Degrees of freedom for error were not adjusted for estimated scores because the analyses used contrast scores; a missing score constituted only a part of the contrast score, so that loss of 1 full *df* for a missing score was inappropriate. It is not clear how the degrees of freedom should be adjusted. The number of missing scores did not exceed 5% of the total number of scores for any dependent measure. The reader may choose to view the *p* values conservatively.

### Planned Contrasts

We decided to conduct two planned contrasts on the curtains factor and its interaction with other factors for all measures. If the infants do not have object permanence, the visibility of the object through the transparent curtain should contrast sharply with the lack of visibility through the semitransparent and opaque curtains (Contrast 1). However, little or no advantage should accrue from the lesser difference in visibility between the semitransparent and opaque curtains (Contrast 2). Thus, for all measures, the 2 *df* and corresponding sums of squares for the curtains factor were partitioned into 1 *df* for the contrast of the transparent curtain with the average of the semitransparent and opaque and 1 *df* for the contrast of the semitransparent with the opaque curtain. Similarly, for all interactions of curtains with other factors, the degrees of freedom and sums of squares were partitioned such that a test was performed on the interaction of Contrast 1 with those other factors and on Contrast 2 with those other factors. Because of the large number of dependent measures, a large number of tests were conducted. However, the number of tests per measure is not out of line with the number of planned comparisons typically used. In addition, sample size (36 in this study) is not an obstacle to conducting multiple tests when the tests are planned in advance. (For further information, refer to Miller's [1981, pp. 31–35] discussion on families of hypotheses.)

## RESULTS

### Manual Search

*Retrieving the object.* The proportion of retrievals was greater for the oldest infants (.44) than for the intermediate (.24) or youngest (.24) infants: $F(2, 33) =$

3.95, $p < .05$. Contrast 1 revealed that infants retrieved the object more often from the transparent curtain (.53) than from the semitransparent and opaque curtains (.19): $F(1, 33) = 43.66$, $p < .001$. Contrast 2 showed that infants also retrieved the object more often from the semitransparent curtain (.24) than from the opaque curtain (.14): $F(1, 33) = 6.64$, $p < .05$. Thus, the degree of visibility of the object had a significant effect on infants' retrieval.

A significant interaction of Contrast 2 with delay demonstrated that with no delay, retrievals with the semitransparent curtain (.17) were the same as retrievals with the opaque curtain (.19), but with a 3-sec delay, retrievals with the semitransparent curtain (.32) occurred four times as often as retrievals with the opaque curtain (.08), $F(1, 33) = 8.68$, $p < .01$. Contrast 2 also interacted with distraction, $F(1, 33) = 6.93$, $p < .05$. When the curtain was opaque, retrieval was the same with (.14) or without (.14) distraction. But when the curtain was semitransparent, retrieval occurred twice as often without (.33) distraction as with (.16).

*Revealing the object.* The three age groups did not differ in the number of times they revealed the object. However, infants revealed the object more frequently when the curtain was semitransparent (.27) than when it was opaque (.18), $F(1, 33) = 4.66$, $p < .05$. Infants also revealed the object more frequently when there was no distraction (.28) than when there was distraction (.16), $F(1, 33) = 9.15$, $p < .01$. Interpretation of the distraction effect is complicated by a significant Curtain × Delay × Distraction interaction, $F(1, 33) = 5.99$, $p < .05$. Further analyses revealed that the distraction condition was only having a significant effect with the semitransparent curtain under the delay condition, in which the mean was .41 without distraction but only .12 with distraction, $F(1, 33) = 10.23$, $p < .01$. As with the retrieval measure, the combination of a delay with the semitransparent curtain appears to be beneficial, but the absence of distraction is required.

*Touching the object.* Contrast 1 demonstrated that infants touched the object significantly more often with the transparent curtain (.57) than with the semitransparent and opaque curtains (.25), $F(1, 33) = 18.11$, $p < .001$. Inspection of the Curtain × Age and Curtain × Distraction interactions, both of which were not quite significant, revealed no systematic patterns.

*Touching the curtain and object.* At all three age levels, Contrast 1 revealed that infants touched the curtain and object together more often with the transparent curtain (.91) than with the semitransparent and opaque curtains (.46), $F(1, 33) = 38.87$, $p < .01$. Contrast 2 showed that infants did not touch the curtain and object more frequently with the semitransparent curtain (.50) than with the opaque curtain (.42). The combined touch was made more often when there was no distraction (.69) than when there was distraction (.53), $F(1, 33) = 5.78$, $p < .05$. This distraction effect is qualified by a significant Curtain × Delay × Distraction interaction, $F(2, 66) = 3.50$, $p < .05$, shown in Figure 2. The means suggest that when the curtain was transparent, the effect of distraction occurred regardless of delay, but the frequency of the joint touch remained high. When the curtain was semitransparent, the effect of distraction was limited to the delay condition; the means suggest the same facilitating effect of the combination of the semitransparent curtain with delay when there was no distraction. When the curtain was opaque, the joint contact occurred on only about 30% of the trials, except when there was no distraction or delay.

*Touching the curtain.* The only significant result for this measure was an Age × Delay interaction, $F(2, 33) = 4.22$, $p < .05$. Without delay, the means for the youngest, intermediate, and oldest infants were .35, .46, and .40, respectively, and with delay they were .50, .24, and .46, respectively.

*Number of reaches.* Contrast 1, $F(1, 33) = 24.12$, $p < .001$, revealed that infants reached more often to the transparent curtain (2.37 reaches) than to the semitransparent and opaque curtains (1.76), but this contrast interacted with age, $F(2, 33) = 5.18$, $p < .05$. The mean values for the youngest, intermediate, and oldest infants were 1.00, .77, and .06. respectively. The mean was significantly different from 0 for the youngest infants, $F(1, 33) = 21.59$, $p < .001$, and for the intermediate age infants, $F(1, 33) = 12.78$, $p < .01$, but not for the oldest infants. A significant ef-

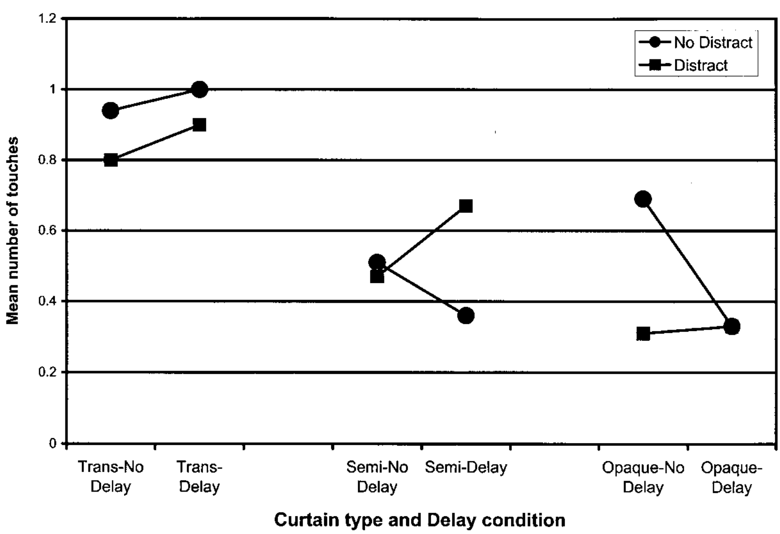


**FIGURE 2** Mean number of times infants touched the curtain and object together, as a function of curtain type, delay condition, and distraction condition.

fect of delay, $F(1, 33) = 8.17$, $p < .01$, revealed that infants reached more with delay (2.11 reaches) than without (1.82). Finally, a significant effect of distraction, $F(1, 33) = 7.30$, $p < .05$, revealed that infants reached more often without distraction (2.08 reaches) than with distraction (1.85).

*Centimeters.* This measure assessed the distance between the infant's hand and the apparatus at the start of the reach. Contrast 1 demonstrated that infants reached farther for the apparatus with the transparent curtain (23.95 cm) than with the semitransparent and opaque curtains (17.94 cm), $F(1, 33) = 28.66$, $p < .001$. Infants also reached farther for the apparatus when there was no distraction (23.34 cm) than when there was distraction (18.56 cm), $F(1, 33) = 12.41$, $p < .01$. In addition, a Contrast 1 × Distraction interaction occurred, such that the transparent–nontransparent contrast was greater with no distraction (27.35 cm vs. 20.54 cm, respectively) than with distraction (19.32 cm vs. 16.57 cm), $F(1, 33) = 4.50$, $p < .05$.

## Visual Attention

*Total look-away time.* Contrast 1 revealed that infants spent less time looking away from the apparatus with the transparent curtain (10.50 sec) than with the semitransparent and opaque curtains (15.38 sec), $F(1, 33) = 39.64$, $p < .001$. Contrast 2 showed that infants also looked away less when the curtain was semitransparent (14.64 sec) than when it was opaque (16.11 sec), $F(1, 33) = 4.33$, $p < .05$. Finally, infants looked away less when there was no distraction (12.08 sec) than when there was distraction (15.42 sec), $F(1, 33) = 36.25$, $p < .001$.

*Latency to the first look away.* Contrast 1 demonstrated that the latency to the first look away was longer with the transparent curtain (6.12 sec) than with the semitransparent and opaque curtains (2.06 sec), $F(1, 33) = 51.93$, $p < .001$. Figure 3 shows that this contrast interacted with age, $F(2, 33) = 3.47$, $p < .05$. Latency to the first look away remained the same across age when the curtain was semitransparent or opaque, but went down with age when the curtain was transparent. This is probably because the older infants were able to obtain the object from behind the transparent curtain faster than the younger ones were.

An effect of delay revealed that infants looked away sooner if the movement of the apparatus toward them was delayed (2.84 sec) than if it was not (3.98 sec), $F(1, 33) = 8.94$, $p < .01$. This finding is important because it allows rejection of the suggestion made to us that infants look away because of the looming of the apparatus as it approaches them. If the look away were due to the looming of the apparatus, infants should have looked away sooner with no delay than with delay because the apparatus approached them and was closer to them sooner.

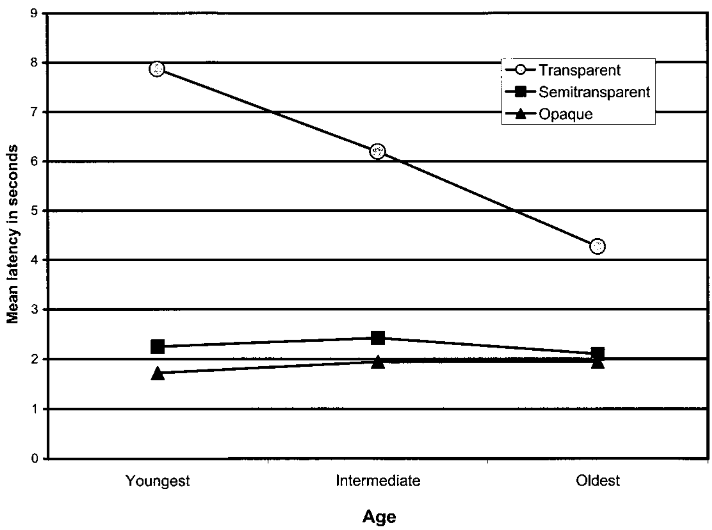


**FIGURE 3** Mean latency to the first look away, as a function of age and curtain type.

An effect of distraction also revealed that infants looked away sooner with distraction (1.93 sec) than with no distraction (4.89 sec), $F(1, 33) = 47.61$, $p < .001$. Contrast 1 and the distraction effect are qualified by a Curtain × Distraction interaction, $F(2, 66) = 10.76$, $p < .001$, which can be seen in Figure 4. The difference between distraction and no distraction was larger for the transparent curtain (5.59 sec) than for the semitransparent and opaque curtains (1.64 sec). We interpret this finding as indicating that the less likely the infants are to know that the object is behind the curtain, the sooner they were to look away, and therefore the more redundant the effect of distraction was. It is as if occlusion itself functioned as a distractor or repeller of attention.

The pattern of values in Figure 4 suggests that when the curtain was transparent, the effects of delay and distraction were additive but when the curtain was semitransparent or opaque, the delay only had an effect when there was no distraction. Analysis for the transparent curtain alone showed no Delay × Distraction interaction but analysis for the semitransparent and opaque curtains showed a Delay × Distraction interaction, $F(1, 33) = 8.08$, $p < .01$. With no distraction, infants looked away 1.36 sec faster under delay than under no delay, but with distraction the difference was only .07 sec. This lack of effect of delay for the semitransparent and opaque curtains under distraction suggests a possible floor effect, perhaps indicating that the infants looked away about as fast as they could. The results appear consonant with the notion that the less the infants could see the object, the more rapidly they were distracted.

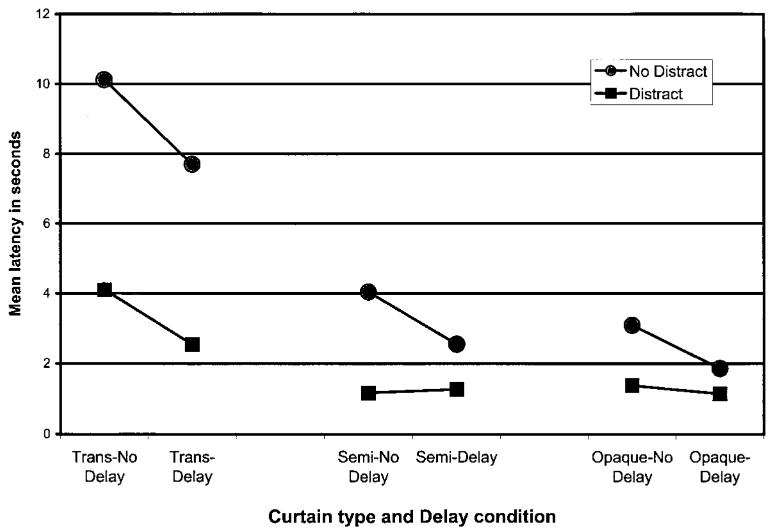


**FIGURE 4** Mean latency to the first look away, as a function of curtain type, delay condition, and distraction condition.

*Duration of the first look away.* Contrast 1 revealed that infants' first look away was shorter with the transparent curtain (2.98 sec) than with the semitransparent and opaque curtains (4.08 sec), $F(1, 33) = 20.39$, $p < .001$. The first look away also lasted longer with distraction (4.88 sec) than without (2.55 sec), $F(1, 33) = 88.44$, $p < .001$. Figure 5 shows a significant Curtain × Distraction interaction, $F(2, 66) = 8.67$, $p < .001$. With no distraction, the duration of the first look away was virtually identical for the three curtains at an average of 2.55 sec. With distraction, the duration of the first look away with the semitransparent and opaque curtains remained identical but rose to an average of 5.66 sec, whereas with the transparent curtain the rise was to only 3.34 sec. When the curtain was not transparent, distraction not only drew the infant's attention away sooner, but also held attention away longer than when the curtain was transparent.

*Direction of head turn.* There were more first head turns to the right of midline (90°) when the curtain was opaque (108.85°) than when it was semitransparent (99.02°), with the transparent curtain yielding an intermediate value of 102.62° that did not differ from either of the other two, $F(2, 66) = 3.08$, $p = .05$. More turns to the right were expected because the distraction event took place on the infant's right. The effect of distraction, $F(1, 33) = 118.20$, $p < .001$, confirms this expectation: With no distraction, the average first head turn was to 89.19°, indicating that without distraction, head turns were made as often to the left as to the right. On the other hand, with distraction, the average first head turn was to 116.86°, indicating that the distraction event effectively captured infants' attention.

## No-Object Trials

We conducted a contrast on all dependent measures for the opaque curtain trial with no delay or distraction versus the opaque curtain–no-object trial (with no delay or distraction). Infants with object permanence would be expected to engage in more intentional search when they see an object hidden than when they do not. However, of the seven measures on which the two events were compared, there were only three significant effects. First, infants reached more often when an object was hidden behind the opaque curtain than when it was not (1.58 reaches vs. 1.08), $F(1, 33) = 4.83$, $p < .05$. Second, infants reached farther when an object was hidden behind the opaque curtain than when it was not (18.34 cm vs. 11.48 cm), $F(1, 33) = 4.53$, $p < .05$. Third, the duration of the first look away was longer when no object was hidden than when an object was hidden for the intermediate and oldest age groups, but the reverse was true for the youngest age group, $F(2, 33) = 3.37$, $p < .05$.

In regard to the first two results, because the opaque–no-object trial was always the last trial in the experiment, the infants were perhaps relatively more bored or fatigued by that point. To investigate the boredom–fatigue hypothesis, number of reaches was plotted as a function of trials. Number of reaches tended to increase

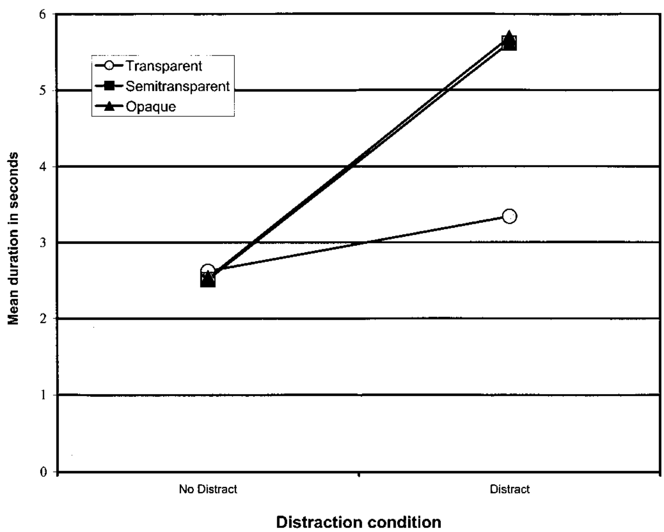


**FIGURE 5** Mean duration of the first look away, as a function of curtain type and distraction condition.

over the first half of the trials, reaching a maximum on Trial 7 and then dropping over the remaining trials, reaching a minimum on Trial 13. A quadratic polynomial fit to the trial means gave an inverted "U" pattern with a curvilinear correlation of .66. Removing the final point for Trial 13, the no-object trial still yielded an inverted U-shaped curve with a curvilinear correlation reduced to .40. Because type of event was balanced over the first 12 trials, the data suggest that the decreased responsiveness to the 13th no-object trial may have been due to a response decrement that was independent of the type of trial. The confounding of the no-object trials with trial number in this study weakens the result but perhaps should be pursued in future work.

## DISCUSSION

The major finding was that the degree of occlusion significantly affected young infants' manual search and visual attention. When the object was visible behind the transparent curtain, relative to the average of the semitransparent and opaque curtains, infants reached farther, reached more often, touched the object more often, and retrieved the object more often. Furthermore, infants looked away sooner and longer when the object was hidden behind the semitransparent and opaque curtains than when it was behind the transparent curtain. There were additional effects of age, delay, and distraction indicating that a younger age, a 3-sec delay, and a distraction event depressed manual search and visual attention. Finally, the results suggest little difference in infants' behavior whether the opaque curtain hid an object or not.

These findings contribute to the body of research on object permanence in young infants. It has repeatedly been shown that infants do not uncover a hidden object until between the ages of 8 and 10 months (e.g., Appel, as cited in Gratch, 1976; Bower & Wishart, 1972; Bruner, 1970; Gratch & Landers, 1971; Kimball, 1971; Piaget, 1954; Schofield & Užgiris, as cited in Gratch, 1975, 1977; Užgiris & Hunt, as cited in Gratch, 1975, 1977; Willatts, 1984). However, many researchers have reported that young infants' looking behavior on occlusion tasks suggests that they have substantial knowledge about occluded objects before 8 to 10 months old (e.g., Baillargeon, 1986, 1993; Baillargeon & DeVos, 1991; Baillargeon & Graber, 1987; Baillargeon et al., 1985; Bower, 1967; Bower et al., 1971; Gratch, 1982; Kimball, 1971; Munakata et al., 1996; Murai & Nihei, 1983; Nelson, 1974; von Hofsten & Lindhagen, 1982). A deficit in means–end planning has been proposed to account for the apparent discrepancy between reaching and looking: The claim is that young infants may know the hidden object is there but cannot coordinate their motor behavior to move the cover away from the hidden object (means) to then reach for the object (end).

These results do not support the means–end deficit explanation. If the means–end deficit explanation were correct, then infants should have had just as much difficulty searching for the object behind the transparent curtain as for the objects behind the semitransparent and opaque curtains. Yet, they were significantly more likely to reach, touch the object, and retrieve the object in the transparent event than in the semitransparent and opaque events. This result corresponds to the findings of others (e.g., Bower & Wishart, 1972; Gratch, 1972; Munakata et al., 1997; Neilson, 1982; Yonas, as cited in Bower & Paterson, 1972), suggesting that it was the visibility of the object that primarily determined infants' behavior, and not a means–end motor deficit. Furthermore, infants were also more likely to reveal the object, retrieve the object, and look away less in the semitransparent event than in the opaque event. These results fail to support to the hypothesis that search limitations are rooted in a means–end deficit. In contrast, the finding is consistent with the proposal that infants' representations may be graded in nature (Munakata, 1997).

This study was different from other studies using transparent occluders, however. We used a yielding cloth occluder, with the expectation that it would be even easier for infants to negotiate than a rigid transparent occluder. We also included an intermediate curtain type that was semitransparent. There were enough differences in performance to show that the infants were sensitive to the difference between the reduced visibility of the object with the semitransparent curtain and no visibility of the object with the opaque curtain. Nevertheless, although adults reported that they could see the object behind the semitransparent curtain, most infants acted as if the object were no longer present.

This study was also unique in that it investigated concurrent looking behavior during what was essentially a reaching task. We believed visual attention may be reflective of higher level cognitive activity if such were occurring. Contacts that occurred while the infant was looking toward the object's location more often appeared deliberate than contacts that occurred while the infant was looking elsewhere. Furthermore, assessing behavior such as latency to the first look away demonstrated that infants visually "disconnected" fairly quickly after the object became invisible. This finding suggests that they were not mentally engaged in searching for the object or trying to determine a reaching solution. We have recently noted in our laboratory (Shinskey, 2000) that 10-month-old infants who clearly have object permanence almost never look away after an object is hidden until they have it in hand. They remain visually engaged in the task, despite being unable to see the object. The question arises as to why younger infants would look away if they know the occluded object is behind the occluder, in light of the fact that older infants who definitely know the object is there do not look away.

Because this study also contained a no-object trial, it allowed us to see whether infants would behave any differently whether an object was actually hidden or not. Although there were two results suggesting that infants were less likely to search when no object was hidden than when an object was hidden, the remaining results were not significant. However, methodological problems limit the conclusion.

Nevertheless, other investigators have reported little or no difference among infants' behavior in comparisons of hidden-object events and no-object events (Appel, as cited in Gratch, 1976, 1977; Appel & Gratch, 1984; Charlesworth, as cited in Gratch, 1977; McCall & Clifton, 1996; Munakata et al., 1997).

If a means–end deficit does not appear to account for the discrepancy in results from looking and reaching experiments with young infants, then what does? Why do young infants appear to have sophisticated object concept knowledge at 3 or 4 months old in looking studies, and yet appear to lack object permanence at 6 or 7 months old in reaching studies? One possibility is that the two types of events tap different kinds of representations. Perhaps a relatively weak or latent representation is sufficient to guide infants' responses in visual habituation studies, but a stronger, more active representation is necessary to guide manual search in reaching studies (Munakata, 1997). Yet another possibility is that there is really no discrepancy at all; it may be that the visual habituation studies assess something other than object permanence. Infants' looking times to possible and impossible occlusion events may be determined by perceptual processes rather than object permanence knowledge. In support of this account, some investigators have found that infants' looking times in some visual habituation studies can be explained by novelty preferences, familiarity preferences, and preferences for more motion (Bogartz et al., 1997; Bogartz & Shinskey, 1998; Bogartz et al., in press; Rivera et al., 1999).

Despite the lack of support for the means–end deficit hypothesis by the results presented in this article, the study has limitations. First, as in all infant research, failure to demonstrate a particular ability does not necessarily indicate that infants lack the ability. It could be that young infants do have the concept of object permanence but were unable to demonstrate it in these particular tasks. Furthermore, there may be some other unknown limit apart from any deficits in means–end motor skill that prevents infants with object permanence from manually searching for hidden objects.

Second, although only contacts that occurred while infants were looking toward the apparatus were analyzed (because contacts that occurred while infants were looking elsewhere were clearly accidental), it is likely that not all such contacts were intentional or deliberate attempts to search for the hidden object. It is possible that some such contacts were intentional search attempts and others were not. Infants may have engaged in contact with the semitransparent and opaque curtains because there was little else for them to do, and not because they were searching for the object. Or, they may have contacted the curtains because they were deliberately searching. In our judgment, the majority of infants in this study contacted the semitransparent and opaque curtains to play with them and not to retrieve the object behind them; however, some of the behavioral measures do not decisively demonstrate this.

Finally, we make no claim that these results definitively refute the means–end motor deficit hypothesis. There is some evidence that the means–end motor deficit hypothesis does not primarily account for young infants' performance with occluded objects because infants were significantly more likely to search when the curtain was transparent than when it was not. However, it is not clear that the transparent event was truly a means–end task for infants. We noted that when infants reached for the object behind the transparent curtain, they often reached directly through the curtain, touching the object through the curtain. This rarely happened when the curtain was not transparent, although the same behavior was certainly possible; that is, infants could have reached directly through the curtain to get the object whether the curtain was transparent or not.

Nonetheless, some aspect of motor planning ability may yet account for young infants' search limitations. It is possible that young infants do know that hidden objects continue to exist but simply have more difficulty planning a reach for an object they cannot see. That is, rather than being unable to coordinate the actions of first removing the occluder and then reaching for the object, perhaps the problem is that infants cannot program a reach without the exact coordinates of the target in space. Thus, it is possible that motor-related deficits still have a significant effect on infants' search for hidden objects.

We continue to entertain the hypothesis that young infants do not have object permanence, and we believe this topic is deserving of more research. We believe it will be important to further study the means–end deficit hypothesis to explain how and why infants' behavior differs on reaching and looking tasks with occluded objects. If young infants' search limitations are primarily due to a means–end deficit, then removing or reducing means–end task demands should lead infants to search comparably for both hidden and visible objects. One way to study the effect of removing means–end demands has been to examine infants' reaching for objects hidden by darkness, a line of research that continues to be worthy of pursuit. In addition, Shinskey (2000) further addressed this issue by presenting infants in the light with events that allow direct reaching for hidden and visible objects, instead of means–end reaching. (To our knowledge, events in which objects hidden in the light can be retrieved by a direct reach have not been previously used.) In one experiment, objects were submerged in transparent and opaque liquids in front of the infant. In a second experiment, objects were placed behind transparent and opaque curtains with a vertical slit cut down the middle, allowing infants to reach directly through the curtain. Results demonstrated that 6-month-old infants searched less and looked away more when the object was hidden than when it was visible or partly visible, despite their ability to make a direct reach, but 10-month-old infants' behavior was not differentially affected by the visibility of the object. These results suggest that younger infants' search limitations are not due to the means–end motor deficit that has been argued to account for the differences between looking studies and reaching studies. We envision that future work will result in converging evidence suggesting that a deficit in the concept of object permanence, rather than a deficit in means–end ability, is the primary cause of young infants' limitations in searching for hidden objects.

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