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REPORT

Are infants in the dark about hidden objects?

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Abstract

Infants appear to search for objects hidden by darkness earlier in development than they search for objects hidden by an occluder in the light. However, these two types of search tasks have differed in numerous ways that may have contributed to better performance in the dark (e.g. in whether the hidden objects made sound, in the number of familiarization trials with visible objects). The current studies controlled such incidental differences between search tasks, so that they could be directly compared. Six-and-a-half-month-olds received four types of test events, in which either a toy or no toy was presented and then hidden in the dark or under a cloth in the light. Infants searched more often on toy than no-toy trials in the dark than with a cloth. The advantage in searching for hidden objects in the dark thus appears to be genuine. Theoretical implications are discussed.

Introduction

What do infants know about hidden objects? The question is relevant to understanding the origins of our knowledge about the physical world. However, the issue is complicated by the fact that infants seem to know different things in separate tests designed to measure the same knowledge. For example, infants are less likely to search for objects hidden by occluders from 5 to 7 months than they are from 8 to 10 months (e.g. Bower & Wishart, 1972; Corman & Escalona, 1969; Freedman, Fox-Kolenda, Margileth & Miller, 1969; Gratch, 1972; Miller, Cohen & Hill, 1970; Piaget, 1952, 1954; Uzgiris & Hunt, 1975; Willatts, 1984). However, they appear to search reliably for objects hidden by darkness between about 5 and 7 months (e.g. Bower & Wishart, 1972; Clifton, Perris & McCall, 1999; Clifton, Rochat, Litovsky & Perris, 1991; Goubet & Clifton, 1998; Hood & Willatts, 1986). And, they appear sensitive to hidden objects in violation-of-expectation studies as early as 3 to 5 months, by looking longer at events that violate the hidden object's existence than at events that do not (e.g. Baillargeon, Spelke & Wasserman, 1985; Spelke, Breinlinger, Macomber & Jacobson, 1992; Wynn, 1992). These dissociations have implications for theories about the nature and development of object knowledge. For example, at least two explanations are consistent with the dissociation between behavior with an object hidden in the dark and behavior with an object hidden by an occluder. Infants may search more in the dark than with occluders because they lack the means–end skill for removing an occluder (the means) in order to retrieve an object (the end), despite knowing the object is there (Baillargeon, Graber, DeVos & Black, 1990; Bower & Wishart, 1972; Clifton, Perris & Bullinger, 1991; Diamond, 1991). In contrast, infants' representations may be graded, such that fragile representations of hidden objects at 5 to 7 months can withstand the global darkening of a room to support reaching, but not the direct interference from an occluder in the light (Munakata, McClelland, Johnson & Siegler, 1997).

The current study takes a crucial step toward investigating this particular dissociation by addressing whether it may be more apparent than real. Means–end tasks and reaching-in-the-dark tasks have typically differed in incidental ways, beyond the manner of occlusion, that may have favored reaching in the dark. Such differences include: whether the object makes sound, whether infants watch the object being hidden, the number of trials familiarizing the infant with reaching for a visible object before test, the percentage of visible-object trials interspersed among hidden-object trials during test, the percentage of no-toy trials during test, how much time is allowed for search, and the dependent measure of search (see Table 1). For example, one of the more consistent differences between the paradigms is that the objects make sound in most reaching-in-the-dark tasks but are silent in most means–end tasks. Although sound apparently

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Table 1 *Incidental differences between means–end and reaching-in-the-dark tasks, and current controls*

Task	Variables							
	Age (mos)	Sounding toy	See toy hidden	Visible-toy fam. trials	Visible-toy test trials	No-toy test trials	Search time	Search measure
Means–end								
Piaget (1954)	6–10	Sometimes	Yes	0?	0?	0?	?	Uncover object
Corman & Escalona (1969)	5–10	No	Yes	0	0	0	?	Uncover object
Freedman *et al.* (1969)								
Test B	5–12	No	Yes	1 partly visible	0	0	?	Move screen & manipulate object
Test C	5–12	Yes	No	1 partly visible	0	0	?	Move/go behind/look behind screen
Miller *et al.* (1970)	6–8, 10–12	No	Yes	3 (6–8), 0 (10–12)	0	0	?	Obtain object from under cloth
Bower & Wishart (1972)	5	No	Yes	1	0	0	3 m	Uncover object & retrieve quickly[1]
Gratch (1972)	6.5	No	Yes	5 (3 partly visible)	25%	0	?	Uncover object
Ginsburg & Wong (1973)	6	33%	Yes	0	0	0	1 m	Pull cover off & reach immediately
Uzgiris & Hunt (1975)	1–24	No	Yes	0	0	0	?	Pull cover off & obtain object
Jackson *et al.* (1978)	6–8.5	No	Yes	3 partly visible	0	0	20 s	Move screen, look/reach on 2/3 trials
Rader *et al.* (1979)	5.5	No	Yes	4	0	0	30 s	Pick up object on 2 of 3 trials
Dunst *et al.* (1982)	6, 8, 10	No	Yes	0	0	0	?	Remove barrier & retrieve object
Bigelow (1983)								
Phase I	6.75–18	No	Yes	1 partly visible	0	0	?	Find object
Phase II	6.75–18	Yes	Yes	1 partly visible	0	0	?	Find object
Willatts (1984)	6–8	No	Yes	2	0	0	30 s	Retrieve object
Legerstee (1994)								
Vision first	6, 8, 10	No	Yes	0	0	0	15 s	Push door open
Sound only	6, 8, 10	Yes	No	0	0	0	15 s	Push door open
Combined	6, 8, 10	Yes	Yes	0	0	0	15 s	Push door open
Munakata *et al.* (1997)								
Towel	7	No	Yes	2	25%	50%	20 s	Pull entire towel or touch toy
Button	7	No	Yes	2	25%	50%	20 s	Push button
Shinskey & Munakata (2001)	7	No	Yes	2	25%	50%	5 s	Pull screen down
Current study	6.5	No	Yes	3	25%	50%	10 s	Uncover circular search space
Reaching-in-the-dark								
Bower & Wishart (1972)	5	No	Yes	1	0	0	3 m	Obtain object
Wishart *et al.* (1978)								
Exp. 1	4–12	Yes	No	0	50%	0	3 m	Contact object
Exp. 2	4.5–11	Yes	No	0	50%	0	2 m	Contact object
Exp. 3	5–11	50% trials	50%	0	0	0	?	Contact object
Hood & Willatts (1986)	5	No	Yes	3–9	0	33%	25 s	One infant hand-width within object
Perris & Clifton (1988)	7	88% trials	No	5	29%	0	20 s	Reach into 15° sector flanking object
Stack *et al.* (1989)								
Exp. 1	2–7	Yes	No	0	50%	0	30 s	Contact object
Exp. 2	5, 7	Yes	No	0	50%	0	20 s	Contact object
Clifton *et al.* (1991)	6–7.5	Yes	No	2	33%	0	20 s	Reach into space occupied by object
Clifton, Rochat *et al.* (1991)	6.5	Yes	No	8	40%	0	20 s	Contact object; 1 vs. 2-handed reach
Hillier *et al.* (1992)	4, 6, 8	Yes	No	1	25%	12.5%	20 s	Contact object
Goubet & Clifton (1998)								
Exp. 1	6.5	Yes[2]	No	6	33%	0	15 s	Contact object/surfaces in front of it
Exp. 2	6.5	Yes[3]	No	6	33%	0	15 s	Accuracy of first contact
McCall & Clifton (1999)	8.5	Yes[4]	Yes	4–7	33%	33%	20 s	Reach into space occupied by cover
Clifton *et al.* (1999)	7	Yes	No	0–3	27%	0	20 s	Reach into 15° sector flanking object
LaGasse *et al.* (1999)	7.5–11	Yes	Yes	8	0	0	20 s	Contact/grasp object
Current study	6.5	No	Yes	3	25%	50%	10 s	Reach into circular search space

[1] With latency between uncovering and retrieving object shorter than latency to retrieve object when uncovered.
[2] Toy stopped sounding upon landing in toy tray, before infant could retrieve.
[3] Toy stopped sounding 1 s before landing in toy tray, before infant could retrieve.
[4] Toy stopped sounding after infant opened toy door halfway, but before toy contact.

does not aid search in the light (Bigelow, 1983; Freedman *et al.*, 1969; Legerstee, 1994; Piaget, 1954; but see also Ginsburg & Wong, 1973), it may play a more salient role in the dark, providing a perceptual cue to both the object's existence and location. Likewise, reaching-in-the-dark studies typically have a higher percentage of visible-toy trials during test, which might inflate infants' reaching on hidden trials during test. And, although the greater number of visible-toy familiarization trials in most reaching-in-the-dark studies does not by itself significantly affect search on test trials in the dark (Clifton *et al.*, 1999), this factor in combination with other task differences might have a cumulative effect resulting in an advantage in the dark.

These differences between means–end and reaching-in-the-dark tasks do not suggest inherent design flaws in the studies, because many of the studies were not designed for direct comparison. For example, a number of reaching-in-the-dark studies were instead designed to assess infants' auditory localization or auditory–manual coordination (e.g. Clifton, Perris & Bullinger, 1991; Hillier, Hewitt & Morongiello, 1992; Perris & Clifton, 1988; Stack, Muir, Sherriff & Roman, 1989; Wishart, Bower & Dunkeld, 1978). The results of several have been interpreted as evidence for infants' representation of hidden objects (e.g. Clifton, Perris & Bullinger, 1991; Hillier *et al.*, 1992; Perris & Clifton, 1988). Such results have supported the conclusion that infants demonstrate more sensitivity to hidden objects in the dark than with occluders in the light, without the direct comparison of these conditions. Even in the single study that did directly compare infants' search in means–end and reaching-in-the-dark tasks (Bower & Wishart, 1972), the tasks differed in important ways (e.g. in their ordering, and in a more lenient definition of search in the dark (Hood & Willatts, 1986)) that may have favored reaching in the dark.

Thus, incidental differences between the tasks were controlled in the current study to allow a direct comparison (see Table 1). Infants received two means–end events (toy under cloth and no toy under cloth) and two reaching-in-the-dark events (toy in dark and no toy in dark). (See Figure 1.) The purpose of the study was to determine whether infants would search more on toy than no-toy trials in the dark than with the cloth. Because infants are generally less active in the dark than in the light (e.g. Clifton, Rochat *et al.*, 1991; LaGasse, VanVorst, Brunner & Zucker, 1999; Stack *et al.*, 1989; Wishart *et al.*, 1978) and have high baseline activity with a cloth (e.g. Munakata *et al.*, 1997; Willatts, 1999), comparing Dark-Toy to Cloth-Toy trials alone would be misleading. Instead, it was crucial to test relative sensitivity to toy versus no-toy trials across the two occluders.

Figure 1 *The events of Experiment 1, from the top: Cloth (No Toy and Toy), Dark-No Toy and Dark-Toy. The cloth events appeared to the infant as shown; the dark events were not visible after the light went out.*

Therefore, the principle comparison was the interaction of Occluder (Cloth or Dark) and Toy (Toy or No Toy).

Experiment 1

Method

Participants

Thirty-two full-term 6.5-month-olds participated ($M = 6$ months, 13 days; range of 6 months, 8 days to 6 months, 21 days; 15 girls and 17 boys) in both the cloth and dark

events. Sixteen additional infants were tested but not included in the sample because of fussiness (7), parental interference (6),[1] difficulty retrieving visible toys (2) and experimenter error (1). Participants were recruited from state birth records via a letter shortly after birth and a follow-up phone call at approximately 6 months. Participation was voluntary.

Apparatus and stimuli

Testing occurred at a wooden table (91 by 60.5 cm) in an experiment room (255 by 325 cm) blocked from all external light sources and illuminated by a 40-watt bulb. Infants sat on their parent's lap across the table from the experimenter, who presented the events, timed them by listening through headphones to an audio tape of a metronome that beeped once per second, and operated the lamp with a foot switch. A video camera, equipped with infrared for recording in the dark, recorded the infant from above and behind the experimenter. Because the experimenter could not see the infant's behavior in the dark, an observer watched the session on a television monitor from the adjacent room, signaling the experimenter with a brief tone ('ding') over a computer speaker in the experiment room when the infant searched in the dark. The search space was a circle of clear contact paper, 12 cm in diameter and outlined in black ink, secured to the table with the circle's front edge 18 cm from the infant. A 1.5-cm circle of tan Velcro was attached to the center of the circle, where the objects were placed. The cloth was a tan finger-tip towel (28 by 45 cm) with fringe on the ends. Stimuli consisted of 15 colorful plastic and rubber toys ranging in size from 4.5 by 3 by 4.5 cm to 5 by 12 by 4.5 cm. Attached to each toy was a 1.5-cm circle of tan Velcro to keep the toy in the search space when infants pulled the cloth.

Design

The primary factors in the design were the within-participant factors of Occluder (Cloth or Dark) and Toy (Toy or No Toy). Trials of the same type of event (e.g. all Cloth-Toy trials) were blocked. Further, blocks with the same type of occluder were paired, so that Cloth-Toy and Cloth-No Toy blocks were presented consecutively, and Dark-Toy and Dark-No Toy blocks were presented consecutively. The order of events was counterbalanced as a between-participants factor based on which events an infant received first: Cloth-Toy, Cloth-No Toy, Dark-Toy or Dark-No Toy. The order of familiarization events (cloth first or dark first) was also counterbalanced as a between-participants factor. Thus the design was a 2 (Occluder) by 2 (Toy) by 2 (Familiarization Order) by 4 (Test Order) factorial design.

Procedure

The procedure began with the infant playing with the cloth for familiarization purposes while the parent signed a consent form. The infant sat on the parent's lap throughout the session. Parents were instructed to prevent the infant from searching immediately by restraining the infant's arms until 1 s after the toy was placed on the table (Visible-Toy condition), 1 s after the cloth was placed on the table (Cloth conditions), or 1 s after the light went off (Dark conditions). Parents were instructed to otherwise not interact with the infant unless the infant became fussy.

Infants received three types of familiarization events prior to test. In the Dark familiarization event, the parent restrained the infant's arms, the experimenter turned off the light, and the parent released the infant's arms 1 s later. The experimenter ended the trial after 5 s by turning on the light, then repeated the procedure for a total of six trials. In the Cloth familiarization event, the parent restrained the infant's arms while the experimenter placed the cloth in the center of the table, over the search space and 5 cm from the edge of the table nearest the infant. The parent released the infant's arms 1 s after the experimenter released the cloth. The experimenter ended the trial after 5 s by removing the cloth, then repeated the procedure for a total of six trials. The Visible-Toy familiarization event began with arm restraint, while the experimenter placed a toy in the search space. The experimenter tapped her fingers behind the toy to ensure that the infant fixated it. The parent released the infant's arms 1 s after the experimenter removed her hand from the table. The experimenter ended the trial when the infant's hand crossed into the search space or when 10 s elapsed, then repeated the procedure for a total of three trials.[2] Infants who crossed into the search space were allowed to play with the toy for several seconds after the trial.

Test trials for the four blocks (Cloth-Toy, Cloth-No Toy, Dark-Toy, Dark-No Toy) followed immediately, each beginning with arm restraint. Each block consisted of four repeated trials of the same test event with one Visible-Toy trial in the middle; however, Visible-Toy trials

[1] Data for participants dropped for parental interference generally went in the same direction as the kept data.

[2] Infants received three familiarization trials with the visible toy but six familiarization trials with the cloth and with the dark because infants are already more familiar with reaching for visible toys than with being presented with total darkness or with a cloth.

were not included in the analysis. Visible-Toy test trials were identical to the Visible-Toy familiarization trials described above. In the Cloth-Toy event, the experimenter placed the toy in the search space, tapped her fingers behind the toy to ensure that the infant fixated it, and drew the cloth over the toy from back to front while the infant watched. The edge of the cloth was 5 cm from the edge of the table nearest the infant. The parent released the infant's arms 1 s after the experimenter released the cloth. The trial ended when the infant uncovered any part of the search space, or after 10 s elapsed. Cloth-No Toy trials were identical except that the search space was empty and all trials ended at 10 s, to avoid conditioning infants to search at ceiling levels by rewarding them with the trial's end as soon as they uncovered the search space. In the Dark-Toy event, the experimenter placed the toy in the search space, tapped her fingers behind the toy to ensure that the infant fixated it, and turned the light off. The parent released the infant's arms 1 s after the experimenter turned the light off. If the infant's hand crossed into the search space, the observer watching the TV monitor in the adjoining room signaled the experimenter with a 'ding' over a computer speaker to turn on the light. The trial ended when the infant crossed into the search space, or after 10 s elapsed. Dark-No Toy trials were identical except that the search space was empty and all trials ended at 10 s. Infants who searched successfully on toy trials were allowed to play with the toy for several seconds after the trial.

Measures and analyses

For Cloth events, the dependent measure assessed whether the infant uncovered any part of the search space within 10 s. For Dark events and the Visible-Toy event, the dependent measure assessed whether the infant's hand crossed into the search space within 10 s. One observer coded the trials for all infants and a second observer who was blind to the study purposes coded the trials for half the infants, selected randomly. Agreement was 99% (313 of 316 observations). The data were subjected to a 2 (Occluder) by 2 (Toy) by 2 (Familiarization Order) by 4 (Test Order) repeated-measures analysis of variance, with Occluder and Toy as within-participant factors and Familiarization Order and Test Order as between-participants factors. As described in the Introduction, because of infants' differing levels of activity in the dark and with a cloth, it was crucial to test relative sensitivity to toy versus no-toy trials across the two occluders. Thus, the principle comparison was the interaction of Occluder (Cloth or Dark) and Toy (Toy or No Toy). If infants are genuinely more sensitive to objects hidden in the dark, then their behavior in toy and no-toy conditions should differ depending on how the toy was hidden (i.e. cloth or dark).

Results and discussion

Infants searched more on toy trials than no-toy trials in the dark than with the cloth (Figure 2), as indicated by

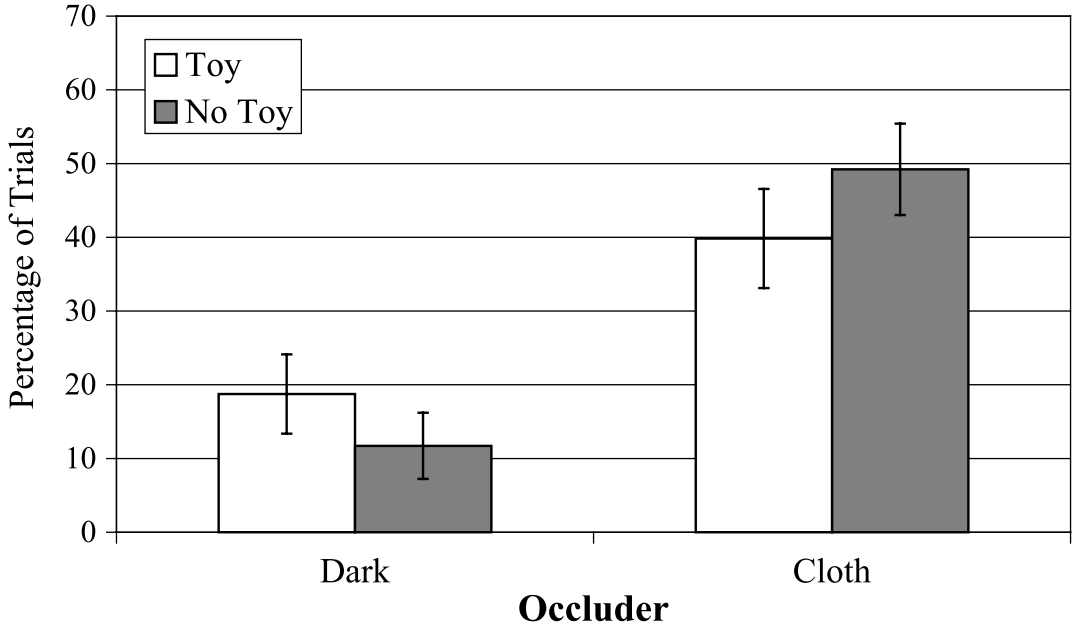

Figure 2 *Percentage of trials on which infants searched in Experiment 1, as a function of Occluder and Toy. (Error bars represent SE.)*

the Occluder by Toy interaction: $F(1, 24) = 10.26$, $p < .01$. In pair-wise comparisons of the two dark events, infants searched significantly more on toy than no-toy trials: $t(31) = 2.06$, $p < .05$. In contrast, in pair-wise comparisons of the two cloth events, infants were more likely to search on no-toy than toy trials, though the result failed to reach statistical significance: $t(31) = -1.98$, $p < .10$. A main effect of Occluder also revealed that infants reached less in the dark than with the cloth, $F(1, 24) = 21.17$, $p < .001$, consistent with previous findings that infants are less active in the dark (e.g. Wishart *et al.*, 1978). There were no order effects (all Fs < 2.8). These results suggest that when incidental differences between the tasks are controlled, infants show greater sensitivity to an object hidden in the dark than to one hidden under a cloth.

One concern about the data, however, was that the frequency of reaching in the dark in Experiment 1 was lower than the frequency of reaching in the dark reported in other studies. Seventeen infants (53%) never reached in the dark, whereas in other studies reporting the percentage of infants who never reached in the dark, values ranged from 5% to 41%, with a median of 20% (Clifton, Perris & Bullinger, 1991; Clifton, Rochat *et al.*, 1991; Goubet & Clifton, 1998; LaGasse *et al.*, 1999; Stack *et al.*, 1989). If sound cues aid search, then reaching in these studies might be higher because the objects made sound in the dark. However, search in the current study might have been low because the object was too far away or because global darkness disoriented infants enough to prevent them from remembering the object's location even if they remembered its existence. Distance was not a problem on Visible-Toy trials, as infants retrieved the toy on 94% ($SE = 3\%$) of Visible-Toy trials. Nevertheless, although infants distinguish between objects within and beyond reach in the dark when objects make noise (Clifton, Perris & Bullinger, 1991), this distinction may be more difficult in the dark when objects are silent. Anecdotal evidence indicated that infants sometimes reached toward the search space after the light went off and patted the table, without reaching far enough to cross into the search space. These concerns were addressed in Experiment 2 by moving the search space 2 cm closer to the infant and by adding glow-in-the-dark tracks on both sides of the search space to orient infants in the dark (Figure 3).

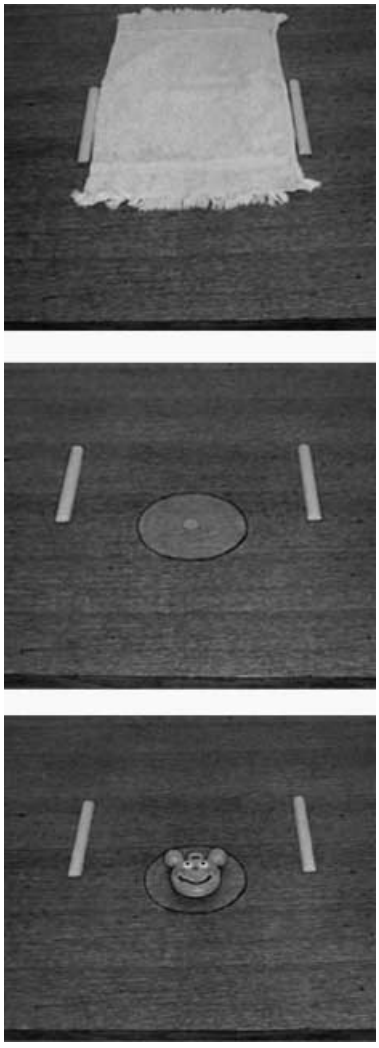

Figure 3 *The events of Experiment 2, from the top: Cloth (No Toy and Toy), Dark-No Toy and Dark-Toy. The cloth events appeared to the infant as shown; the dark events were not visible after the light went out.*

Experiment 2

Method

Participants

Sixteen full-term 6.5-month-olds participated ($M = 6$ months, 12 days; range of 6 months, 7 days to 6 months, 19 days; 8 girls and 8 boys) in both the cloth and dark events.[3] Eleven additional infants were tested but not included in the sample because of fussiness (9) and parental interference (2). Participant recruitment was identical to that in Experiment 1.

[3] Because Experiment 2's manipulations were expected to provide more data for analysis, a sample of 16 infants rather than 32 was deemed adequate.

Apparatus and stimuli

The apparatus and stimuli were identical to those in Experiment 1, with the following exceptions. To better capture search behavior, the video camera was placed above and behind the infant, rather than above and behind the experimenter. The search space was 2 cm closer to the infant. In addition, wooden tracks (1.5 by 15 cm) flanked both sides of the search space, parallel to one another and 28.5 cm apart, to accommodate the cloth between them. The tracks were 22 cm from the edge of the table nearest the infant, and painted a yellow-green color with a clear varnish that glowed yellow-green in the dark. Finally, some stimuli were different from those in Experiment 1, and included a variety of colorful plastic and rubber toys ranging in size from 3.5 by 6 cm to 9 by 12 cm. Toy height did not exceed 2 cm, to minimize protrusion under the cloth.

Design and procedure

The design and procedure were identical to that in Experiment 1, with the following exceptions. Rather than asking the parent to count 1 s before releasing the infant's arms, the experimenter signaled the parent to release the infant's arms after 1 s by tapping the parent on the foot. In addition, on Cloth trials, instead of placing the cloth at the infant's fingertips, the experimenter placed it farther from the infant so that the cloth's front edge just covered the search space.

Measures and analyses

The dependent measure of search was the same as in Experiment 1 with the following exception. To address any concerns that the manipulations of Experiment 2 (specifically, moving the search space closer and adding glow-in-the-dark tracks) might increase noise or unintentional 'search', search was assessed using a stricter latency criterion of 5 s. Latency was measured from the time the infant's arms were freed until the infant uncovered the circle (Cloth) or reached into the circle (Dark). One observer coded the trials for all infants and a second observer who was blind to the study purposes coded the trials for half the infants, selected randomly. Agreement was 98% for search (157 of 160 observations) and Pearson's r was .99 for latency. As in Experiment 1, the data were subjected to a 2 (Occluder) by 2 (Toy) by 2 (Familiarization Order) by 4 (Test Order) repeated-measures analysis of variance, with Occluder and Toy as within-participant factors and Familiarization Order and Test Order as between-participants factors. Again, the principle comparison was the interaction of Occluder (Cloth or Dark) and Toy (Toy or No Toy). In addition, to test whether Experiment 2's manipulations increased search in the dark, overall dark search (across Dark-Toy

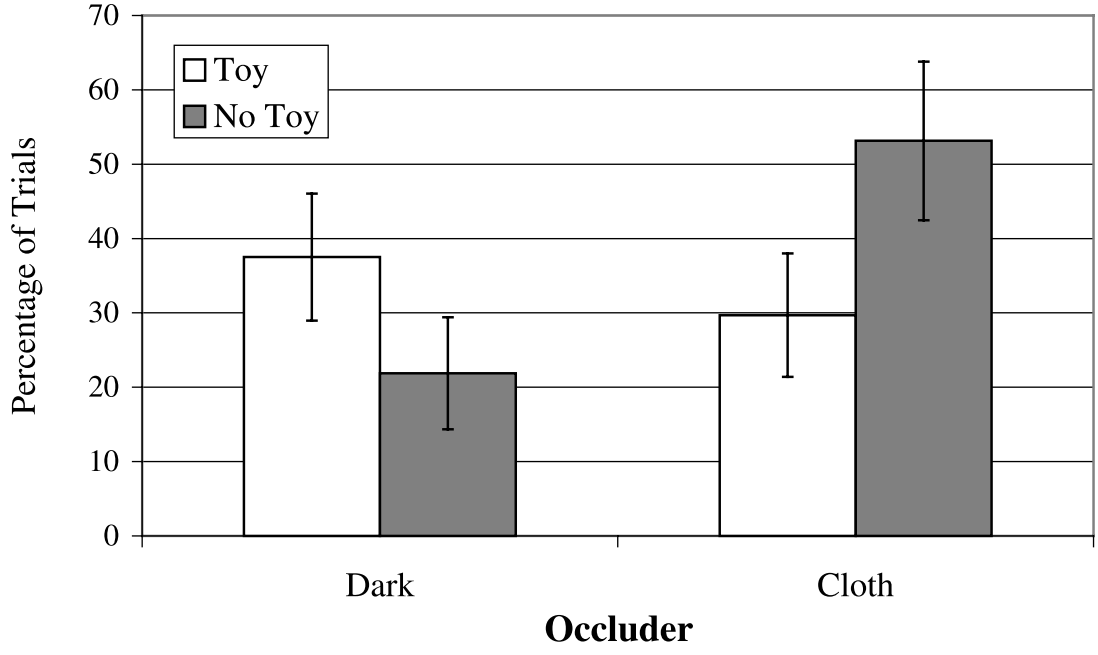

Figure 4 *Percentage of trials on which infants searched in Experiment 2, as a function of Occluder and Toy. (Error bars represent SE.)*

and Dark-No Toy trials) was subjected to a pair-wise comparison with Experiment (1 or 2) as the between-participants factor.

Results and discussion

Infants' search in Experiment 2 replicated the pattern in Experiment 1. That is, infants searched more on toy than no-toy trials in the dark than with the cloth, as demonstrated in the Occluder by Toy interaction (Figure 4): $F(1, 8) = 11.36$, $p < .05$.[4] In pair-wise comparisons of the two dark events, infants searched significantly more often on toy than no-toy trials: $t(15) = 2.44$, $p < .05$. In contrast, in pair-wise comparisons of the two cloth events, infants searched significantly more often on no-toy than toy trials: $t(15) = -2.80$, $p < .05$. This pattern suggests some type of sensitivity to an object hidden by a cloth; potential explanations are discussed below. There were no order effects (all Fs < 2.3). Experiment 2 thus replicated the principle results of Experiment 1 with approximately twice the amount of reaching in the dark as in Experiment 1 (a marginally significant effect, $t(46) = -1.72$, $p = .09$), indicating that these results are not an artifact of low reaching levels in the dark.

General discussion

In both experiments, when incidental differences were controlled between search tasks with an object hidden by a cloth and search tasks with an object hidden by darkness, infants searched more on toy than no-toy trials in the dark than with a cloth. Thus, infants' sensitivity to hidden objects in the dark appears to be genuine. The finding is important because more than one theory (i.e. means–end deficit account, graded representations account) assumes that infants are more successful at searching for objects hidden by darkness than for those hidden by occluders in the light. Yet, until the current study, the paradigms had not been directly compared with the necessary controls.

Other outstanding questions remain. For example, why did infants search more on no-toy than toy trials with the cloth (a trend in Experiment 1 and a significant effect in Experiment 2)? Three potential explanations are considered. First, infants may have reached for the cloth merely to play with it, but seeing the cloth after a toy made the cloth seem less interesting, reducing reaching. However, in other studies, infants did not reach less for an occluder when seeing it after a toy, relative to seeing the occluder alone (Munakata, 1997; Shinskey & Munakata, 2001; Smith, Thelen, Titzer & McLin, 1999). Second, the means–end demands of relating the cloth to the object may have reduced reaching, relative to the condition of the cloth alone (which had no such means–end demands). However, in other studies with means–end demands for retrieving hidden objects, infants did not show this same pattern of reduced reaching on toy trials relative to no-toy trials (Munakata *et al.*, 1997; Shinskey & Munakata, 2001). Thus, although explanations based on the relative appeal of the occluder or on the role of means–end demands might account for the current pattern of results, they are inconsistent with other findings, and so seem inadequate.

Third, infants may have shown reduced reaching whenever a planned reach was interrupted. Perhaps infants planned a straight reach for the object before it was occluded, while their arms were restrained. In the dark, infants could succeed in retrieving the object simply by following through on that plan. In contrast, a cloth would interrupt this straight reach plan, reducing reaching. This explanation is similar to a means–end deficit explanation in proposing that the problem lies primarily with the execution component of search. However, the accounts are different in that a means–end deficit account proposes that infants have difficulty relating two objects in the search process, whereas a plan-interruption account proposes that infants have difficulty adjusting a search plan after it has been disrupted. According to the latter explanation, other studies with means–end demands did not show reduced reaching on toy trials relative to no-toy trials because no plan was interrupted. In some cases, the relevant plan for retrieving an object (e.g. pushing a button or pulling a towel) was not interrupted when the object was occluded (Munakata *et al.*, 1997); the same behavior would still yield the object. In other cases, infants may not have formulated a plan for retrieving the object because the object was out of reach until after it was occluded by a barrier (Shinskey & Munakata, 2001).[5] Of notable importance, infants in these previous studies that lacked the plan-interruption factor did not

[4] These results are representative of the various cut-offs one might consider in addition to the 5-s criterion. To evaluate whether the 5-s results were representative, the Occluder by Toy interaction was tested at every 1-s interval from 1 s to 10 s. The interaction was significant with all criteria from 3 s to 7 s inclusive: all Fs(1, 8) > 5.38, $p < .05$. Likewise, in pair-wise comparisons the difference between Dark-Toy and Dark-No Toy trials was significant with all criteria from 3 s to 6 s inclusive: all ts(15) > 2.33, $p < .05$. Also, in pair-wise comparisons the difference between Cloth-Toy and Cloth-No Toy trials was significant with all criteria from 3 s to 7 s inclusive: all ts(15) < −2.16, $p < .05$.

[5] One might argue that infants formulate reaching plans even when objects are out of reach. In this case, infants' behavior in the barrier study would challenge the plan-interruption account. According to this account, infants' plans to reach for toys would have been disrupted by the barrier, such that they should have reached less often on toy than on no-toy trials (like infants in the current study), but they did not.

discriminate between occluded toy and no-toy trials. Thus, the plan-interruption factor might contribute to greater reaching on no-toy than on toy trials in the current studies, and is consistent with findings from other studies; however, this explanation alone cannot account for infants' poor discrimination in searching for objects hidden by visible occluders.

In summary, the evidence confirms that infants have a genuine advantage in searching for objects hidden in the dark, opening the door for further investigations into the question of why. Perhaps means–end demands play some role (Baillargeon *et al.*, 1990; Bower & Wishart, 1972; Clifton, Perris & Bullinger, 1991; Diamond, 1991). Or, perhaps darkness interferes less with a tenuous representation than a visible occluder does (Munakata *et al.*, 1997). We are currently investigating these accounts, with the hope that this and future work will clarify the nature of dissociations in infants' behavior across tasks, leading to a comprehensive account of the development of object knowledge.

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