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What's in a cue? The role of cue orientation in object displacement tasks

Diane Marie J. Mangalindan*, Mark A. Schmuckler

University of Toronto Scarborough, Canada

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ABSTRACT

The current study looked at two theoretical proposals explaining toddlers' abilities to use cue information for recovering a hidden object that had rolled down a ramp behind an occluded screen. These two approaches, the theory of object directed attention and a landmark-based account, make different predictions regarding the efficacy of an obliquely aligned cue to object position. Accordingly, the search by forty 24-month olds, forty-two 30-month olds, and forty-one 36-month olds for a hidden toy that was cued using either a short versus a long cue, or a vertically aligned versus an obliquely aligned cue, were compared. Analyses of search accuracy revealed that children were more successful when faced with short as opposed to long cues, and when using vertical as opposed to oblique cues. These findings support a landmark-based approach, as opposed to an object-directed attention account, and are discussed with reference to their implications for spatial orientation more generally.

Footprints on the sand, a half-eaten donut, a lipstick mark on a champagne glass—these are the types of cues that allow us to infer what has previously transpired. As adults, we are adept in reasoning about the existence of objects and events that we have not ourselves witnessed, and in drawing successful and accurate conclusions about the current state of these objects and events based on these inferences. Given that much of what happens in the world is not actually part of our immediate experience, such inferential ability is critical for our survival. Without this ability, our world would be incomplete, consisting only of snapshots of events for which we were literally present. With this ability, though, our experiences have a sense of continuity and fluidity. How do we come to develop such ability?

Understanding the development of children's inferential abilities in their knowledge of the continuity of objects and events has been extensively researched. A topic relevant to this ability involves the study of children's skills at tracking the unseen (or partially seen) movement of an object, and inferring its final resting position based on cue information (Berthier, DeBlois, Poirier, Novak, & Clifton, 2000; Butler, Berthier, & Clifton, 2002; DeLoache, 1986; Hood, 1995, 1998; Hood, Carey, & Prasada, 2000; Hood, Cole-Davies, & Dias, 2003; Keen, 2003, 2005; Keen, Carrico, Sylvia, & Berthier, 2003; Mash, Keen, & Berthier, 2003; Mash, Novak, Berthier, & Keen, 2006; Moore & Meltzoff, 2004). Within this framework, multiple complex paradigms have been employed to investigate children's ability to make use of cues when searching for such moving (and frequently hidden) objects, such as visual search and hide-and-seek tasks (DeLoache, 1986; DeLoache & Brown, 1983; Keen et al., 2003; Nardini, Atkinson, & Burgess, 2008; Smith et al., 2008; Sutton, 2006; Twyman, Friedman, & Spetch, 2007). One well-known paradigm involves an object search task in which children observe a ball roll down a ramp whose trajectory is occluded by an opaque screen with multiple doors (Hood et al., 2003). In this procedure, a wall or barrier is placed along the ramp, behind one of the doors, to stop the ball, with the top portion of this barrier remaining visible above the opaque

* Corresponding author.
E-mail address: mangalindan@utsc.utoronto.ca (D.M.J. Mangalindan).

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screen. Using this paradigm, researchers have found that children under three years of age often make significant errors in object retrievals, frequently opening the incorrect door to find the ball (Butler et al., 2002; Hood et al., 2003; Keen et al., 2003; Mash et al., 2003), whereas three-year olds will reliably succeed in this task.

Interestingly, children make these errors despite the visual availability of the barrier above the screen. According to Keen (2005), children ignore the top of the barrier because the barrier itself is only adjacent to the door that hides the to-be-recovered object, and is not physically connected to this object. In other words, it is only an indirect (e.g., spatially separated) cue to the object's location. In contrast, actually seeing the ball move down the ramp and disappear behind the doors are cues that are directly connected to the hidden object. Thus, 2-year olds' difficulties in using the barrier as a cue stems from a general difficulty in using indirect cues to determine object location (DeLoache, 1986; Kloos, Haddad, & Keen, 2006; Smith et al., 2008).

Why are children unable to use indirect cues? Shutts, Keen, and Spelke (2006) explain this phenomenon with a theory of object-directed attention, which states that attention directed towards an object is affected by both object boundaries and proximity relations, with attention spreading in a gradient-like fashion within the object. Accordingly, a cue will more likely be attended to and consequently used if it is directly connected to the target object and if it is located near the centre of that object. In contrast, an indirect cue, which is disconnected from the target object, will more likely be ignored. Object-directed attention improves throughout development as people learn better search strategies, either through the maturation of long-term memory representations to guide search, or quantitative changes in attentional mechanisms that allow one to incorporate such factors to aid search.

In support of this theory, Shutts et al. (2006) conducted a series of search studies with 2-year olds, employing a modified version of the ramp apparatus in which there were two opaque doors with transparent windows above them. Toddlers saw a car roll down the ramp, come to rest behind one of the two opaque doors, and were then motivated to retrieve this hidden object from behind one of the doors. Attached to this car by means of a thin pole that varied in length was a pompom. Not only was the cue (i.e., pompom) now directly connected to the hidden object, but also when the car came to rest behind the door, the cue was visible either above the occluding screen (when attached by a long pole) or in the transparent window above the door (when attached by a short pole). Shutts et al. (2006) found better performance when the pompom was attached to the car by a short pole, as opposed to a long pole. This finding demonstrates the importance of proximity in the spread of attention, with farther cues being less effective than nearer cues. In a subsequent experiment, when the wall that stopped the car was now visible in this window, performance dropped dramatically. This finding demonstrates the importance of object boundaries in the spread of attention, with directly attached cues (the pompom) being more effective in signaling object location than indirect cues. Thus, toddlers' search for hidden objects is affected by the proximity of a visible part of the object itself, and not by the proximity of a separate visible landmark.

Although a compelling hypothesis, there is at least one straightforward alternative that involves the spatial relation between the cue and to-be-recovered object's location (i.e., the location of the cue with reference to the target location). Specifically, it is possible that the cue in this study simply drove children's attention towards particular locations that were spatially close to the cue, with subsequent search influenced by this attention. Accordingly, children's difficulties in the long cue condition arose because the long cue drove attention towards the space directly below the cue, which was the front wall of the apparatus. In contrast, the short cue drove attention to the to-be-searched in door itself, thus producing better performance.

This explanation fits with a theoretical framework concerning the nature of children's spatial orientation and search emphasizing the availability of, and the ability to use perceptually distinct environmental landmarks (Acredolo & Evans, 1980; Bremner, 1978; Bushnell, McKenzie, Lawrence, & Connell, 1995; DeLoache, 1986; DeLoache & Brown, 1983; Plumert & Hawkins, 2001; Rieser, 1979; Schmuckler & Jewell, 2007; Schmuckler & Tsang-Tong, 2000). Multiple studies have demonstrated that children can successfully search for items when they are marked by a direct landmark or a beacon (i.e., a perceptually distinct cue coincident with the target location), as opposed to an indirect landmark (i.e., a perceptually distinct cue not coincident with the target location). For example, Bushnell et al. (1995) found that 24-month-old infants were successful at locating a toy using a direct landmark, whereas the presence of an indirect landmark actually led to worse performance than no landmark at all. Similarly, other researchers (e.g., DeLoache, 1986; DeLoache & Brown, 1983; Plumert & Hawkins, 2001; Sutton, 2006) have found that it is not until well past their second year that children can properly use indirect landmarks.

What is the significance of the differences between these two theoretical proposals? One could argue that having a cue drive attention towards a specific location in space (the landmark view) is not especially different from having attention spread out from an object in space (the object-directed attention approach). Although clearly similar, one important distinction is that the former contains an explicit role for the spatial relation between the cue information and the location of the hidden object, whereas the latter is relatively quiet concerning the importance of spatial information. And of course, the ability to incorporate a role for spatial relations is a decided theoretical advantage, given the wealth of evidence demonstrating the importance of spatial relations on infant search for objects and events (Acredolo, 1979; Acredolo, Adams, & Goodwyn, 1984; Acredolo & Evans, 1980; Bushnell et al., 1995; Rieser, 1979; Schmuckler & Jewell, 2007; Schmuckler & Tsang-Tong, 2000). At the very least, demonstrating a role for spatial relations would underscore an important limitation to Shutts et al.'s (2006) account, and would necessitate that this theory explicitly incorporate a spatial constraint on object-directed attention. And at its worse, such a finding would significantly undermine the fundamental basis of this theory.

Accordingly, it is crucial to demonstrate that such spatial relations are important in this situation. One intriguing window to examine this question involves modifying the spatial relations between the cue and the to-be-retrieved object, while retaining the actual distance between the cue and the object. According to a landmark-based theory, children's ability to recover the hidden object could well be influenced by the nature of the spatial relation between cue and target location. In contrast, according to Shutts et al.'s (2006) theory, variations in this spatial relation will have little impact on search behavior.

One compelling manipulation of spatial relations within this context would be to shift the orientation of the cue from a vertical alignment to an oblique alignment. The significance of this modification rests on the well-known *oblique effect* (Appelle, 1972), which refers to the idea that there is a processing advantage for horizontal and vertical alignments (what are called orthogonal or cardinal orientations) over oblique orientations. This idea of a privileged psychological status for orthogonal over oblique orientations has, over the years, received a great deal of study and support (Annis & Frost, 1973; Birch, Gwiazda, Bauer, Naegele, & Held, 1983; Bomba, 1984; Bornstein & Krinsky, 1985; Coletta, Padhmalatha, & Tiana, 1993; Essock, 1990; Gentaz & Hatwell, 1999; Gwiazda, Brill, Mohindra, & Held, 1978; Gwiazda, Scheiman, & Held, 1984; Heeley & Buchanan-Smith, 1990; Jouen, 1985; Latto & Russell-Duff, 2002; Leehey, Moskowitz-Cook, Brill, & Held, 1975; McGurk, 1970; Meigen, Legreze, & Bach, 1984; Murasuqi & Cavanagh, 1988; Quinn & Bhatt, 1998; Quinn & Bomba, 1986; Quinn, Siqueland, & Bomba, 1985; Ross, 1992; Saarinen & Levi, 1995; Treisman, 1988). For instance, researchers have found that infants respond differently to orthogonal versus oblique orientations in aspects like visual acuity (Bornstein & Krinsky, 1985; McGurk, 1970; Quinn & Bhatt, 1998; Quinn et al., 1985) and perceptual organization, discrimination, and categorization (Bomba, 1984; Bomba & Quinn, 1986; Quinn & Bhatt, 1998; Quinn & Bomba, 1986; Quinn et al., 1985), with such differences continuing on among older children (Birch et al., 1983; Gwiazda et al., 1984; Ross, 1992) and adults (Annis & Frost, 1973; Coletta et al., 1993; Latto & Russell-Duff, 2002; Murasuqi & Cavanagh, 1988; Ross, 1992).

Intriguingly, to our knowledge there exist no studies explicitly demonstrating hat obliquely versus cardinally oriented landmarks have differential effects on spatial orientation and search. Based on the oblique effect, however, it clearly seems possible that varying the orientation of a cue relative to its target could impact the efficacy of the cue. Applied to the experimental context of Shutts et al. (2006) and with reference to a landmark-based approach, this means vertically versus obliquely oriented cues would produce differential performance, with a vertically oriented cue attached to a target (e.g., a pompom placed at a 90° angle from the car) producing better search than an obliquely oriented cue attached to a target (e.g., a pompom placed at a 45° angle from the car). Investigating whether such oblique effects occur within spatial orientation situations was the principal experimental goal of this study.

Along with examining the role of cue alignment, the current study also explored the impact of varying cue length (short versus long) on search, as well as investigating these factors within a developmental context. Both aspects derive from the work of Shutts et al. (2006), who found that varying cue length influenced children's abilities to employ this type of cue, and who restricted their observations to 2-year-old children. Given the hypothesis that object-directed attention improves with age, it is important to examine these proximity and orientation manipulations across a wider range of age groups, to enable a fuller understanding of the impact of these variables on children's use of cue information for object retrieval.

1. Methods

1.1. Participants

The final sample of participants consisted of forty 24-month-old (*M* age = 24.20, *SD* = 1.32; 26 male, 14 female), forty-two 30-month-old (*M* age = 30.14, *SD* = 1.12; 21 male, 21 female), and forty-one 36-month-old (*M* age = 37.66, *SD* = 2.85; 20 male, 21 female) children. An additional eight children were tested (three 24-month olds, three 30-month olds, and two 36-month olds), but data from these children were not included due to apparatus malfunction ($n = 1$), fussiness ($n = 4$), parental influence ($n = 1$), no interest ($n = 1$), and the child being the wrong age ($n = 1$). These age groups were selected based on previous research (Butler et al., 2002; Hood et al., 2003; Mash et al., 2003; Shutts et al., 2006) that has suggested a developmental transition in this paradigm.

Children were recruited from the N'sheemaehn Child Care Centre, located at the University of Toronto Scarborough or from a list maintained by the Laboratory for Infant Studies. The families of these children were all from in or around the Scarborough, Ontario community. All children received a toy and a certificate for participating in this study. Detailed information regarding ethnic background and socioeconomic status were not collected.

1.2. Materials

The experiment employed an apparatus (see Fig. 1) modeled after the materials used in Shutts et al. (2006). The apparatus contained a white ramp that was 73 cm long, 16 cm high, and 18 cm deep, that sloped downward from left to right at a 75° angle, with a white foam core (73 cm long and 51 cm tall) backing. This ramp contained a hidden track that ensured the moving object made a smooth, straight path down the ramp. A 4 cm wide transparent window ran across the entire length of the occluding screen at about the same angle as the ramp, just above the doors.

The apparatus also contained two green wooden walls (2 cm thick, 18 cm deep), that when placed along the ramp, stood 8.5 cm above the occluding screen. These walls could be positioned just to the right of each door opening, and were held in place by slots cut out of the occluding wall.

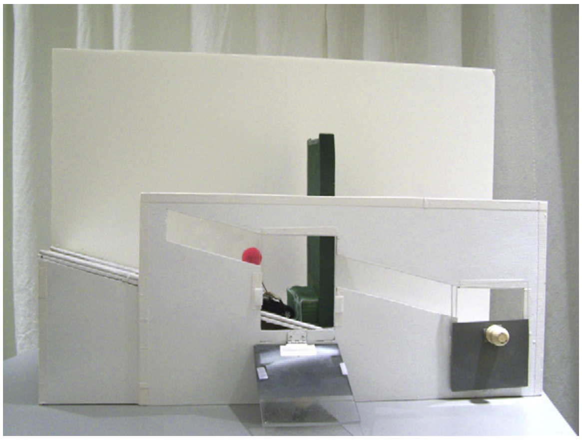

Fig. 1. A picture of the ramp apparatus, with the occluding screen in place and the left door open, revealing the ramp, the wall, and the car with a short, oblique pompom attached to it.

Table 1
Number of children at each age group assigned to each condition.

Conditions	Age (months)			
	24	30	36	Total
Short-vertical	10	9	10	29
Long-vertical	10	10	10	30
Short-oblique	10	11	10	31
Long-oblique	10	12	11	33
Total	40	42	41	123

A small black car (7 cm long, 2.5 cm wide, and 2 cm high) with an attached bright red fuzzy pompom (3 cm in diameter) was used as the to-be-recovered object. The pompom was attached to the car by a silver wire antenna that varied in length and could be connected to the car at two different orientations. The pompom was always visible either through the transparent window running across the occluding screen, or above the occluding screen.

A Sony digital video camera (DCR-TRV103) was set up in the experimental room to record children's retrieval behavior during the experiment. It was located behind the children, and positioned about 90 cm from where the children were sitting.

1.3. Conditions

The children were randomly assigned to one of four experimental conditions; Table 1 presents the number of children in each age group assigned to these conditions. In the *short-vertical* condition, the pompom was attached to the car at a 90° angle by a 7.5 cm long silver wire antenna. In the *long-vertical* condition, the pompom was attached to the car at a 90° angle by a 28 cm long silver wire antenna. In the *short-oblique* condition, the pompom was attached to the car at a 45° angle by a 7.5 cm long silver wire antenna. And in the *long-oblique* condition, the pompom was attached to the car at a 45° angle by a 28 cm long silver wire antenna.

1.4. Design and procedure

Each child participated in this experiment while seated on his/her parent's lap. Parent and child sat on a chair facing a gray table consisting of the experimental apparatus (see Fig. 1). The experimenter stood on the other side of the table, facing the child and the parent.

Similar to Shutts et al. (2006), the experiment was divided into a training and a test phase. The goals of the training phase were to familiarize the child with the apparatus and how it worked, as well as to teach the child that to retrieve the car, he/she had to open one of the doors. During the training session, the experimenter first introduced the car, drawing the child's attention to the pompom attached to it. Next, the experimenter introduced the ramp, highlighting the doors and showing the child how these opened and closed. The ramp apparatus was placed on the table such that it was out of reach for the child, and also so that the child could not look over the screen. The experimenter then introduced the wall and placed it along the ramp, behind one of the doors. After placing the car at the top of the ramp, the experimenter reminded the child to pay attention to the car as it rolled down the ramp.

After familiarizing the child with the apparatus, four training trials were conducted. In the first two training trials, both doors were opened, and the car was rolled down the ramp such that the child observed its trajectory until it had stopped. After pointing out that the car stopped by the wall, the experimenter moved the apparatus towards the child and asked the child to retrieve the car. In one of these training trials, the car stopped at the left door, and in the other trial it stopped by the right door. The last two training trials were similar to the first two, except that both doors were closed before the child was asked to retrieve the car. When the child opened the correct door and retrieved the car, the experimenter cheered; when the incorrect door was opened, the experimenter directed the child to open the correct one. Two different orders were used in training, representing different final positions of the car during the training trials: LRRL or RLLR. Each child was randomly assigned to one of these two orders.

After the training phase, the test phase was begun, and consisted of up to 12 trials. In each trial, the experimenter placed the wall on the ramp behind one of the doors, and the child observed the car roll down the ramp until it disappeared behind the screen and came to rest against the wall. The experimenter moved the apparatus towards the child, and encouraged search for the hidden toy. For each test trial, the experimenter varied the wall's placement along the ramp. Two different orders for the final position of the car were used: LRLLRLRRLRLR or RLRRLRLLRLRL.[1] Again, each child was randomly assigned to one of these two test orders.

The majority (78%) of children completed all 12 test trials. The remaining 21% of children (twelve 24-month olds, ten 30-month olds, and fourteen 36-month olds) completed between 8 and 11 trials. The entire experimental session lasted approximately 15 min.

1.5. Scoring and analysis

For each trial, the child's first door selection was coded as either correct car retrieval (1) or incorrect (0). Percent correct retrieval was then calculated by dividing the sum of each child's retrieval score by the total number of test trials completed. Trials in which the children opened both doors (1.86% of trials in total) and trials in which the children did not select a door (.27% of trials in total) were rare, and not included in the analyses.

Two research assistants coded the child's retrieval scores from the videotaped records. The primary coder scored all sessions, and a secondary coder scored five randomly selected sessions (12%) from each age group. Reliability for door selection was 100%.

2. Results

Preliminary analyses examined children's responses as a function of gender and increasing test trial (i.e., assessing possible fatigue effects). Specifically, a pair of *t* tests were conducted, and revealed no significant differences in correct responding as a function of Gender, $t\,(121) = -.54$, *ns*, or as a function of the first half of the experimental session versus the second half of the session, $t\,(122) = -.42$, *ns*. Accordingly, data were collapsed across these variables for all subsequent analyses.

Because performance on the left door was at ceiling under all conditions ($M = 93.4$, $SD = 1.3$), only performance on the right door was analyzed. It should be noted, however, that comparable analyses employing data from both doors produced equivalent findings to those reported here. In the primary analyses for this study, percent correct retrieval was analyzed using a three-way analysis of variance (ANOVA), with the between-subjects factors of age (24 versus 30 versus 36), cue orientation (vertical versus oblique), and cue length (short versus long).[2] The analysis revealed significant main effects for all three factors; means and standard errors for these effects appear in Fig. 2a–c. Specifically, there was a significant main effect for Age, $F(1, 111) = 7.41$, $MSE = .77$, $p < .01$, $\eta_p^2 = .12$, with better performance associated with increasing age (see Fig. 2a). Post hoc analyses (LSD tests) revealed that the 36-month olds significantly differed from the 24- and the 30-month olds (p's $< .05$), whereas there was no difference between the 24- and 30-month olds. The main effect for cue orientation was also significant, $F(1, 111) = 17.88$, $MSE = 1.87$, $p < .0001$, $\eta_p^2 = .14$, with better performance under vertical cue conditions than oblique cue conditions (see Fig. 2b). Finally, the significant main effect for cue length, $F(1, 111) = 34.57$, $MSE = 3.61$, $p < .0001$, $\eta_p^2 = .24$, revealed better performance in short-cue relative to long-cue conditions (see Fig. 2c).

Of the interactions, the only significant effect was the age × cue length interaction, $F(2, 111) = 4.66$, $MSE = .49$, $p < .05$, $\eta_p^2 = .08$. This interaction, shown in Fig. 3, reveals that for the two younger age groups, the short cue produced better performance than the long cue, whereas for the oldest age group, performance was equal in both conditions. In other words, cue length becomes less of a factor as children age. Of critical experimental interest was the non-significant cue length × cue orientation interaction, $F(2, 111) = .60$, $MSE = .06$, *ns*. This interaction, shown in Fig. 4, reveals that cue orientation did not differentially change the impact of varying cue length.

[1] For replication purposes, the training and test trials originally used in Shutts et al. (2006) were utilized. The trial orders were selected such that the beginning did not suggest that the trials simply alternated from one door to the other (e.g., LRLRLR) and that no more than two trials in a row were at the same door (e.g., LRRR).

[2] Given the non-normal distribution of the data, non-parametric tests and generalized linear modeling were initially used, which yielded similar main effects as the ANOVA. However, because the ANOVA is a robust test that permits examination of interactions of main interest to the current study, the ANOVA is presented.

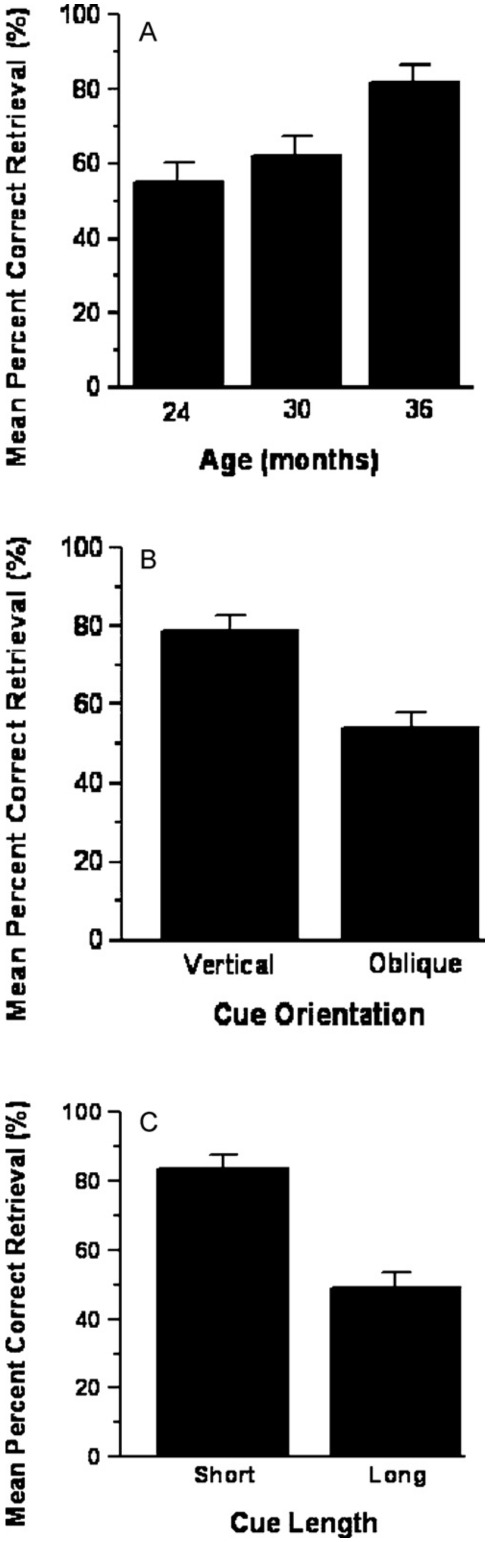

Fig. 2. (a) Mean percent correct retrievals by age group. (b) Mean percent correct retrievals by cue orientation. (c) Mean percent correct retrievals by cue length.

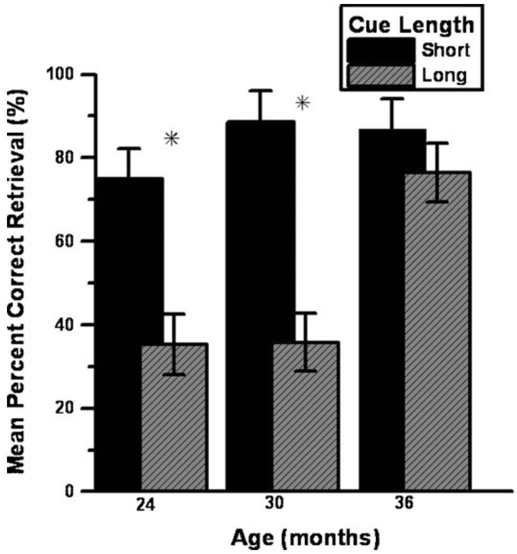

Fig. 3. Mean percent correct retrievals for short and long cues by age group.

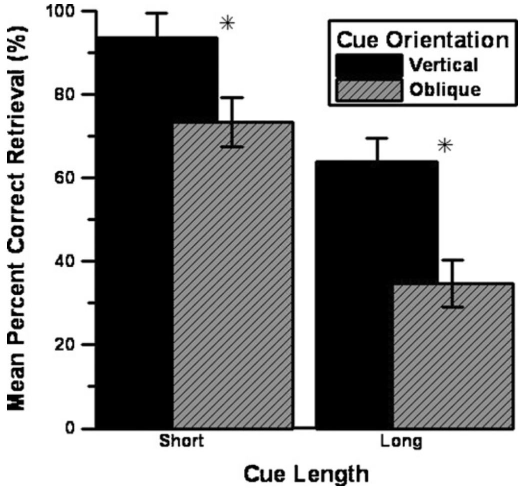

Fig. 4. Mean percent correct retrievals for vertical and oblique cues by cue length.

3. Discussion

The goal of this study was to examine two theoretical proposals for explaining children's performance in a well-known object search task in which an object rolls down a ramp, ultimately coming to rest behind an opaque screen with multiple hiding locations (Berthier et al., 2000; Butler et al., 2002; Hood et al., 2003; Keen et al., 2003; Mash et al., 2003; Shutts et al., 2006). The theory of object directed attention (Shutts et al., 2006) holds that children's attention is typically directed towards the object and spreads in a gradient-like fashion within the object, and thus the efficacy of a cue is influenced by its direct connection to and distance from the hidden object. In contrast, the landmark-based approach (Acredolo & Evans, 1980; Bremner, 1978; Bushnell et al., 1995; DeLoache, 1986; DeLoache & Brown, 1983; Plumert & Hawkins, 2001; Rieser, 1979; Schmuckler & Jewell, 2007; Schmuckler & Tsang-Tong, 2000) posits that the effectiveness of a cue attached to a hidden object is a function of how well this cue acts as a landmark to the location of the object, with the use of the landmark potentially influenced by aspects such as the distance between cue and object (as suggested by Shutts et al., 2006), the spatial relation between the cue and object, and possible other factors as well.

In terms of the current findings, this study presents both novel and convergent results with regards to the existing literature. The most notable new finding of this work is its demonstration that the orientation of the cue *vis a vis* the hidden object significantly influenced search, with vertically aligned cues leading to better performance than obliquely aligned cues. Accordingly, and with reference to the principal goal of this work, this study provides the first evidence to date (of which we are aware) that oblique versus cardinal cue orientations influence children's spatial orientation and search.

This study also highlighted three results that converged with previous findings. First, older children outperformed younger children in object search, a consistent (and unsurprising) result in the literature (Berthier et al., 2000; Butler et al., 2002; DeLoache, 1986; DeLoache & Brown, 1983; Hood et al., 2003; Kloos & Keen, 2005; Mash et al., 2003; Sutton, 2006). Second, there was a left door bias with performance with the left door virtually at ceiling (Shutts et al., 2006).[3] Third, and most importantly, this study replicated Shutts et al.'s (2006) finding that short cues, relative to long cues, led to more successful object retrievals. This final result is essential in that this finding lies at the core of the object-directed attention account in the first place.

As for the implications of these findings, the most straightforward interpretation of these results are in support of a landmark-based explanation for object search, as opposed to the theory of object-directed attention (Shutts et al., 2006). As discussed initially, it is only within a landmark-based framework that modifications of non-distance based spatial relations should impact on search. In contrast, the theory of object-directed attention, as currently instantiated by Shutts et al. (2006), contains no explicit or implicit mechanism for incorporating spatial information into its explanations or predictions. Accordingly, the current findings present an important challenge to this account. In this study, separate effects of distance (i.e., short cues better than long cues) and spatial relations (i.e., vertical cues better than oblique cues) on cue effectiveness were found. The object-directed attention account posits that attention spreads from proximal to distal within the object, and thus can readily explain the distance effect. However, because this theory does not address spatial information, it cannot readily explain the spatial relation effect. In contrast, the landmark account posits that the more the cue serves as a direct landmark for the location of the object, the more effective cue it is. Accordingly, this explanation does account for both the distance and spatial relation effects. Of course, it is certainly possible that object-directed attention theory could be modified to incorporate such spatial information, but such a change would require a significant reformulation of this account, one that would fundamentally change the assumptions and operation of this theory. For instance, the theory should account not only for constraints on object boundaries and proximity relations, but also for spatial constraints on attention spread. It is true that the object-directed attention account cannot be completely disregarded, however as it stands now, the landmark account offers a more encompassing explanation of the current findings.

One alternative to the idea that it is the spatial relation between the cue and the hidden object that is driving performance in this work arises through recognizing that modifying the angle between the cue and the object (e.g., the change from vertical to oblique) also modifies some potentially important distance relations within the experimental apparatus. Specifically, two distances are changed–the distance between the cue (the pompom) and the barrier (the wall) that stopped the movement of the hidden object, and the distance between the cue and the nearest possible search location (the door), irrespective of whether or not it was the correct location.

Subsequent reflection, however, reveals that neither of these distance measures can adequately explain the current findings. In terms of the first distance measure, there are multiple reasons why the distance between the cue and the barrier is not an adequate explanation for these results. First, this distance measure simply fails to account for the observed findings. Although it is true that the oblique cues are generally further than the vertical cues from the barrier (and hence correlate with the differences in performance), for the vertical cues, both the short and long cue conditions have exactly the same distance between the cue and the barrier, and yet, these conditions produced differential responding. Accordingly, distance is inadequate in explaining the observed cue length effect in this, or in previous (Shutts et al., 2006) work. Second, and more fundamentally, previous work has convincingly demonstrated that the barrier is ineffective in cueing the location of the hidden object (Butler et al., 2002; Keen et al., 2003; Mash et al., 2003). Accordingly, the distance to the barrier is simply irrelevant in terms of explaining performance in this context.

As for the distance between the cue and the nearest search location, this measure is also unable to fully account for the current findings. Specifically, the distance between the cue and the nearest search location cannot explain the observed difference between the short vertical and oblique cues, because both of these cues ultimately lay on top of the to-be-searched in door. As such, this distance measure is also unable to thoroughly explain the current findings, and leads to the more global realization that distance-based explanations in isolation are inadequate predictors of these results. Instead, it is only by taking into account the spatial relation between the cues and the to-be-recovered objects that these findings can be fully understood.

The current findings also have implications for the oblique effect itself, as well as for issues related to search tasks and spatial orientation. As for the oblique effect, previous research has demonstrated a huge range of processing advantages for orthogonally versus obliquely oriented stimuli. To this diverse array, the current study now adds that obliquely oriented cues are not as effective as orthogonally oriented cues in functioning as landmarks, a novel finding in the field. This finding could and should be extended in multiple ways. For instance, it would be interesting to examine search with a horizontally aligned cue. Assuming there is indeed privileged processing for vertical and horizontal orientations, this manipulation should have the same impact on search as a vertical cue, leading to enhanced performance relative to an oblique cue.

[3] There are multiple explanations for the left door bias. First, the left door was the door closest to the location at which the car was last seen. Second, the left door was also the most centrally located in the apparatus. Although this study cannot fully disentangle these alternatives, previous work employing a four door apparatus (Berthier et al., 2000; Butler et al., 2002; Hood et al., 2003; Mash et al., 2003) that also observed strong door biases suggests that it is the central location of the door that accounts for this bias. As such, it is likely that this is the factor underlying the bias observed in the current study.

As for theories of landmark-based spatial orientation, the evidence that an obliquely aligned landmark is not as effective in signaling a target location as an orthogonal landmark predicts that this result should be evident in other spatial orientation tasks. For instance, Bushnell et al. (1995) employed a locomotor search task in which the location of a hidden object was signaled by a visually distinct cushion that lay directly atop of the object (beacon) or adjacent to the object (landmark). These authors observed better performance with beacon, as opposed to landmark cues, a finding confirmed by others (Sutton, 2006). The current results suggest that manipulating the spatial relation between the hiding positions and the different landmarks (e.g., a horizontally adjacent cue versus a diagonally adjacent cue) should produce similar influences on search. Theoretically, such findings would support the notion that, at least for young toddlers, spatial orientation in the world is driven largely by constraints on the availability and use of basic perceptual information specifying the layout of the environment, and how object and self movement through this world varies these spatial relations (Presson & Somerville, 1985; Schmuckler & Jewell, 2007; Schmuckler & Tsang-Tong, 2000).

In sum, the present experiment investigated the impact of modifying the orientation of a cue relative to a target object, and found that this orientation significantly modulated children's search behavior. Although potentially explainable within the context of a theory of the spread of object-directed attention, these findings also implicate the importance of direct versus indirect landmark cueing in children's search. More globally, these findings highlight the fact that the environmental cues we use to make inferences about events and the state of the world clearly vary in their informational nature, with some cues more directly informative than others. Within this context, a key developmental achievement involves learning about and understanding such cues, which ones are directly relevant, which are indirectly important, and which can be disregarded altogether. The growth of such sensitivity clearly allows children to become increasingly active, understanding, and intuitive observers of their worlds.

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