TO CUE OR NOT TO CUE: BEACONS AND LANDMARKS IN OBJECT-DISPLACEMENT TASKS

by

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A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy
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2013

Abstract

Two experiments examined the role of various cues on children’s performance in a well-known object-displacement task. In this task, children observed a toy rolling down a ramp whose trajectory was occluded by an opaque screen with doors. A barrier was placed along the ramp, behind one of the doors, to stop the toy. The top portion of the barrier was visible above the screen. To search successfully, children had to retrieve the hidden toy by opening the correct door. Previous work had found that the barrier was an ineffective cue among children less than three years of age. According to a landmark-based account, this was because the barrier was only an indirect cue to object location. If a cue directly marked the location, then it would be more likely attended and utilized. This model underscores the spatial relation between cue and the target. Other cue properties are important in so far that they modify this spatial relation.

In Experiment 1, a cue’s distance from the target object was manipulated (i.e., short vs. long), but the location marked by the cue was kept constant (i.e., correct door was directly below). The search performances of 24- and 30-month old children were compared under no cue, short-cue/short-door, and long-cue/long-door conditions. Both age groups performed equally well under both cued conditions.
In Experiment 2, a cue’s movement (i.e., coincident with the car vs. not coincident with the car) down the ramp was manipulated. The performance of 24- and 30-month old children were compared under attached-direct cue and unattached-direct cue conditions. Both age groups performed well under both conditions.

Collectively, the results provide support for the landmark-based account. The spatial relation between cue and target underlies toddlers’ search. Properties of the cue matter to the extent that they impact how well the cue marks its target.
Acknowledgments

This work was not made possible without a number of people who have helped and supported me throughout my graduate studies. I know that words would not be enough, but with this letter, I give my sincere gratitude to each and every one of you.

First, I give my utmost gratitude to the children and families who participated in my studies. You may not truly understand how much your time, participation, and patience mattered. Because of your continued interest and joy in research, you help to advance knowledge. In a way, without you, there is no work.

Second, I thank my supervisor, Dr. Mark Schmuckler who has guided and supported me for more than a decade. Your patience, time, thoughtful advice, critical analyses, and warm heart have truly helped me become the researcher I am today. Thank you for believing in me. If I can be a quarter of a writer you are, I would be extremely happy.

Next, I thank my committee members, Dr. Michal Perlman, who has also become my adviser and support, most especially earlier on at OISE. You have supported my research interests and have always reminded me of things I forget when examining a situation. I also thank Dr. Matthias Niemeier whose ideas, questions, and analyses have also provided me a better perspective of my work.

I would like to give thanks to all the members of the Laboratory for Infant Studies. These include other graduate students who are both my colleagues and friends – Gelareh, Tim, Dom, Lisa (and Dwayne) who all became fresh sets of eyes and lenders of ears, as well as all the research assistants who aided in recruiting, assisting experiments, babysitting, coding, and doing
reliabilities. Because of all of you, I had a full research experience. I hope that I will never lose you.

And everyone at OISE and UTSC I interacted with and helped me throughout my seven years of graduate studies, thank you.

I would also like to thank my family, especially Mama, Papa, Eric, Natalie, Madelynn, Addyson, Lola, Neng, Mikey, and Tita Ninit (even Walter and Roxie). You reminded me of work that needed to be done, and took me away when I needed a break. Your never-ending love, support, and prayers throughout this process have helped me stayed on my feet, kept a sound head, and reassured me that whatever I do or fail to do in my life, I will always have you.

And last, but not least, I want to thank God. Thank you for this journey and this experience. You let me walked when I could, and carried me when I could not. Without You, there will be none of these. You brought me where I am and made me the person I am today. I pray that I will always be able to do Your will.

From the bottom of my heart, I thank you.
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Chapter 1
Introduction

The ability to make inferences about the current state of events in the world is an essential skill because we are not directly present to observe each and every event that occurs around us. Making inferences is especially important when these involve decisions based on events that previously transpired that will impact our current situations and future outcomes. Thus, having the skill to make accurate inferences is beneficial in our everyday interactions in our world, both physical and social. But how does such a vital skill come to develop?

Understanding infants’ and children’s abilities to make inferences about objects and events in the world has been a primary focus of research in child development. One such topic has involved the examination of young children’s skills at tracking the unseen or partially seen movement of an object, and inferring its final resting position based on a variety of different cue information (Berthier, DeBlois, Poirier, Novak, & Clifton, 2000; Butler, Berthier, & Clifton, 2002; DeLoache, 1986; Hood, 1995; Hood, Carey, & Prasada, 2000; Hood, Cole-Davies, & Dias, 2003; Keen, 2003; Keen, Carrico, Sylvia, & Berthier, 2003; Kloos, Haddad, & Keen, 2006; Kloos & Keen, 2005; Mash, Keen, & Berthier, 2003; Moore & Meltzoff, 2004). Within this framework, multiple paradigms have been employed in order to investigate children’s ability to make use of cues when searching for 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; Sutton, 2006; Twyman, Friedman, & Spetch, 2007). These studies investigate a sophisticated form of object knowledge. Specifically, to perform well, children need to have: (a) an awareness of the existence of an object (i.e., object permanence), (b) the ability to track the unseen or partially seen movement of an object, and (c) the ability to
use environmental cues to infer the object’s final resting position. Each of these capacities has been extensively examined. These literatures will be reviewed and discussed in turn below. This paper, however, argues that it is in the third capacity (i.e., the ability to use environmental cues) for which the greatest differences in search performance lie for young children. Accordingly, this topic will be the one most thoroughly discussed.

1 Early development of object permanence

Object permanence refers to the idea that objects continuously exist, maintain their spatial and physical properties, and are subject to physical laws, even out of sight (Piaget, 1954). According to Piaget (1954), object permanence develops gradually through six stages during the sensori-motor period and essentially, involves the person constructing and developing progressively more complex knowledge structures of the world. These knowledge structures, called schemes, form the bases for organizing actions in order to understand and respond to the environment. As children get more experience, they shift from action-based schemes (i.e., externally driven) to operations that are based on internal mental schemes (e.g., strategies; internalized rules). The idea then is that the development of object permanence begins with children learning about objects through their actions with them. Then, over time and with more experience, children learn that the existence of objects in the world is independent of their interaction with these objects.

Based on classic observations of his children’s manual search of objects, Piaget (1954) found that it is by the fourth stage of the sensori-motor period (roughly between 8 and 12 months) during which infants combine different schemes with the intention of achieving a specific goal that object permanence begins to emerge. At this stage, infants begin to search for completely hidden objects. By the fifth stage (between 12 and 18 months), during which infants experiment
(e.g., trial-and-error) with objects to learn how these objects respond to different actions, the infants begin to recognize the permanence of invisible objects. Through a series of attempts leading to some failures and to some successes, infants are able to track objects and search for these objects in locations where these objects disappeared. Piaget (1954) concluded that infants fully acquire object permanence by the last stage of the sensori-motor period (18 to 24 months).

At this stage, infants begin to think symbolically, mentally constructing new means, and combining different schemes. Thus, it is at this time, that infants are able to make inferences about invisible objects and where these objects are located, even after these objects undergo multiple invisible displacements (Flavell, 1985; Gruber & Vonèche, 1977; Piaget, 1954).

Other researchers (Baillargeon, 1986; Spelke, 1991) have argued that object permanence develops earlier than when Piaget (1954) posited. Specifically, Spelke (1991) argued that infants are born with knowledge about invisible objects and invisible displacements. This core knowledge system includes: (a) continuity, which is the understanding that objects move only on connected paths unless impeded; they do not jump from one place and time to another, (b) solidity, which is the understanding that objects move only on unobstructed paths, and no two distinct objects can occupy the same space and time, (c) gravity, which is the knowledge that objects move downward in the absence of support, and (d) inertia, which is the understanding that objects do not change their motion abruptly and spontaneously. Very similar to adults, infants have a considerable understanding of behaviours of physical objects. This core knowledge system then allows for accurate perceptions and inferences regarding properties of objects during events (e.g., collisions, movement behind occluders), and proper predictions of objects’ current and future motions, even those objects undergoing unseen or hypothetical displacements, both of which have been empirically examined and supported (e.g., Baillargeon,
1986; Baillargeon, Spelke, & Wasserman, 1985; Kim & Spelke, 1992; Woods, Wilcox, Armstrong, & Alexander, 2010).

Baillargeon (1995) has taken a somewhat less stringent stance, positing that infants are born with an appreciation for physical knowledge, and with experience, infants are able to fine tune this knowledge system. Baillargeon, Spelke, and Wasserman (1985) examined young infant’s object permanence using the violation-of-expectation paradigm (Baillargeon, et al., 1985), which taps knowledge about hidden objects without relying on infants’ active search. In this paradigm, infants are habituated to an event depicting an object in motion. Once habituated, infants are then presented with two test events. One is a possible event that shows motion that abides by one of the physical constraints (e.g., a ball stopping by a wall placed in its path). The other is an impossible event that shows motion that violates one of the physical constraints (e.g., a ball continuing on its path, despite the wall placed in its path to impede movement). Differences in looking time for each test event are then examined and compared. Longer looking times to the impossible event is regarded as a reflection of infants’ recognition that some physical law has been violated, which is indicative of their knowledge of physical events. In this study, Baillargeon et al. (1985) repeatedly presented 5-month old infants with a rotating screen (i.e., a screen that moved back and forth through an 180° arc). Once habituated, infants observed that a box was placed behind the screen. Infants were then presented with two test events in which, (a) the screen rotated until it reached the occluded box and then stopped (possible event), and (b) the screen fully rotated, as though the box was not behind it (impossible event). The researchers found that infants looked significantly longer at the impossible event, suggesting not only that infants understood that the box continued to exist even when occluded (law of continuity), but also that infants were surprised that the screen passed through the space occupied by the box, which was a violation of the law of solidity.
In a study with 6- and 8-month old infants, Baillargeon (1986) conducted two experiments to examine not only infants’ representation of a hidden object, but also infants’ representation of its invisible displacement. In these experiments, infants were habituated to a moving object that rolled down a ramp with part of its trajectory occluded by a screen. After habituation, two test events were presented. In the possible event, a barrier was placed behind or in front of the ramp before the object rolled down, moved behind the occluder, and re-emerged at the end of the ramp. The impossible event was similar except that the barrier was placed on the ramp. Replicating what was found among 5-month olds, Baillargeon (1986) found that 6- to 8-month old infants preferred to look at the impossible event, further suggesting that young infants understand that (a) a stationary object continues to exist and maintains its properties despite being occluded, and (b) a moving object continues to exist and pursues its trajectory when passing behind an occluder.

However, the strength of infants’ knowledge about physical properties may not be equally represented among all the object properties. In a series of experiments, Spelke, Breinlinger, Macomber, & Jacobson (1992), further explored infants’ understanding about hidden object displacements and how these movements follow the different physical laws. These researchers examined a much younger age range – infants aged 2.5 and 4 months. The first three experiments examined infants’ understanding of continuity and solidity as the objects underwent hidden vertical and horizontal displacements. For instance, in Experiment 1, the infants observed a ball falling behind a screen with a shelf placed within its path. When the screen was removed, the ball then appeared to land on (possible event) or pass through (impossible event) the shelf placed within its path. Spelke et al. (1992) found longer looking times toward the impossible events, which supported the idea that sensitivity to object solidity and continuity develops before the end of the third month. The latter two experiments examined infants’ understanding of gravity and
inertia. For instance, in Experiment 4, infants’ sensitivity to an object’s continuous fall to a supporting surface was examined. Researchers habituated infants with the same display as in Experiment 1 (i.e., a ball falling behind a screen with a shelf placed within its path), except that in the test trials, the shelf was removed, such that when the screen was removed, the object was seen on the bottom-most surface (possible) or suspended in the air as if the shelf was still there stopping it (impossible). Based on results from Experiments 4 and 5, these researchers did not find evidence that 3- and 4-month olds understand that an object would fall when its support was removed. Thus, the latter two experiments showed that young infants’ sensitivity to gravity and inertia may not be as strongly represented as continuity and solidity. Taken together, Spelke et al.’s (1992) findings support an active representations account that posit that the capacity to represent and reason about the physical world do develop at an early age. Infants represent objects and reason about their movements in accordance to continuity and solidity. Very young infants do have difficulty with gravity and inertia, suggesting that perhaps understanding of these physical constraints may not be as strong earlier on, but sensitivity for these physical constraints among young infants have been found elsewhere.

For instance, in work using visible motion, Kim and Spelke (1992) conducted four preferential-looking experiments with 5- and 7-month olds to determine infants’ sensitivity to the laws of gravity (i.e., the impact of gravity on speed and direction of object motion). In the study, infants were habituated to a ball accelerating down a slope or a ball decelerating up a slope. Once habituated, infants were then presented with test trials that depicted either possible (same as habituation trials) or impossible (ball decelerating down or ball accelerating up the slope) motion. The researchers found that 7-month old infants, but not the 5-month olds, preferred to look at the impossible motion, suggesting sensitivity to the effects of gravity on the speed of object motion. In the subsequent experiments, 5- and 7-month old infants were habituated to an
object moving on a straight path, in a rightward direction and at a constant speed. The infants were then presented with either downward or upward acceleration. If they were sensitive to the effect of gravity, then they should show preference for the impossible event. Again, these researchers found only the 7-month old infants were sensitive to the effects of gravity. Thus, these findings revealed that sensitivity to the effects of gravity develops around 7 months of age, which is a little later than sensitivity to the laws of continuity and solidity. However, even if some representations may not be as strong earlier on, infants are quite adept in representing object motion during occlusion and in predicting where objects should reappear.

In a more recent study, Woods, Wilcox, Armstrong, & Alexander (2010) examined 6-month old infants’ capacity to represent simple and complex occlusion sequences within a three-dimensional display by tracking infants’ looking patterns. In this study, infants tracked an object that moved behind an occluder under two test conditions. In the simple condition, infants observed a ball being rolled back and forth the display, with the middle part of its movement occluded by a screen. In the complex condition, infants observed a ball being rolled from the left side of the display behind an occluder, then a box emerging at the right-end of the display. Then, the box was moved from the right side of the display behind the occluder, and the ball re-emerging at the left-end of the display. This situation implied that two objects were involved in this occluded movement. The researchers found that infants represented objects and the paths of movement that these objects underwent when occluded. During occlusion intervals, infants directed their gaze to the side of the screen that currently hid the object, and when not attending to the location of the moving object, infants tended to look in the direction of object motion. They looked equally in both simple and complex conditions. The findings further confirm that the infants’ cognitive capacities about the physical world are present earlier on in development.
In summary, the awareness for the existence of objects is established very early in development. Researchers have shown using the violation-of-expectation paradigm that infants behave in ways that suggest an extensive understanding of object permanence, as well as an understanding of the physical world, for both visible and invisible movements.

2 Object-displacement task: Tracking unseen or partially seen object movement

Knowledge about invisible objects and invisible displacements had also been examined among toddlers. With toddlers, researchers have typically used an object displacement paradigm first utilized by Berthier et al. (2000). In this task, children observed an object (e.g., ball) rolling down a ramp whose trajectory was occluded by an opaque screen with doors. A wall or barrier was placed along the ramp, behind one of the doors, to stop the ball. The top portion of the barrier was visible above the screen. To search successfully in this ramp paradigm, children had to retrieve the hidden toy by opening the correct door. Using this apparatus, Mash, Keen, & Berthier (2003), designed a looking-time task in which toddlers watched a ball roll down a ramp, and then observed a puppet open either: the incorrect door and not find the ball, or the correct door and not find the ball. After the door was opened (and the ball was not found), the screen was then raised, revealing the ball as either resting in front of the barrier (possible event) or beyond the barrier (impossible event). Similar to infant looking studies, these researchers found that toddlers looked longer at the impossible placement of the ball.

Similar findings had been observed by Hood, Cole-Davies, & Dias (2003). In their study, the researchers investigated 2.5- and 3-year olds in both looking and search tasks using this ramp paradigm. In the looking task, toddlers saw a ball roll down the ramp. After the ball was stopped by the barrier, doors on both sides of the barrier were opened. In the possible event, the ball was
located in the opened door in front of the barrier, whereas in the impossible event, the ball was found on the other side (i.e. the opened door after the barrier). Generally, Hood et al. (2003) found that at all ages, the children looked significantly longer at the impossible outcomes, whereas only the 3-year olds successfully retrieved the hidden toy in the actual search task. Researchers found that children under three years of age often erred in search retrievals (i.e. opening the incorrect door to find the ball).

Other researchers had found similar errors, indicating that children less than three years of age had difficulty with the search task (Berthier, et al., 2000; Butler, et al., 2002; Hood, et al., 2003; Keen, et al., 2003), whereas three-year olds reliably succeeded in this task. For instance, Berthier et al. (2000) examined 2-, 2.5-, and 3-year old children’s search in the ramp apparatus to determine if children knew the ball’s location, which would signal application of their physical knowledge and understanding. Researchers found poor performance by the younger children. Moreover, the researchers analyzed children’s errors and found that children adopted several strategies when they were unsure about the object location, such as opening a preferred or favourite door. Children also engaged in perseveration, which had been found with 2- and 3-year olds (Horn & Myers, 1978; Loughlin & Daehler, 1973) and suggested that children used information from previous successful experience. Thus, children did not randomly search for the hidden object. They did, in fact, take other factors into account. The task may just been more demanding for them.

What exactly was it about the task that made it difficult for 2-year olds? Keen (2005) argued that the discrepancy lies in the task requirements. In looking tasks, children are required to be merely passive observers, with their knowledge or understanding of events deduced from differences in looking behaviour towards various events. In contrast, children are required to do a number of
things in search tasks. These things include prediction, use of indirect cues, and incorporation of perceptual knowledge into solving a problem with appropriate action. Keen et al. (2008) further suggested that the actual manual search task requires several abilities such as attention, understanding of hidden motion, visuospatial reasoning, and response selection and inhibition. Moreover because understanding of objects’ hidden displacement has been shown quite earlier on in development (as discussed in the preceding section), these researchers have suggested that poor performance may be due to difficulty with reasoning about various factors, such as the unseen resting object, the wall, the positions of these two objects with respect to the doors, and the object’s trajectory down the ramp. In other words, what is challenging for 2-year old children is the integration of these different factors.

To support that the integration of various types of information is important, Keen et al. (2008) conducted several experiments that examined children’s understanding of the different factors relevant to the ramp paradigm, and how these factors can impact the search task. In particular, these researchers manipulated the salience of the barrier in different ways such as the addition of a sound as the object made contact with the barrier (Experiment 1) and increased visibility by extending the barrier over the screen (Experiment 2) or by substituting a hand that stopped the object as it rolled down the ramp (Experiment 3). These manipulations only produced slightly better performance for the 2.5-year olds, suggesting that it was not necessarily the failure to attend to the wall that was the problem.

For the latter two experiments, the researchers more closely examined the factors that may have contributed to 3-year olds’ successful performance in the task. In Experiment 4, researchers switched the direction of the object motion (i.e., for half of the trials, the object rolled from left to right, then for the other half, the object rolled from right to left) to examine whether 3-year
olds were using the associative rule in their search. If children were unsure which of the two adjacent doors (separated by the barrier) to open, they would select the door on the side that they had initially found the object. For instance, if the children found the object behind the door that was on the left side of the barrier, they would repeatedly select the left-side door for subsequent trials. This way, the children only associated success to a side, failing to appreciate the role that the wall had played. This use of association would also result in errors during the trials when the direction of object motion switched because in that case, the correct door to open would be the one on the right side of the barrier. Based on results from Experiment 4, researchers found that children selected the appropriate door during pre- and post-switch trials, suggesting that 3-year olds understood the causal relationships in these physical events. In other words, 3-year old children were not simply using the associative rule in search strategy; the children understood the wall’s role in the event. Finally, researchers further complicated the task in Experiment 5 by not only using the direction switch (same as in Experiment 4), but also utilizing a shorter wall, such that the wall was no longer visible above the screen. The use of the short wall was to determine if the wall’s visibility contributed to 3-year olds’ search. Researchers found that the loss of wall visibility led to dropped performance for most children. And children produced more errors once the shift in direction was introduced. In other words, the loss of wall height increased the cognitive load and dramatically impacted 3-year olds’ performance. Thus, findings of these experiments supported the researchers’ argument that the search performance is influenced by children’s integration of a number of different types of information, such as the wall and position of the unseen object.

Another critical piece of information that children need to incorporate to search successfully in the ramp paradigm is an understanding of the object’s trajectory down the ramp. Researchers have examined the degree to which the amount of information about the object’s trajectory could
impact children’s search by manipulating the actual visibility of the object’s trajectory. Researchers have posited that providing more information about the object’s movement would certainly be beneficial because children need not reason about the object’s invisible displacement anymore, which should then lead to improved search performance. For instance, Hood (1995) examined 2- to 4-year old children’s search using a task that involved a ball being dropped down an opaque tube that led into one of three hiding places and found that children below three years of age erred, typically searching in the hiding location directly below where the ball was dropped, even though the tube was not connected to the hiding location. However, when the opaque tubes were replaced by transparent tubes such that the ball’s trajectory was visible, 2.5- and 3-year old children were able to search correctly. Similarly, Butler et al. (2002) utilized a transparent occluder or transparent screen in the ramp apparatus such that children were able to see the object’s trajectory down the ramp, offering more information about the object’s movement. In this study, the researchers examined 2- and 2.5- year olds’ search behaviour and found improved search performance for both age groups.

Mash et al. (2003) also manipulated the extent of information that was provided for the children regarding the object trajectory in several experiments. More specifically, these researchers manipulated children’s visual access to the event’s outcome (i.e., seeing where the object stopped) before search and investigated how this manipulation guided 2- and 2.5-year old children’s search. In this study, half of the children observed the entire trajectory of the object until the object stopped by the barrier before the screen was lowered, and thus had full visual access to the event outcome. With this information, children did not need to predict the object location. The children’s task was to simply recall the location of the object and determine which door corresponded to object’s location on the ramp. The other half of the children did not observe the entire trajectory of the object down the ramp until the object stopped, and so, had no
visual access to the event outcome. According to the researchers, if search performance rested on children’s ability to predict the event outcome, then children should be more successful under the condition in which full visual access was provided because prediction was removed. Supporting this prediction, researchers found that the additional information about the object’s trajectory led to improved search performance for both age groups.

In summary, examination of toddler understanding of invisible displacement produced similar findings as work on infant understanding of object permanence, with children displaying good understanding object hidden object displacements in looking tasks. However, this understanding did not quite translate well in search tasks, with children producing errors in search retrievals. Researchers have argued that the task requirements between the two tasks were different, and what made the search task most challenging for toddlers was the fact that the search task required the integration of information from various factors. In fact, when some of these factors were manipulated, children’s search performance was influenced, such as what occurred when providing increased visibility of the object trajectory down the ramp (i.e., Butler, et al., 2002; Mash, et al., 2003). With these modifications, the task was reduced to simply recalling object location on the ramp and translating this location with regards to the correct door. These modifications have led to improved search performance.

3 Use of various environmental cues

Information regarding object trajectory is also potentially important because it provides a host of additional environmental cues regarding the location of the hidden object. For instance, one additional cue to object location arises from children’s tracking of the object trajectory. Keen (2003) argued that there were two aspects of tracking that were important. They were: (a) the point in which the children stopped tracking the object, and (b) whether children broke their gaze
before door selection. Children need to engage in both of these tracking aspects at the same time to be successful because correct tracking of the ball did not always ensure success, and if gaze was broken, children made errors, especially the 2-year olds. For instance, even though Butler et al. (2002) found that children looked at the wall when the experimenter called attention to it and followed the object’s trajectory down the ramp, correct scanning did not always guarantee correct selection and breaking attention from the correct location led to incorrect searches. Moreover, even with a full view of the ball’s movement, the 2-year olds still made significant errors when they broke their gaze (Mash, et al., 2003). The maintenance of attention to the target location was the key to the success, as well as a continuous tracking of the object until it stopped.

Children’s reliance on the information afforded by tracking the ball’s movement to ensure successful retrievals suggests that children were not using the top of the barrier as a cue of the ball’s location. This is most intriguing because the barrier can also provide additional information about the ball’s location – specifically, where the ball actually has stopped. However, children under three years of age continuously made errors in their search despite the visual availability (above the opaque screen) of the barrier that stopped the ball’s movement down the ramp (Berthier, et al., 2000; Butler, et al., 2002; Mash, et al., 2003). This means that the barrier is a relatively ineffective cue for signaling the location of the hidden object. Why would this be the case?

According to Keen (2005), the reason the top of the barrier was ignored by children in these studies is because the barrier itself was only adjacent to the door that hides the to-be-recovered object, and was not physically connected to this object. In other words, the barrier was 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 were cues that were directly connected to
the hidden object (p. 314). Hence, 2-year olds’ difficulties with using the barrier as a cue really stemmed from a general difficulty of using cues that were not directly related to the target object (DeLoache, 1986; DeLoache & Brown, 1983; Gilchrist, North, & Hood, 2001; Horn & Myers, 1978; Smith, Gilchrist, & Hood, 2005; Sutton, 2006). This means that environmental cues vary in the types of information they provide, and children’s search for hidden objects can be influenced by the types of cue available to recover the hidden object. What are the various cues available for children to use, and how are these processed?

3.1 Beacons and landmarks

Work on cue use (e.g., Acredolo, 1978; Acredolo & Evans, 1980; Bushnell, McKenzie, Lawrence, & Connell, 1995; Crowther, Lew, & Whitaker, 2000; DeLoache, 1986; DeLoache & Brown, 1983; Horn & Myers, 1978; Keating, McKenzie, & Day, 1986; Lew, Foster, & Bremner, 2006; Lew, Foster, Crowther, & Green, 2004; Sutton, 2006) has revealed two main types of cues that differ in information they provide. The first type of cue is a beacon, which is a perceptually distinct cue coincident with the target location (i.e., a distinct cue that marks a target directly). Because it directly marks the target, organisms only need to orient towards and approach these cues to reach the target. The second type of cue is a landmark, which is a perceptually distinct cue not coincident with the target location (i.e., a distinct cue that is some distance and direction away from the target). Accordingly, to make use of a landmark, organisms need to encode the target’s location and distance from the landmark. O’Keefe and Nadel (1979, as cited in Sutton, 2006) proposed that the use of these two cues involve basic mechanisms of a larger navigational system. These researchers posited that using landmark cues is called place learning because this process involves locating a target by spatial coding using landmarks (i.e., denoting the spatial
relations among surrounding cues). Beacon cues, on the other hand, are referred to as *guidances* because these cues direct organisms to the actual target.

What underlies the development of using these various cues? Some researchers have posited that development of cue use involves hippocampal maturation (Sluzenski, Newcombe, & Satlow, 2004). Also, Newcombe and Huttenlocher (2000) argued that the development of cue use includes learning from outcomes of navigation with different kinds of cues. Specifically, place learning builds on already established spatial systems, such as beacon learning, and continues to be refined over childhood. Thus, cues vary in the types of information they convey, from beacons to landmarks, and the use of the various cues correspondingly depends on age.

Research in infant orientation and active searching provides support for the above idea. For instance, Acredolo (1978) examined spatial orientation abilities in infants using the peekaboo method – a method that provides a means to dissociate orientation based on environmental cues and orientation based on egocentric response learning. In this paradigm, the infant is placed in a room with two identical windows on either side. A series of training trials are presented such that after a buzzer sounds, an experimenter appears in one of the two windows, essentially playing peekaboo with the infant. Typically, this window is marked by some cue (e.g., large yellow star). Once the infant shows reliable anticipation (i.e., turning towards the window where she expects the experimenter would appear), the infant would then be moved to the opposite side of the room. After the buzzer sounds, the infant’s first look is noted. If the infant has learned a turning orientation, then she is expected to turn her head in the same direction as in the previous training trials. Because of the displacement, however, this would mean that the infant would be turning to the incorrect window (i.e., the other window in which the experimenter never appeared). If the infant has learned to use a beacon, then the infant would adjust her turning orientation and turn
her head in the opposite direction towards the correct window. Using this method, Acredolo and others (Acredolo & Evans, 1980; Crowther, et al., 2000; Keating, et al., 1986) have found that beacon use emerges early in development, in the latter half of the first year of life.

The use of landmark cues within the first year of life is not as clear cut. For instance, under certain conditions, infants as young as 6 months (Lew, et al., 2004) and 8.5 months (Lew, et al., 2006) have been found to use landmarks on the peekaboo method. In contrast, Acredolo & Evans (1980) found that only 11-month olds, but not 6- or 9-month olds were able to use landmarks. Thus, even though there is evidence for landmark use earlier in development, these findings have been inconsistent.

Using a locomotor search task, Bushnell et al. (1995) have also found children’s early use of beacon cues, as well as difficulty with landmarks. These researchers examined 12-month olds’ search for a hidden toy in a circular space filled with colourful pillows. In some conditions, the object was hidden under a distinctive pillow, which served as a beacon to the hiding location, whereas in other conditions, the distinctive pillow was adjacent to where the object was hidden, which served as a landmark to the hiding location. Bushnell et al. (1995) found that 12-month olds showed successful search using beacons as opposed to landmarks. In fact, performance under landmark conditions was poorer compared to conditions in which there were no landmarks at all. Thus, at 12 months, infants were unable to code for the distance and location of a distinctive cue from the target location, which hindered their search performance.

Children’s ease with utilizing beacons and difficulty with utilizing landmarks have both been consistently found in other search studies (DeLoache, 1986; DeLoache & Brown, 1983; Horn & Myers, 1978; Sutton, 2006). For instance, Horn and Myers (1978) observed 2- and 3- year olds search under several combinations of spatial and pictorial cue availability and emphasis. The 3-
year olds, relative to the 2-year olds, performed well in conditions in which relevant pictures were used to signify the locations of the hidden objects (i.e., where pictures were used as cues for the hidden objects). However, children under 3 years of age have difficulty using cues unrelated to the hidden object and its placement.

Similarly, DeLoache (1986) examined the search behaviour of children aged 21 to 28 using distinctive containers as hiding locations in one condition and then using the same containers as cues for the hiding locations in another condition. Also, in some conditions, these containers remained stationary, whereas in others, the containers were moved before children searched. The researcher found that children did well only under conditions in which children needed to remember the location of a hidden object using the visually distinctive containers. In fact, the successful performance was comparable to performance in natural, large-scale hide-and-seek games, which used items of furniture as hiding locations. This finding suggests that the degree of distinctiveness is the determining factor of the hiding place. Furthermore, no age differences were found, supporting Hasher and Zacks’ (1979) argument that location is encoded automatically, which means developmental differences should be minimal. However, when these containers were used as cues for hiding locations, age differences emerged. Younger children performed as well as the older children when the container cues remained stationary, but poorer when the cues moved, replicating other work that also found an age difference (DeLoache & Brown, 1983). Moreover, younger children’s use of cues to encode and remember the location of a hidden object requires the support of highly salient and immobile objects. The older children could utilize a mobile cue so long as it was salient or a non-salient cue that remained stationary. This was true even if the experimenter explicitly instructed the children about the existence and importance of the available cues. Taken together, children as young as 21 months of age can
remember locations for hidden objects, as long as the hiding places are visually distinctive, and thus, highly salient.

The relation between the hidden object and the distinctive location is also critical. If it is direct (i.e., the distinct container is the actual hiding location), then the task is simply to remember the distinct container. Even young children are able to use such cues to aid their search. However, when it is a two-step process, such as remembering first how the hidden object is directly related to the box in which it is placed, and then remembering how each box is directly related to the cue to which it is attached, problems may arise. It could be that children have difficulty with remembering the two relations simultaneously (Sugarman, 1983), or perhaps they have difficulty with integrating the two relations. Accordingly, if there is a direct or previously established relation between the target object and the distinctive information specifying its location, the relation is readily used to guide retrieval. If such a relation does not exist, then cognitive effort is required. And the more the children integrate unrelated information themselves, the more effort the process requires for the children.

Using a touch-screen computer monitor, Sutton (2006) examined 2-, 3-, and 4-year olds’ ability to integrate different types of information that varied in saliency as they played a hide-and-seek game. The search scene was a barnyard scene consisting of discrete elements that were either non-distinctive (e.g., identical trees) or distinctive (e.g., barn, cow). The target was Barney the dinosaur who went and hid behind one of these items. After a delay, children were instructed to press the item they believed was Barney’s hiding location. Two of these trials were beacon trials because Barney hid behind a distinct object. In these conditions, the distinct object was the hiding location and thus, directly marked the target. The other two other trials were landmark trials because Barney hid behind a tree that was near a distinct object. In these conditions, the
distinct object served as a landmark, indirectly marking the target. The researcher found that although all children were accurate on beacon trials, the 2-year olds were less accurate on landmark trials. This was true even if the number of distractors (i.e., identical trees) was reduced.

In subsequent experiments, Sutton (2006) examined if children actually took into account the spatial relationship of the hiding place and landmark item by modifying the position of one landmark after the delay. This change in landmark led to errors in all age groups. When the Sutton analyzed initial search, she found that the 3- and 4-year olds, not the 2-year olds, followed the landmark. This finding suggests that children are sensitive to the direction and distance of the landmark to the hiding location. Thus, the ability to code a location using a nearby landmark as a spatial referent develops a little later, around 3 years of age. This finding that children less than three years of age are not able to make use of landmark as a spatial referent explains young children’s general difficulty in using cues that are not directly related to the target object in the ramp paradigm. It follows then that if the cue is directly related to the object, the cue will more likely be attended to and subsequently used. One way for a cue to be directly related to the object is if there is a physical connection between the cue and the object. This means then that properties of the hidden object can impact object search, which is highlighted by the theory of object-directed account.

3.2 Theory of object-directed attention account

Shutts, Keen, and Spelke (2006) presented the theory of object-directed account. According to this model, the difficulty with indirect cues can be explained by a theory of object-directed attention. This account argues that children’s attentional system functions the same as with adults (Baylis & Driver, 1993; Carey & Xu, 2001; Duncan, 1984; Egly, Driver, & Rafal, 1994; Scholl, Plyshyn, & Feldman, 2001). Attention is directed towards an object and spreads continuously
within it in a gradient-like fashion, from proximal to distal. Attention stays focused on the object when the object moves in and out of view on continuous paths. 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. These cue properties allow for the effective spread of attention within the object. In contrast, a cue that is disconnected from the target object (e.g., landmark) will more likely be ignored. According to these authors, 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 through quantitative changes in the attentional mechanism that allows one to incorporate factors such as cues that indirectly mark the target location or landmarks. These changes, then, account for the successful use of landmark information in searches by both older children and adults.

In support of the theory of object-directed attention, 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 that had transparent windows above them. In these studies, toddlers saw a car roll down the ramp apparatus, and come to rest behind one of the two opaque doors. Similar to previous studies, the children were asked to retrieve the hidden object (the car) from behind the door. Attached to this car by means of a thin pole was a pompom, such that when the car came to rest behind the door, the attached pompom was visible in the transparent window above the door. Shutts et al. (2006) found that children were more successful in retrieving the car when the pompom was attached to the car by a short pole, and was closer to the car and visible in the window directly above the door, as opposed to when it was attached by a long pole, and was further away from the car and only visible above the opaque screen in front of the ramp apparatus. This finding demonstrates the importance of proximity in the spread of attention, with farther cues less effective than nearer cues in driving attention to a target object.
In a subsequent experiment (Experiment 4), rather than having the pompom visible in the window above the door, the wall that stopped the car was now visible in this window (as well as above the opaque screen). Even though the distance between the wall cue and the car was approximately the same as that between the pompom cue and the car in the previous studies, performance in this study dropped dramatically, relative to performance with the pompom cue. This finding demonstrates the importance of object boundaries in the spread of attention. When the cue was attached directly to the to-be-recovered object, attention was able to spread from the cue to the object effectively. However, when the cue was adjacent to the target object, and hence only indirectly indicated the to-be-recovered object, attention did not spread back and forth between object and cue. Putting these two findings together, 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. To put it differently, a cue is most effective if it is located closer to the centre of the object so that attention spread is minimal and less subject to distractions and errors. More importantly, a cue needs to be physically attached to the object in order for attention spread to occur in the first place.

3.3 Landmark-based account

An alternative explanation to the findings in Shutts et al.’s (2006) study can be derived from a landmark-based account. Specifically, it was possible that the cue in their study simply drove children’s attention towards particular locations that were spatially close to the cue, with subsequent search influenced by this direction in attention. This explanation fits with a theoretical framework concerning the nature of children’s spatial orientation and search (Acredolo & Evans, 1980; Bremner, 1978; Bushnell, et al., 1995; DeLoache, 1986; DeLoache & Brown, 1983; MacDonald, Spetch, Kelly, & Cheng, 2004; Plumert & Hawkins, 2001; Rieser,
in which researchers have noted that the availability of, and the ability to use, perceptually distinct environmental landmarks are critical to children’s spatial orientation. Multiple studies (some of which were described in the previous sections) have demonstrated that children can successfully search for items when they are marked by a direct cue or a beacon as opposed to an indirect cue or landmark. Other researchers (DeLoache, 1986; DeLoache & Brown, 1983; Plumert & Hawkins, 2001; Sutton, 2006) have found that it is not until well past their second year that the children can properly use indirect cue or landmarks.

According to the landmark-based account, children’s difficulties in recovering the hidden object 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 (i.e., occluding screen). This explanation also holds true for the trials in which the barrier replaced the pompom behind the visible window (Shutts, et al., 2006), as well as in all the other work (Berthier, et al., 2000; Butler, et al., 2002; Mash, et al., 2003) that found that the top of the barrier did not effectively cue object location. In all these cases, immediately below the top of the barrier was the occluding screen. In contrast, under the short cue condition, immediately below the pompom was the correct door. Because attention is directed towards the space directly below the cue, this means that attention would be directed to the to-be-searched in door itself, thus producing better performance. Put differently, only the short cue directly marked the location of the hidden object.

One of the primary distinctions between the theory of object-directed account and the landmark-based account is that the landmark-based account explicitly states that the spatial relation between the cue and the target (i.e., the location of the cue in reference to the target location) is what underlies search performance using cues. This spatial relation was an aspect not explicitly
considered in the theory of object-directed attention. According to the theory of object-directed attention account, because attention spreads in a proximal to distal fashion according to this account, the efficacy of a cue attached to a hidden object will be influenced by the distance between this cue and the object, but relatively unaffected by the spatial relation between the cue and the target. So, short cues may be more effective than long cues, but oblique cues would not differ from cardinal (horizontal and vertical) cues in indicating the location of a hidden object. However, for the landmark-based account, aspects such as the cue’s length and orientation with regards to the target object should be important if they impact the spatial relation between cue and target. In other words, the cue properties (i.e., length and orientation or angle) would determine whether the cue functions as a beacon or landmark. In this case, only short and cardinal cues would be more effective if they place the cue directly marking the object location.

Mangalindan and Schmuckler (2011) directly examined the importance of the spatial relations between cue and object in an object retrieval task based on the paradigm employed by Shutts et al. (2006), except that there was a transparent window that ran across the occluding screen. These authors examined children’s search under conditions in which the spatial relation between the cue and target object varied. Specifically, in two conditions, the orientation of the cue was shifted from a vertical alignment to an oblique alignment, while retaining the actual distance between the two. Replicating Shutts et al.’s (2006), results showed that short cues, relative to long cues, led to more successful object retrievals. However, modifying the orientation of the cue from vertical (90°) to oblique (45°) significantly reduced successful retrievals. Supporting the landmark-based account, Mangalindan and Schmuckler’s (2011) findings showed that by shifting the orientation of the cue from vertical to oblique, attention was drawn from a location that was directly above the correct door to a location that was not directly above the correct door, respectively, and thus compromising performance. Thus, the spatial relation is an important
factor in cue use. Toddlers’ difficulties with using the barrier as a cue really stems from a general difficulty of using cues that do not directly mark the target location (i.e., landmarks).

In summary, beacon use emerges a bit earlier, as evident in previous research that involves spatial orientation and search tasks, whereas landmark use seems to get established later in development. The argument presented in this paper is that the differential development of beacon and landmark use is also what underlies children’s performance in the object displacement task using the ramp apparatus.

4 Summary of Introduction

Successful performance in search tasks involves a sophisticated form of knowledge that includes an understanding of object permanence, the ability to track object movement, and the use of various environmental cues to guide search. Work on toddlers examining their ability to make inferences about locations of objects using search tasks had shown that children under three years of age have difficulty making use of certain types of cues. Very early in development, children are able to make use of beacons, which are cues that mark the target location. If cues do not mark the target location, such as landmarks, then young children are more likely to make errors in their search. Thus, it seems that the key aspect to search performance is how well cues drive attention to locations in space that directly mark the target.

Object displacement tasks have never directly tested children’s use of beacons and landmarks. Children less than three years of age are unable to make use of the barrier as a cue to object location because it functions as a landmark, only indirectly marking the target. Children less than three years of age, however, are able to make use of a cue that functions as a beacon, which directly marks the target (e.g., a pompom appearing above the correct door). These findings
underscore that the spatial relation between the cue and target location is important to attention and the subsequent search. What other cue properties may be critical to spatial relation?

A wider conceptual question is also presented. One intriguing finding uncovered from work examining cue use is that even though the environment is rich with various cues that provide different information regarding object existence and location, toddlers do not always make use of cues that are especially relevant in aiding their search. Such results lead to the question of what factors might underlie children’s use of environmental cues, rendering some cues more likely to be used than others.

Examining whether cue properties impact spatial relation, as well as examining the wider conceptual question are the general aims of these studies. In particular, the present experiments examined children’s search under varying conditions of cue properties, while keeping spatial relations between the cue and the target constant. Using a modified version of the paradigm used in Mangalindan and Schmuckler (2011), Experiment 1 varied the length of the cue (i.e., distance of the cue from the target object) and Experiment 2 varied the type of movement of the cue.
Chapter 2
Experiment 1

1 Research question and hypotheses

As discussed in the introduction, in previous work on object displacement tasks using the ramp apparatus, researchers found that children under three years of age benefit from the presence of a direct cue or beacon to aid in their search (Mangalindan & Schmuckler, 2011; Shutts, et al., 2006). For instance, children’s search significantly improved when a cue (i.e., pompom) attached to the target object was made visible through a transparent window above the door. This way, attention was driven to the space immediately below the cue, which was the correct door. When the same cue no longer marked the correct door, performance dropped. For instance, when the pompom was extended such that it was visible above the occluding screen (Mangalindan & Schmuckler, 2011; Shutts, et al., 2006), much like how the top portion of the wall was visible. In contrast to the object-driven account, the landmark account assumes that attention is driven to the area immediately surrounding the relevant cue. This hypothesis explains the fact that long cues lead to worse performance than short cues, because the location that is attended in the former case is the wall above the to-be-searched in door, whereas in the latter case, attention is driven to the to-be-searched in door itself.

If the landmark account is correct, and cues serve to simply drive attention to locations near the cue, then this idea leads to some interesting predictions. For instance, if one were to simply increase the size of the to-be-searched-in door, such that a long cue now drives attention to this location, then performance should be comparable to performance under a short cue. The reason
for equal performance is because under both cases, the distance between the cue and the edge of the door remains constant.

Experiment 1 examined this hypothesis by comparing children’s performance under three conditions: no cue (no pompom is attached to the car), short-cue/short-door (a pompom is attached at a 90° angle to the car’s centre by a short antenna), and long-cue/long-door (a pompom is attached at a 90° angle to the car’s centre by a long antenna). According to the previously discussed landmark account (Mangalindan & Schmuckler, 2011), and in contrast to performance typically seen with long cues (Mangalindan & Schmuckler, 2011; Shutts, et al., 2006), children were expected to perform equally well under short- and long-cue conditions in Experiment 1 because in both conditions, the distance between the cue and target location are the same. Children’s performance under no cue conditions was expected to be at chance level.

2 Methods

2.1 Participants

The final sample consisted of 42 children (27 boys, 15 girls) in total. Specifically, there were twenty-four 24-month-olds ($M = 24.13, SD = 1.26$) and eighteen 30-month-olds ($M = 30.24, SD = 1.39$). Eight additional children (five 24-month olds, and three 30-month olds) were tested, but data from these children were not included due to the children being the wrong age ($n = 2$), refusing to continue ($n = 5$), and fatigue ($n = 1$). These age groups were selected based on previous research (Butler, et al., 2002; Hood, et al., 2003; Mangalindan & Schmuckler, 2011; Mash, et al., 2003; Shutts, et al., 2006) that have suggested that children show developmental transition in using this paradigm.
Children were recruited from a list maintained by the Laboratory for Infant Studies at the University of Toronto Scarborough. 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.

2.2 Materials

The experiment employed a modified version of the apparatus used in past work (Berthier, et al., 2000; Butler, et al., 2002; Hood, et al., 2003; Mash, et al., 2003; see Figures 1, 2, & 3). Specifically, the apparatus contained a ramp, which was 101 cm long and 20 cm wide. The ramp was painted white and sloped downward from left to right. The ramp contained a track, which consisted of two white, wooden dowels placed 7.5 cm apart and lined with white felt. A white wooden panel (101 long and 52 cm high) was attached to the back of the ramp.

The apparatus also contained two occluding screens, which could be inserted in front of the ramp. Both screens were painted grey and contained a 6 cm wide transparent window that ran across the occluding screen. Screen 1 was 80 cm long and 38 cm high and contained four doors, which were 14 cm wide and 17 cm high. Screen 2 was 46 cm high and 80 cm long and contained four doors, which were 14 cm wide and 28 cm high. For both screens, each door (5 cm apart from each other) was made out of transparent Plexiglas, which was painted grey except for the top part, which was left transparent (6 cm wide). Also, each door contained a grey knob (2 cm in diameter) and located 7 cm from the top part of the door.

Finally, walls or barriers could be inserted into four locations on the ramp. These wooden barriers were coloured green, 0.5 cm thick, and 19 cm wide. The barriers varied in height between 45 cm to 49 cm to accommodate the slope of the ramp. This means that once any of the
four barriers was placed on the ramp, the barrier stood 8 cm above Screen 1 (see Figures 1 and 2), but was not visible above Screen 2 (see Figure 3). Finally, a pink, foam block (9 cm long, 3.5 cm high, and 3.5 cm deep) was placed at the bottom of each wall to minimize the sound the car produced as it stopped by the wall.

Three small black cars (7 cm long, 2.5 cm wide, and 2 cm high) were used as the to-be-recovered object. Two of the cars, with a bright red fuzzy pompom (3 cm in diameter) attached were used during the cued conditions (discussed below), and the third car, without a pompom attached, was used during the no-cue condition (also discussed below). The pompom was attached to the car by a silver wire antenna that varied in length. The pompom was always visible through the transparent window running across the occluding screen.

A Sony digital video camera (DCR-TRV103), mounted on a tripod, was set up in the experimental room to record the children’s retrieval behaviour during the experiment. The camera was located behind curtains on the left-hand side of children, positioned about 90 cm from where the children were sitting.
Figure 1. The ramp apparatus used in Experiment 1. Screen 1 is in place with all the doors open to reveal the ramp, the wall and the car without a pompom attached to it. The top of the green wall is visible above the screen.

Figure 2. The ramp apparatus used in Experiment 1. Screen 1 is in place with all the doors open to reveal the ramp, the wall and the car with a pompom attached to it by a short wire. The green wall is visible above the screen.
**2.3 Conditions**

The children were randomly assigned to one of three experimental conditions. There were equal numbers of children per age group (eight 24-month-olds and six 30-month-olds) assigned to these conditions. In the no-cue condition, no pompom was attached to the car (see Figure 1). In the short-cue/short-door condition, the pompom was attached to the car at a 90° angle by 7.5 cm long silver wire antenna (see Figure 2). In the long-cue/long-door condition, the pompom was attached to the car at a 90° angle by a 23 cm long silver wire antenna (see Figure 3).

**2.4 Design and procedure**

Parent and child entered a curtained experimental room. Each child participated in the experiment while seated on his/her parent’s lap, and both sat on a chair facing a table consisting of the ramp apparatus. The chair was located 108 cm from the table. The experimenter stood on
the other side of the table, facing the child and the parent. For every trial, the parent was
instructed to move the chair forward at a distance such that the child would be able to open the
doors to retrieve the car. Once the child retrieved the car, the parent was instructed to move the
chair back to the original position, such that the starting position was consistent for every trial.
The starting position was marked by a small piece of white tape on the floor.

The experiment was divided into training and test phases. 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. For the cued conditions, the experimenter also drew the child’s attention
to the pompom attached to the car. Next, the experimenter introduced the ramp, highlighted the
doors, and showed the child how the doors opened and closed. Because the child was seated
further from the table, the child was not able to look over the occluding 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 left opened as the car rolled down the ramp such that the
child was able to observe the car’s trajectory until it stopped. After pointing out that the car had
stopped by the wall, the experimenter asked the parent to move the chair forward towards the
table and asked the child to retrieve the car. The last two training trials were similar to the first
two, except that the experimenter closed the doors before asking the child 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 asked the child to open another door. After the
second selection, if the child still opened another incorrect door, the experimenter directed the child to open the correct one.

After the training phase, the test phase began 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 then 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. Similar to other work using this apparatus (Berthier, et al., 2000; Butler, et al., 2002; Hood, et al., 2003; Mash, et al., 2003), the test trials consisted of three blocks of four trials, with each trial representing the final positions of the car (i.e., as they related to the four different doors). The order of these trials was selected at random with the condition that the car stopped at each location for every block and that the same location was not repeated in two consecutive trials.

The majority (71%) of children completed all 12 test trials. The remaining 29% of children (nine 24-month olds, and three 30-month olds) completed between 6 and 11 trials. The entire experimental session lasted approximately 15 minutes.

2.5 Scoring and analysis

For each trial, the child’s first door selection was coded as either correct (1) or incorrect (0) car retrieval. Percent correct retrieval was then calculated by dividing the total number of correct retrievals by the total number of test trials completed, and multiplying the quotient by 100. Trials in which the children opened both doors (0% of trials) and trials in which the children did not select a door (0.6% of trials) were very rare, and were not included in the analyses.
Two research assistants coded the child’s retrieval scores from video-taped records of the experimental sessions. The primary coder scored all sessions, and a secondary coder scored 14 randomly selected sessions (33%), seven from each age group. Reliability for door selection was 100%.

3 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, $t(44) = -.71$, $ns$, with boys and girls performing comparably with each other ($M = 69.8, SD = 31.7$ vs. $M = 75.3, SD = 27.9$). There were also no significant differences as a function of the first half ($M = 70.7, SD = 29.9$) of the experimental session versus the second half ($M = 71.7, SD = 34.9$) of the session, $t(45) = -.73, ns$. Accordingly, data were collapsed across these variables for all subsequent analyses.

In the primary analysis, percent correct retrieval was analyzed using a two-way Analysis of Variance (ANOVA), with the between-subject factors of Age (24 vs. 30) and Condition (no cue vs. short cue/short door vs. long cue/long door). The analysis revealed a significant effect of Age, $F(1, 36) = 15.53, p < .0001, \eta^2_p = .30$ (as shown on Figure 4), with increasing performance with increasing age.
Figure 4. Mean percentages for percent correct retrieval as a function of age group.

There was also a significant main effect of Condition, $F(2, 36) = 141.41, p < .0001, \eta^2_p = .89$. Tukey HSD tests revealed that the no-cue condition was significantly different from both cued conditions (all $p$’s < .0001), but the short cue/short door and long cue/long door conditions did not differ from each other (see Figure 5).
Finally, there was a significant Age x Condition interaction, $F (2, 36) = 3.61, p < .05, \eta^2_p = .17$. Tukey HSD tests revealed that children performed least successfully under the no-cue condition (all $p$’s < .0001), but performed equally well under short-cue/short-door and long-cue/long-door conditions. This was true for both 24- and 30-month olds (as shown on Figure 6).

To examine this interaction more closely, 24- and 30-month olds were compared on each of the test conditions. Specifically, three independent-samples $t$ tests were conducted using Bonferroni adjusted alpha levels of .02 per test ($\alpha_{\text{adjusted}} = \alpha/c = .05/3$). These tests revealed that 30-month olds performed better than the 24-month olds only on the no-cue condition, $t (12) = -3.19, p < .01$. 

*Figure 5.* Mean percentages for percent correct retrieval as a function of condition.
3.1 Analyses of performance against chance

Subsequent analyses compared children’s performance relative to chance (i.e., 25%). Specifically, a series of one-sample t tests were conducted for each of the conditions per age group. Tests revealed that under the no-cue condition, 24-month olds’ performance was at chance level, \( t (7) = .76, \text{ ns} \), but 30-month olds’ performance was significantly above chance, \( t (5) = 3.52, p < .05 \). Under the short-cue/short-door condition, performance of the 24- and the 30-month olds were significantly above chance, \( t (7) = 25.86, p < .0001 \) and \( t (5) = 37.00, p < .0001 \), respectively. Finally, under the long-cue/long-door condition, performances were also
significantly above chance for both the 24-month olds, $t (7) = 15.08, p < .0001$, and the 30-month olds, $t (5) = 53.00, p < .0001$.

### 3.2 Analyses of long cue/long door condition

To examine if the manipulation in the current experiment significantly impacted children’s performance while using a cue that was found to be previously ineffective, performance under the long-cue/long-door condition in the current study was compared to performance under the long-cue (short-door) condition in Mangalindan & Schmuckler (2011). Specifically, one-sample $t$ tests were conducted to compare retrieval performances of each age group under the long-cue (short-door) condition to the means obtained in Mangalindan and Schmuckler (2011) for the 24-month olds ($M = 35.3, SE = 7.2$) and 30-month olds ($M = 35.8, SE = 6.9$). The tests revealed significant differences for each age group (see Figure 7). Specifically, for 24-month olds, percent correct retrieval in the present study was significantly greater than the percent correct retrieval of children in Mangalindan and Schmuckler (2011), $t (7) = 12.62, p < .0001$. Similarly, 30-month olds’ percent correct retrieval in the present study also significantly improved, $t (5) = 45.08, p < .0001$. 
Figure 7. Comparison of mean percentages for percent correct retrieval as a function of age group under long-cue/long-door condition in Experiment 1 and long-cue (short-door) condition in Mangalindan & Schmuckler (2011).

3.3 Analyses of incorrect searches

Similar to previous work (Berthier, et al., 2000; Butler, et al., 2002; Hood, et al., 2003), an analysis of children’s incorrect searches was conducted to determine if children adopted certain strategies. These strategies included: (a) difficulty with inhibiting a prepotent response on the first reach for every trial, (b) a preference for a particular door across all trials, and (c) perseverative errors (i.e., selecting a door where the object was found in the immediately preceding trial). Each of these strategies was discussed below.
Children’s lack of inhibition was first examined. Children may have known where the object was, but were unable to inhibit an incorrect response on the first door selection. If this was the case, then children would more likely select the correct door on their second selection, relative to their first attempt. Thus, the first door selections of all trials were examined. Of the 69 trials in which the first selection was incorrect, 24-month olds selected the correct door 28 times on their second attempt (40.6%). Similarly, out of the 38 incorrect first selections, 30-month olds selected the correct door 19 times on their second attempt (50.0%). Percentage scores for correct second door selection were calculated for each child, and these percentages were then compared to chance levels (33%) using one-sample t tests. The performance of the 24-month olds was above chance, t(16) = 2.41, p < .05 but not the 30-month olds’ performance, t(8) = 2.13, ns. These findings suggest that the 24-month old children may have difficulty inhibiting an incorrect response during their first attempt. In contrast, 30-month olds genuinely may not know where the toy was.

Another strategy examined was selection of a preferred or favourite door across all the trials. If children truly did not know where the object was located, they could have selected a favourite door, rather than randomly opening any door. For each door, the percentage of trials in which it was selected was calculated for each age group, and each proportion was compared against chance (25%), using one-sample t tests. Preference was defined as the door with percentage of selection that was significantly different from chance levels. Both 24- and 30-month olds did not have a clear preference for any door. All children selected each door equally likely, all t’s > -.78, all p’s > .08. There is, however, a least favourite door among 24-month olds, t(16) = -2.57, p < .05, which was Door 1 (the first door down from the top of the ramp; M = 10.8, SD = 22.7). In contrast, the 30-month olds did not show this pattern.
Finally, a strategy examined was perseveration. If children did not know where the object was, then they would select the door where they previously saw it, suggesting that they remembered this information and used it to guide their search. Percentage of perseverative errors was calculated for each age group and compared to chance (25%), using one-sample \( t \) test. On average, 24-month olds perseverated 16.6\% (\( SD = 19.6 \)) and 30-month olds perseverated 7.9\% (\( SD = 13.4 \)) of the trials, both of which were significantly below chance, \( t (26) = -4.34, p < .0001 \) and \( t (18) = -8.17, p < .0001 \), respectively. Thus, perseveration was not one of the strategies adopted by the children.

Taken together, the 24-month olds showed a lack of inhibition of a pre-potent response, which led to errors in their first door selection. There were no other strategies adopted by the children.

4 Discussion

The goal of Experiment 1 was to examine a theoretical proposal 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 landmark-based approach (Acredolo & Evans, 1980; Bremner, 1978; Bushnell, et al., 1995; DeLoache, 1986; DeLoache & Brown, 1983; Mangalindan & Schmuckler, 2011; 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 marks the location of the object, with the use of the cue potentially influenced by aspects of the spatial relation between cue and object. Specifically, a cue that directly marks the target location is superior to a cue that only indirectly does so, among children less than three years of age.
In Experiment 1, children searched for a hidden toy under conditions in which a cue’s distance from the target object was manipulated (i.e., short vs. long), but the location marked by the cue was kept constant (i.e., correct door was directly below the cue for both cases). Previous work (Mangalindan & Schmuckler, 2011; Shutts, et al., 2006) that utilized a long cue found that such a cue led to poor search performance. These earlier studies used this cue under conditions in which there was a great distance between the cue and the target location, which meant that the cue did not directly mark the target door. However, if both short and long cue directly marked the target location, then the distance between cue and target object should not matter. According to the landmark-based account, what matters is not the distance between the cue and target object per se, but how well the cue denotes the target location.

The current findings present both novel and convergent results with regards to the existing literature. The most notable new finding of this work, and in contrast to previous work that utilized a similar long cue (Mangalindan & Schmuckler, 2011; Shutts, et al., 2006), was its demonstration that a cue located at a longer distance from the target object functioned as well as a cue that was located closer to the target object, as long as they both directly cued the target location. Accordingly, this study provided evidence that the cue’s spatial relation with regards to the target location is what drives search performance.

The current experiment also highlighted two results that converged with previous findings. First, as expected, older children outperformed younger children in object search (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), suggesting that as children get older, their performance also improve.
Second, analyses of children’s incorrect searches have revealed that 24-month old children’s errors in their first door selections were driven by a difficulty of inhibiting an incorrect response (Butler, et al., 2002). This finding suggests that, at least for the younger children, they may have known where to correctly search, but a pre-potent response overshadowed their correct selection. Difficulty with inhibition at this age reflects the continuous maturation of the frontal cortex, which subserves the ability to coordinate multiple pieces of information in working memory, as well as inhibiting an automatic response (Byrd, van der Veen, McNamara, & Berg, 2004; Christ, White, Mandernach, & Keys, 2001). Alternatively, this error may be explained by the attention-driven cognition/action trade off, termed by Boudreau & Bushnell (2000) to describe the impact on the motor or cognitive performance depending on the location of attentional focus during perception and action coupling tasks. In this case, because the child needed to think ahead and integrate the position of the barrier and translate its position with regards to the door (i.e., cognitively demanding), the act of reaching for the correct door (i.e., motor task) was compromised. In fact, in closer inspection of children’s errors in the first reach, out of the total 69 errors produced by the 24-month old children, 53 of these errors (77%) were produced under the no-cue condition, which was the only condition in which there was no beacon marking the target location, thereby making the condition demanding for young children.

Taken together, the main findings of Experiment 1 support the landmark-based account for object search. As discussed initially, it is only within a landmark-based framework that modifications based on the distance of the cue to the target object should impact search, in so far that these modifications lead to changes in the spatial relation between the cue and the target. Attention is driven to locations spatially close to the cue, which aids subsequent search. Thus, the most critical aspect is how well the cue marks the target location. And so, both a short cue and a long cue would be effective as long as they directly mark the target location.
Accordingly, the current findings present an important challenge to the theory of object-directed attention. According to this account, a short cue would be a more effective cue compared to a long one because spread of attention would be less, and should lead to better search. Thus, the critical aspect was the cue’s distance from the target object. Changes to aspects that were unrelated to the target object (e.g., door length) should not impact search however. Thus, this account could not explain the increased performance under conditions that increased the length of the door.

There are multiple ways to capture attention and highlight particular target locations. One of the ways to do so is by manipulating the door length to ensure that the cue would directly mark its target location. The current experimental set up also provides additional information that might be critical, and this is the movement of the cue. Thus, another way to highlight a target location is by having the cue move to attract attention and stopping the cue’s movement to focus attention on a particular location. This idea about the importance of the cue’s movement also converges with previous work highlighting the importance of tracking object trajectory (Butler, et al., 2002; Keen, et al., 2003; Mash, et al., 2003) because the cue’s movement down the ramp makes it easier to track the object and also attracts attention such that gaze is not broken. In this case however, it is the cue’s movement coincident to the car’s movement that is vital. Both of these explanations could actually explain why the pompom was an effective cue in Experiment 1, as well as in other previous work that utilized a similar cue (Mangalindan & Schmuckler, 2011; Shutts, et al., 2006). Both explanations could also hold true for why the top of the wall had been found to be an ineffective cue because the wall, disconnected from the car, never moved with the car. So what is it exactly about the cue’s movement that leads to successful performance? It is unclear whether successful performance was due to the pompom’s movement better able to capture children’s attention and more directly cuing the correct location than the wall, or due to
the pompom’s movement, coincident with the car’s movement down the ramp, which allowed tracking of the object’s trajectory down the ramp and attracting attention to the correct location. Experiment 2 addressed this very issue.
Chapter 3
Experiment 2

1 Research question and hypotheses

As mentioned previously, in all the search studies that utilized the ramp apparatus (Berthier, et al., 2000; Butler, et al., 2002; Hood, et al., 2003; Mash, et al., 2003), the wall had already been in place even before the object rolled down the ramp. In contrast, the pompom was always the object in motion in both Mangalindan and Schmuckler’s (2011) and Shutts et al.’s (2006) studies, which made the pompom, as a cue, highly salient for children. Thus, it could possibly be that the pompom’s movement better captured children’s attention to the correct location. Alternatively, it could be the pompom’s movement, coincident to the car’s movement that allowed continuous tracking of the target object until the target object stopped at the hiding location, thereby capturing attention to this location. And the reason why the pompom moved with the car was because the pompom was directly connected to it. Hence, it is not clear what role the movement of the pompom played in capturing children’s attention.

According to the landmark-based account, the effectiveness of a cue depends on how well it cues the object location. This theory does not posit that the cue needs to be directly or physically connected to the target object. To be most effective for toddlers, a cue only has to function as a beacon or direct cue – attracting attention to the target location, by whatever means possible. Although this has always been in terms of the movement of a cue attached to the target object down a ramp (Mangalindan & Schmuckler, 2011; Shutts, et al., 2006), there are other ways to drive attention to the target location.
One way to drive attention to the target location is by employing a pompom that is not directly attached to the car. For instance, a pompom can be pulled into position above the correct door. Because of the movement, this unattached cue can capture children’s attention, much like how a cue attached to the car can capture attention. However, in the former case, the movement is not coincident with the movement of the car, and in the latter case, it is. If it is critical that there be a direct connection between the cue and the target object, then the unattached cue should not be an effective cue; if movement plays a role simply in attracting attention, however, then the unattached cue should function as well as the attached cue.

Experiment 2 compared children’s performance under two conditions: *attached-direct cue* (a pompom was directly attached to the car’s centre and visible through the window above the door), and *unattached-direct cue* (a pompom was pulled into place by a thin string, thereby not directly connected to the car, and came to rest such that it remained visible through the window above the door). Under both attached-direct and unattached-direct cue conditions, the cue functioned as a beacon or direct cue for the target location because the cue was visible through the window above the correct door, appearing at the same location for the children. The only difference was that under the attached-direct cue conditions, the pompom was directly connected to the car, whereas under the unattached-direct cue conditions, it was not.

If the landmark view is correct and attention is directed to locations spatially close to the cue, then children were expected to perform equally well in both attached-direct and unattached-direct cue conditions because in both conditions, attention was directed towards the target location (i.e., the to-be-searched in door). Because children get better with landmark use, 30-month old children were expected to perform better than the 24-month old ones.
However, if direct connection between the cue and target object is critical, then differences in the search performance were expected. Specifically, better performance was expected from the children under the attached-direct cue condition, whereas children under the unattached-indirect condition were expected to perform at chance levels.

2 Methods

2.1 Participants

The final sample consisted of 32 children (14 boys, 18 girls). There were sixteen 24-month old ($M = 25.14$, $SD = 1.06$) and sixteen 30-month old children ($M = 30.23$, $SD = 2.11$). One additional 24-month old was tested, but did not complete the experimental condition, thus data from this child was not included in the final sample.

2.2 Materials

Experiment 2 utilized a slightly modified version of the ramp apparatus (shown in Figure 8) used in Experiment 1. The main difference between the two ramp apparatuses was that there was no transparent window running across the screen. The transparent windows above the doors were reduced in size such that only the pompom would be visible once the car had stopped beside the wall. No other information regarding the car’s trajectory down the ramp was provided. This ensured that the two experimental conditions appeared similar to the children, with the exception of seeing a car with a pompom attached (for the attached-direct cue condition) or a car without a pompom attached (for the unattached-direct cue condition) at the top of the ramp, just before the car rolled down. Four red fuzzy pompoms attached to a thin string were taped behind the back wall of the ramp apparatus. The distance between where each pompom was attached corresponded to the distance between each door, such that a pompom could be pulled into place at every door.
Experiment 2 utilized only one occluding screen. The screen was 80 cm long and 38 cm high and contained four doors, which were 14 cm wide and 17 cm high. Each door (5 cm apart from each other) was made out of transparent Plexiglas, which was painted grey except for the topmost part, which was covered with white tape, and only a small window (3.5 cm wide and 3 cm high), located in the centre of the door, was left transparent. Also, each door contained a grey knob (2 cm in diameter) and located 7 cm from the top part of the door.

As in Experiment 1, 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 during one of the experimental conditions (discussed below). The pompom was attached to the car by a silver wire antenna. A second black car, identical to the other one, was also utilized, but there was no pompom attached.

Similar to Experiment 1, a Sony digital video camera (DCR-TRV103), mounted on a tripod, was set up in the experimental room to record the children’s retrieval behaviour during the experiment. It was located behind curtains on the left-hand side of children, positioned about 90 cm from where the children were sitting.
Figure 8. The ramp apparatus used Experiment 2. The occluding screen is in place with all the doors closed to show the pompom visible through the small transparent window.

2.3 Conditions

All the children participated in two experimental conditions. In the attached-direct cue condition, a pompom was attached to the car at a 90° angle by 7.5 cm long silver wire antenna (see Figure 9). In the unattached-direct condition, there was no pompom attached to the car (see Figure 10). Using a thin string, the pompom was pulled into position such that it was visible through the small window above the dooriii. Half of the children participated in the attached-direct condition first then the unattached-direct condition, whereas the other half participated in the unattached-direct condition first followed by the attached-direct cue condition.
Figure 9. The ramp apparatus with the occluding screen in place and all the doors open to reveal the ramp, the wall, and the car with a pompom attached to it.

Figure 10. The ramp apparatus with the occluding screen in place and all the doors open to reveal the ramp, the wall, the car, and the pompom pulled into place by a thin string.
2.4 Procedure

Experiment 2 followed the same procedure as Experiment 1, except that the experiment was divided into three parts. All children participated in the training phase, followed by the test phase, which consisted of the two experimental conditions. Each experimental condition consisted of eight trials\textsuperscript{iv}. The test trials consisted of two blocks of four trials, with each trial representing final positions of the car. Similar to Experiment 1, the order of these trials was selected at random with the constraint that the car stopped at each location for every block and that the same location was not repeated in two consecutive trials.

All the children completed all 16 test trials. The entire experimental session lasted approximately 25 minutes.

2.5 Scoring and analysis

Scoring was the same as in Experiment 1. For each trial, the child’s first door selection was coded as either correct (1) or incorrect (0) car retrieval. Percent correct retrieval was calculated by dividing the total number of correct retrievals by the total number of test trials completed, and the quotient was multiplied by 100. Trials in which the children opened both doors (0.4% of trials) and trials in which the children did not select a door (0% of trials) were very rare, and not included in the analyses.

Two research assistants coded the child’s retrieval scores from video-taped records of the experimental sessions. The primary coder scored all sessions, and a secondary coder scored 10 randomly selected sessions (31%), five from each age group. Reliability for door selection was 100%.
3 Results

Preliminary analyses examined children’s responses as a function of Gender, Increasing Test Trial (i.e., assessing possible fatigue effects), and Order (i.e., assessing possible effects of the experimental conditions). Specifically, a pair of independent-samples t tests (one for each condition) were conducted, and revealed no significant differences in correct responding as a function of Gender for the attached-direct and unattached-direct cue conditions, \( t (30) = .23, ns \) and \( t (30) = -.18, ns \), respectively. Next, two paired-samples t tests were conducted to assess potential Test Trial effects, and revealed no significant differences as a function of the first half of the experimental sessions versus the second half of the sessions, for both the attached-direct cue condition, \( t (31) = -.32, ns \) and the unattached-direct cue condition, \( t (31) = -.16, ns \). Finally, one paired-samples t test was conducted to examine Order effects, and revealed no significant differences as a function of the first experimental condition vs. the second experimental condition, \( t (31) = -1.63, ns \). Consequently, data were collapsed across these variables for all subsequent analyses.

In the main analysis, percent correct retrieval was analyzed using a mixed-design ANOVA, with the between-subject factor of Age (24 vs. 30) and the within-subjects factor of Condition (attached-direct cue vs. unattached-direct cue). Age was not significant, \( F (1, 30) = .42, ns \). As shown in Figure 11, 24- and 30-month olds’ performances were comparable to each other.
Figure 11. Mean percentages for percent correct retrieval as a function of age group.

There was a significant main effect of Condition, $F(1, 30) = 6.38, p < .05, \eta^2 p = .18$. As evident in Figure 12, there was a slightly better performance under attached-direct cue condition compared to the unattached-direct cue condition.
This effect, however, was qualified by a significant Age x Condition interaction, $F(1, 30) = 5.21, p < .05, \eta^2_p = .15$. Subsequent paired-samples $t$ tests revealed that 24-month olds performed better under the attached-direct cue vs. the unattached-direct cue condition, but 30-month olds performed equally well under both conditions (see Figure 13).

3.1 Analyses of performance compared to chance level

Further analyses that compared children’s performance relative to chance (i.e., 25%) were conducted. In particular, one-sample $t$ tests were conducted for each of the conditions per age group. Tests revealed that under the attached-direct cue condition, performances of the 24-month olds and 30-month olds were significantly above chance, $t(15) = 26.67, p < .0001$ and $t(15) = 14.02, p < .0001$, respectively. Under the unattached-direct cue condition, performance of the 24-
and the 30-month olds were also significantly above chance, $t(15) = 6.46, p < .0001$ and $t(15) = 9.97, p < .0001$, respectively.

![Figure 13](image.png)

*Figure 13.* Mean percentages for percent correct retrieval under attached-direct and unattached-direct cue conditions as a function age group.

### 3.2 Analyses of performance compared to the no-cue condition (Experiment 1)

Children’s percent correct retrieval rates in Experiment 2 were also compared relative to means obtained in Experiment 1 under the *no-cue* condition (i.e., under conditions when there was no cue attached to the car) for both the 24-month olds ($M = 27.4, SE = 3.7$) and the 30-month olds ($M = 50.1, SE = 4.3$). These means were treated as baseline rates under conditions in which there was no visible cue to mark the target location. As shown in Figure 14, one-sample $t$ tests
revealed that the percent correct retrieval of 24-month old children in the no-cue condition significantly differed from the percent correct retrieval of 24-month under the attached-direct cue condition, $t(15) = 25.87, p < .0001$, and unattached-direct cue condition, $t(15) = 6.20, p < .0001$.

Similarly, for the 30-month olds, the percent correct retrieval of children in the no-cue condition significantly differed from the 30-month olds’ percent correct retrieval for both the attached-direct and unattached-direct cue conditions, $t(15) = 8.51, p < .0001$ and $t(15) = 6.00, p < .0001$, respectively.

Figure 14. Comparison of mean percentages for percent correct retrieval as a function of age group under the no-cue condition in Experiment 1 and under attached-direct and unattached-direct cue conditions in Experiment 2.
3.3 Analyses of incorrect searches

Similar to Experiment 1, analyses of children’s incorrect searches were conducted to determine if children adopted certain strategies. First, children’s difficulty with inhibition was examined. The idea was that children may have known where the object was, but were unable to inhibit an incorrect response (e.g., selecting a favourite door) on the first door selection. Given a second attempt though, they would more likely select the correct door. Of the 42 trials in which the first selection was incorrect, 24-month olds selected the correct door 14 times on their second attempt (33.3%). Similarly, out of the 29 incorrect first selections, 30-month olds selected the correct door 11 times on their second attempt (37.9%). Percentages for correct second-door selection were calculated and compared to chance levels (33%) using one-sample \( t \) tests. Both 24- and 30-month olds’ performance were not significantly different from chance, \( t(8) = 1.02, ns \), and \( t(6) = .59, ns \), respectively. These findings suggest that children’s errors in this study were not due to a difficulty with inhibiting a correct response.

The next strategy examined was selection of a preferred or favourite door. Rather than randomly selecting any door, children could have selected a favourite door if they did not know where the object was located. For both 24- and 30-month olds, the percentage of trials in which it was selected was calculated for each door. Each proportion was then compared against chance (25%), using one-sample \( t \) tests. Preference was defined as the door with percentage of selection that was significantly different from chance levels. It was found that only the 24-month olds showed a preference, selecting Door 3 (the third door down from the top of the ramp; \( M = 78.6, SD = 39.3 \) significantly more than the other doors, \( t(6) = 3.60, p < .05 \). This was true only for the attached-direct condition. And similar to Experiment 1, 24-month olds also had a least favourite door, which was Door 1 (the first door down from the top of the ramp; \( M = 8.1, SD = 15.6 \), \( t(7) \))
= -3.07, \( p < .05 \). This was true only for the unattached-direct cue condition. In contrast, the 30-month olds did not show any or lack of preference, selecting each door equally likely, for both the attached-direct and unattached-direct cue conditions, all \( t's > = -1.43 \), all \( p's > .25 \), respectively.

The final strategy examined was perseveration, which was defined as the selection of the door where the object was previously seen. Children’s perseveration suggests that they remember information from the immediately previous trial, which they then use to guide their search. Percentage of perseverative errors was calculated for each age group and compared to chance (25%), using one-sample \( t \) tests. Results revealed that on average, 24-month olds perseverated 7.14% (\( SD = 10.1 \)) and 30-month olds perseverated 6.7% (\( SD = 12.1 \)) of the trials, both of which were significantly below chance, \( t (15) = -7.07, p < .0001 \) and \( t (15) = -6.06, p < .0001 \), respectively. These results suggest that perseveration was not one of the strategies adopted by the children.

Taken together, the analyses of incorrect searches have revealed that in Experiment 2, only 24-month olds have adopted a strategy for their first door selection. They selected Door 3 significantly more than the others, indicating a preferred door strategy. Although, it should be noted that this was true only the attached-direct cue condition. No other strategies were adopted.

4 Discussion

The goal of Experiment 2 was to examine if 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) can account for children’s search performance under conditions that involved a moving cue that varied the direct connection between the cue and the target object, while
keeping constant the spatial relation between the cue and the target location. Specifically, Experiment 2 compared the effectiveness of a cue that moved with the car down the ramp into the location above the correct door because it was directly connected to the car (i.e., pompom attached to a car by a wire) and a cue that popped into the location above the correct door and was not connected to the car (i.e., pompom that was pulled into place by a thin string). The two cues were comparable because they functioned as beacons or direct cues, directly marking target location (i.e., appearing at the same location above the correct door). Moreover, both cues contained movement, which might function to attract infants’ attention to a given target location. The principal distinction was the type of movement, with one case containing movement coincident with the car’s motion, and the other case containing movement that was uninformative with the movement of the object itself, but was informative as to the final location of the car.

The landmark account posits that attention is directed towards locations that are spatially close to the cue. And the cue that is coincident to the target location (e.g., cue sitting above the correct door) aids children’s search performance most effectively. This should be true, regardless of the type of movement and whether or not the cue is directly connected to the target object. In other words, the two types of cue in the current study should have functioned equally well. If however, it is the direct connection between cue and target object that is critical, then only the performance under the attached-direct cue condition would be above chance.

Findings of Experiment 2 showed both a novel finding and a replication of previous work. Specifically, a novel finding was that both age groups performed significantly above chance levels under conditions in which a cue directly connected to the target object moved down the ramp and under conditions in which a cue, not connected to the target object, was pulled into
place. Furthermore, a comparison with the performance under conditions were there was no pompom available showed that these two cued conditions led to better performances than the condition without any cue, a consistent (and unsurprising) result in the literature (DeLoache, 1986). Thus, both a cue directly connected to a target object and a cue pulled into position but unattached to the target object led to better search performances compared to conditions where there was no cue at all. This was because both types of cues functioned as a direct cue or beacon to the target location.

Replicating other work using the same paradigm (Berthier, et al., 2000; Butler, et al., 2002; Mash, et al., 2003), analyses of children’s incorrect searches have revealed that 24-month olds’ have a bias towards a favourite door (i.e., Door 3). Work that has found the same error had suggested that it is the central location of the door that accounts for this bias. Because of the layout of the apparatus, the second and third doors were located within the middle of children’s visual field. Thus, if they were unsure of which door to open, they would more likely select the doors that were spatially within their visual field. In Experiment 2, it was the third door. However, because this strategy was only adopted by the younger children and only under the attached-cue condition, the effect of door preference in this study was at most, minimal.

The most direct implication of the findings of Experiment 2 was to provide further support for the landmark-based explanation for this object displacement task. As discussed initially, it is within a landmark-based framework that modifications to the direct connection between cue and target should not impact search. To put it differently, these findings suggest that the cue’s movement captured children’s attention to the target location, regardless of whether or not the cue’s movement was coincident to the car’s movement. The most vital aspect was that the cue
directly marked the target location, and thus spatial relation between the cue and target location was more important.

It can be pointed out that the impact of the cues was different for the two age groups. For 30-month olds, both beacons led to equally well performance, suggesting that regardless of the connection between the cue and target object, the cue was effective as long as it directly marked the target location. For 24-month olds, however, the attached-direct cue led to slightly better performance than the unattached-direct cue. However, performance under the unattached-direct cue condition was significantly above chance, even for the 24-month olds, suggesting this cue certainly aided their performance. An explanation for the difference in performance among the 24-month olds is that even though cues are most effective if they function as beacons or direct cues, it can be the case that beacons or direct cues vary in effectiveness, with some direct cues being more informative than others. And because the ability to recognize and make use of cues is still developing, perhaps 24-month olds are highly sensitive to these differences. Cheng and Spetch (1998) have suggested there is a preference for more reliable cues. In Experiment 2, the unattached-direct cue only appeared (through the visible window above the door) after the car rolled down the ramp and stopped by the wall. The children did not see the cue with the car at the top of the ramp. In contrast, the attached-direct cue appeared both at the beginning and at the end of the car’s movement. Because of the greater number of times this cue was visible during the car’s trajectory down the ramp and because this cue allowed for consistent tracking of the car’s movement down the ramp, children may have viewed the attached-direct cue as the more reliable cue for object location. But both cues were still beneficial in 24-month olds’ search, as reflected in the children’s above-chance performance under both cue conditions. This explanation fits well within the landmark-based account.
One could also argue that because the entire movement of the car down the ramp was occluded, the children who participated in the attached-direct cue condition first may have forgotten that the cue was not physically connected to the car under the unattached-direct cue condition. This means that the children may have believed that in both conditions, the cue was attached to the car, and so, still relied on the direct connection between the cue and the target object. If this was truly the case, then children who participated in the unattached-direct cue condition before the direct-cue condition should have performed poorly in the first condition. This poor performance would be because these children would have not seen the pompom prior to the testing trials, and so would not have encountered the idea that the pompom could be attached to the car and could be used as a cue to the car’s location. However, this was not the case. Children performed equally well (i.e., above chance performance) in both attached-cue and unattached-cue conditions. The finding that children were able to use an attached cue and unattached cue, regardless of the order that these conditions were presented suggests that children do not rely on the direct connection between the cue and target object.

Another potential difference between the attached-direct and unattached-direct conditions was that under the unattached-direct cue condition, a string was utilized to pull the pompom into place (i.e., above the to-be-searched-in door) after the car stopped by the barrier. Although this was a transparent string, it was still visible above the occluding panel. Perhaps, the presence of the string impacted performance. Specifically, the presence of the string may have confused the children or distracted the children from attending to the target location. If children were confused, they would have performed worse under the unattached-direct cue condition compared to the attached-direct cue condition. Again, this was not the case – with equally well performance under both conditions. Moreover, the presence of the string should not have distracted children’s attention from the target location because the location of the string was
above the occluding panel, which was nowhere near the location of the cue. In fact, it was located in the same area as the top of the barrier. According to the landmark-based account, attention would be directed to locations spatially close to the cue. Thus, the presence of the string should not have captured children’s attention more than the pompom did. Thus, the string could not have impacted children’s performance.

Finally, even though every effort was made such that the timing for when the cue was pulled into position when the car stopped by the barrier under the unattached-direct cue condition was the same with the timing when the cue went into position when the car stopped by the barrier under the attached-direct cue condition, there might still have been minor temporal differences that could have impacted performance. In other words, the movement of the unattached cue was more variable than the attached cue, and this variability might have influenced performance. On the one hand, the variability might have made the cue more salient, and thus, attracted attention leading to increased performance. For instance, if there was a delay in pulling the pompom, this movement within the vicinity of the target location may have better captured children’s attention. If this was the case, then children would have performed better under this condition. Again, this was not the case. Also, Shutts et al. (2006; Experiment 3) directly examined if children’s door selections were based on the most recent movement that occurred. The researchers did so by placing a distractor cue (i.e., cue that marked the incorrect door) after the pompom appeared above the correct door. The researchers found that children still used the appropriate cue when searching for the toy car, even though this pompom’s movement into position was not the most recent movement that occurred. On the other hand, variability could have made the cue less reliable, which would lead to decreased performance. This was certainly not the case with the 30-month olds. In contrast, variability could explain why 24-month olds found the attached-direct cue more reliable than the unattached-direct cue, leading to differences in performance.
However, only a small difference between the two conditions was found, suggesting that the impact of variability is minor, at best.

In sum, Experiment 2 investigated the impact of modifying a cue’s properties (e.g., the direct connection of a cue relative to a target object, movement down the ramp), while keeping the spatial relation between the cue and target location constant. Findings revealed that changes to the direct connection did not significantly modulate children’s search behavior. And it was also not the type of movement that mattered. As long as the cue remained coincident to the target location, the cue was effective in aiding children’s search. Moreover, cues may vary in its effectiveness to denote the target location, and children who are still learning how to use different types of cues may be highly sensitive to these differences, and thus, are greatly impacted by these various cues.
1 Main findings and how they relate to existing literature

The findings of Experiment 1 and Experiment 2 are in full support of the landmark-based account. Search performance by toddlers in this well-known object displacement task is driven by attention to locations that are in close proximity to the cue (e.g., immediately below the cue). If the target location is spatially close to the cue, then the cue directly marks this location, serving as a beacon or a direct cue to its target. Under such beacon conditions, successful search is performed. If the cue does not directly mark the target location, but located at a specific distance from it, the cue serves as a landmark to its target, and consequently, search is compromised. These effects are most important among children less than three years of age.

The present findings also highlight that the cue’s effectiveness vary as a function of the cue’s spatial relation to the target location, and not so much on the properties of the cue itself. For instance, as observed in Experiment 1, a cue that was found to be inefficient in previous work (Mangalindan & Schmuckler, 2011; Shutts, et al., 2006) became effective. This was because by reducing the distance between the cue and target location (i.e., the correct door), the cue became a beacon (as opposed to a landmark) to the target location. As a beacon, toddlers were able to make use of this appropriate cue.

Additionally, successful search performance was not due to the movement of a cue or if the cue was directly attached to the target object, rather successful search resulted from the cue moving into a position that directly marked the target location. As observed in Experiment 2, children’s performance was unaffected by the physical connection or the lack thereof. It also did not matter
whether this cue moved down the ramp or popped into place after the car stopped. What was most critical in all these situations was that the cue functioned as a beacon, directly marking its target.

The current findings fit well with the findings of Mangalindan and Schmuckler (2011) in which the orientation of the cue was examined using the same object displacement task. In this study, the researchers found better performance under conditions in which a vertical cue was used because this cue directly marked the correct door. In contrast, under conditions in which an oblique cue was used, the cue no longer marked the correct door, and so, children’s performance dropped. Thus, the orientation of the cue was critical in so far that it changed the spatial relation between the cue and the target location.

The advantage of beacons over landmarks in this well-known object displacement task adds to the wealth of evidence in other spatial orientation tasks that compared these two types of cues (e.g., Acredolo & Evans, 1980; DeLoache & Brown, 1983; Rieser, 1979; Sutton, 2006). As discussed earlier, Bushnell et al., (1995) observed better performance with beacons, as opposed to landmarks. In fact, the use of landmark cues led to worse performance than when no cue presented. In the current study, poor performance was observed under conditions when children only have to rely on the wall (i.e., no-cue condition), because under these conditions, the wall functioned as a landmark or indirect cue for the object’s location. This stood in stark contrast to children’s performances under all of the cued conditions.

Finally, the current findings highlight the role of the spatial relation between cue and target location. The spatial relation not only helps in differentiating beacons and landmarks in this object displacement task, but also underscores the importance of various cues in successfully completing this task. Such findings support recent ideas calling for a re-evaluation of the
importance of landmark information in spatial orientation (Lew, 2011). Beginning with Tolman’s (1948) experiments with rats using a food maze, the proposal that the organism establishes a cognitive map based on the input that the environmental provides and the organism selectively processes has been established. This cognitive map is elaborate and determines which behavioural responses or courses of action are appropriate for the task at hand. And the complexities of these maps are revealed through the organism’s actions when faced with changes to the given environment. According to Lew (2011), the role of environmental boundaries, due to their stability during organisms’ spatial navigation, had taken precedence over the role of landmarks in more recent cognitive map models (Barry, et al., 2006; Cheng, 1986; Dŏeller & Burgess, 2008; Wang & Spelke, 2002). These models have also suggested a separate processing of boundaries. However, Lew (2011) argues that both boundaries and landmarks are processed by a common spatial mechanism, such that if boundaries are not available for the organism, landmarks could be utilized and would be as effective.

2 Other findings and how they relate to existing literature

Other findings in the current experiments also tie well with previous research. The lack of inhibition among the 24-month old children found in Experiment 1 replicated previous work that found the same type of error in children’s performance (Butler, et al., 2002; Keen, et al., 2008). The finding of lack of inhibition resulting in errors is somewhat similar to the findings by Hood and colleagues using a different invisible displacement task. In this task, children are asked to find a ball that is dropped down an opaque plastic tube that leads into one of three potential hiding locations. Using this paradigm, Hood and colleagues have found that children would repeatedly err by searching for the ball in the hiding location directly below the tube where the object is dropped. This gravity error occurs, even if the tube is not connected to hiding location
(i.e., there was no direct path leading to it) or if the tube is connected to a hiding location not directly below it. This error is most marked at 2 years of age. Hood (1995) proposed that children have a naive theory of gravity (i.e., objects fall straight down), based on extensive experience with falling objects (Piaget, 1954), which is then reflected in their pre-potent response of selecting a hiding location immediately below where the tube that the ball was released, regardless of hiding location where the tube was actually connected. In this paradigm, the naïve theory or gravity error results to the inability to inhibit a pre-potent response. This suggests that once the source of the pre-potent response is removed, children should be able to successfully complete the task. Hood (1998) examined this by removing the gravity component in some conditions of this task (i.e., the ball travelled upwards in the tube). He found that when the task involved upward motion, 2-year old children successfully found the hidden object, suggesting that infants operate using a naïve theory that constrains children’s potential inferences.

This straight path bias (based on experience) had also been found to be operative in horizontal trajectory. Hood et al. (2000) examined search strategies for objects travelling in both vertical and horizontal trajectories with 2-year olds, and results showed that children made errors in both conditions. Thus, it might be the case that some of the 24-month olds in Experiment 1 have been operating with this straight path bias, effectively understanding that once the car was released from the top of the ramp, it would continue in its straight path. And when it did not appear at the other end of the ramp, then it would have been somewhere behind the occluding screen. Perhaps, this was the reason why if children were unsure which door to open when asked to retrieve the car, children selected the first door (i.e., the door closest to the top of the ramp) least as the car’s hiding location, suggesting that the children understood that the car could not possibly behind this door if it was travelling down the ramp.
What accounts for this lack of inhibition? Inhibitory control is a complex construct that involves a variety of skills, such as planning and engaging in appropriate responses (Carlson, 2005), suppressing inappropriate responses, such as a pre-potent response (Rothbart, Ahadi, & Evans, 2002) or delaying certain motor responses (Murray & Kochanska, 2002), and shifting perspectives or loci of focus (Diamond, 2006). The development of the inhibitory control has been found to develop with the maturation of the frontal cortex, which occurs between the ages of 3 and 6 years of age (Byrd, et al., 2004; Christ, et al., 2001; Diamond & Taylor, 1996; Gerstadt, Hong, & Diamond, 1994; Levin, et al., 1991). For instance, Byrd et al. (2004) examined the effect of response requirements on the tower-transfer planning task of 3-, 4-, and 5-year olds. Children performed the task under manual-only (children moved the ball themselves without talking), spoken-only (children verbally expressed their moves and experimenter moved the ball for them), or spoken-manual (verbally described and then moved the ball themselves). The researchers found better performance from older preschoolers when they were asked to make a spoken response only and worse performance when the older preschoolers were asked to make a manual response only. These findings suggest a lack of response inhibition or conscious control over cognition.

Other work, using different measures, has revealed that inhibitory control changes across development. This is supported by a study by Christ et al. (2001) who examined a wide age range of individuals. More specifically, these researchers examined age-related changes in the ability to inhibit a pre-potent response, shift in response set, and generate a response incompatible with pre-potent tendency with 6- to 80-year olds. Participants were asked to press buttons during compatible and incompatible conditions, and their response times were compared between conditions. Researchers found that both children and older adults, compared with young adults, required more time to inhibit a pre-potent response and generate an incompatible one,
with older adults requiring more time than children. After controlling for processing speed, the difference between older and younger adults, as well as children and older adults remained. Thus, the lack of inhibition is not necessarily the problem then. In the current experiments, children were asked to retrieve the car only minutes after it had stopped by the wall. Because of the immediacy of the response to the event, the 24-month olds did not have a lot of time to process the information and so, were unable to inhibit the pre-potent response.

In addition, the link between the development of attention and the development of executive function components, including inhibitory control has been previously examined. Garon, Bryson, and Smith (2008) argued that the development of attention provides the foundation for developmental gains in all other executive function components, which includes inhibitory control. Reck and Hund (2011) examined the extent to which attention predicts inhibitory control across childhood (3- & 6-year olds) because past work has revealed the link between the two among infants and toddlers (Kochanska, Murray, & Harlan, 2000) using both laboratory measures and parental reports. Specifically, Reck and Hund (2011) examined sustained attention, which is the ability to maintain continuous focus on a specific stimulus (Posner & Peterson, 1990) and involves the ability to direct and control one’s attention endogenously. Researchers found that sustained attention predicted inhibitory control (as revealed in both observation measures and parental reports), such that increasing attention problems predicted less inhibitory control. In other words, if individuals were unable to sustain their attention, they were more likely to err by lack of inhibition. This could also help explain the 24-month olds’ errors in the present work. Perhaps, the younger children were distracted more easily or were unable to maintain sustained attention to the task at hand, and so, were more likely to display errors in the task.
This is in direct agreement with Keen’s (2005) argument that the lack of inhibitory control does not cause the problem, but rather emerges when children cannot solve the problem (as cited in Keen, et al., 2008). This means that if children are unsure of where the object is, they are more likely to be influenced by some pre-potent response or a preferred door strategy. However, this response is not the source of the poor performance; it is only an offshoot or consequence of it. This is precisely why the lack of inhibition of a pre-potent response occurred only in Experiment 1 and not in Experiment 2 among the 24-month olds. It is only in Experiment 1 that there was a no-cue condition. This no-cue condition was the most demanding for the 24-month olds because with the absence of a cue, children truly did not have an idea where the object could be. Thus, supporting Keen (2005; as cited in Keen, et al., 2008), an increase in lack of inhibitory control was observed.

3 Future directions

There are many questions that can be addressed in future work based on the current findings. For instance, are there only one category of beacons and one category of landmarks, or are there different types of beacons and landmarks? Findings from Experiment 2 especially point to varying levels in effectiveness among beacon cues. In this study, the cue that was visible for a greater frequency during the object’s trajectory down the ramp was considered slightly more reliable. And thus, more likely used by the children during their search. Furthermore, only the younger children used the more reliable cue. So, it would be good to examine if there are indeed more reliable beacons over others, and in what age would reliability of beacons matter most.

A related question is to examine what other properties or factors of a cue can potentially impact its effectiveness to signal the target location. Some factors that have been examined thus far include orientation (Mangalindan & Schmuckler, 2011) and distance (Experiment 1), as well as
movement and direct connection to the target object (Experiment 2). Other factors of a cue that can be examined include distinctiveness and dimensionality. Perhaps these factors can impact a cue’s effectiveness in conveying information.

In addition, previous work on beacons and landmarks (e.g., Bushnell, et al., 1995; Crowther, et al., 2000; DeLoache, 1986; Lew, et al., 2006; Lew, et al., 2004; Sutton, 2006) had always examined these two types of cues separately. However, how will these cues be processed if both types of cue are presented simultaneously? To put it differently, how directly spatially coincident does a cue have to be to be considered as a beacon as opposed to a landmark? Are there certain spatial properties that are more important in determining whether a cue is a beacon vs. a landmark (e.g., is orientation more or less important than distance). Moreover, how might this distinction between beacons and landmarks change as a function of development? Can the same cue function as a beacon for a 30-month old, but only as a less effective landmark for a 24 month old? For instance, what if there are two hiding locations that are adjacent to each other, and in some conditions, one hiding location is the target, whereas in others, the other hiding location becomes the target. Both hiding locations can be cued such that each cue will function as a beacon and landmark, depending on which hiding location is the target. In this situation, will children of various ages be able to use the appropriate cue?

Another interesting question related to the idea that beacons and landmarks can overlap in a particular situation includes investigating if it is just the spatial relation between the cue and the target that makes the difference for a beacon and a landmark. Or are there other factors that can turn a beacon into a landmark, and a landmark into a beacon?

It will be worthy to further explore the developmental trajectories of beacon use and landmark use. There has been conflicting findings in the literature. Previous research have shown that
beacon use appears first, then landmark use, which suggests that the mechanisms underlying the
former may develop earlier than the latter (Bushnell, et al., 1995; DeLoache & Brown, 1983;
Huttenlocher, Newcombe, & Sandberg, 1994; Sluzenski, et al., 2004; Sutton, 2006). Some have
even suggested that mechanisms for landmark use build upon mechanisms for beacon use
(Newcombe & Huttenlocher, 2000). Landmark use has been found to get established around
three years of age. However, other work has provided evidence that suggest that landmark use
may appear earlier than expected (Acredolo & Evans, 1980; Lew, et al., 2006; Lew, et al., 2004).
If this is the case, then this suggests that the mechanisms underlying these two processes may
develop in parallel with each other, making it possible for both to be present early in
development. Determining which is the case between the two scenarios certainly merit further
study.

It will also be interesting to examine if beacon and landmark cues function similarly in other
modalities (e.g., auditory, tactile). For instance, the sound of a door creaking as someone opens it
or the sound of shattering glass as a glass figurine hits a marble floor can function as a beacon
because they directly signify the event that just transpired. In a way, it directly marks the event.
In contrast, the sound of a big thud preceding a loud shrill of a baby can function as a landmark
because even though it can signify the event following it, it does not directly mark it. The baby’s
cry could have resulted from another event, such as being hungry or feeling wet. It will be
interesting to examine if these types of cues are perceived the same way as visual cues. More
importantly, do these types of cues even exist in these modalities, or are these type of cues
specific only to vision?

Finally, another area of future study can examine factors that can relate to potential differences
among toddlers. For instance, intelligence has been found to relate to certain attention-related
processes, such as the scope of attention (i.e., the storage capacity of attention), as measured in attention-allocation tasks (Cowan, et al., 2005; Cowan, Fristoe, Elliott, Brunner, & Saults, 2006). For instance, in Cowan et al. (2006), participants were presented with lists of stimuli in two sensory modalities (e.g., vision and audition), and were asked to recall stimuli from one modality. Researchers have found that participants who recalled more stimuli from the ignored modality tended to score lower in the intelligence measures. Because these studies utilized tasks which were more complex, however, researchers have examined these processes among older children and adults. In addition, other researchers have failed to observe links between intelligence and other attention-related processes, such as shifting, inhibition, and sustained attention (Friedman, et al., 2006; Shacter, 1933). Granted, differences in attention to environmental cues have typically been related to the maturation of the hippocampus, and the search task includes processes (i.e., planning, sustained attention, inhibition) that have been found to be unrelated to intelligence, a link between attention and intelligence may not be found here as well. However, it would be interesting to examine if researchers incorporate in the search task attention-related processes that have been found to relate to intelligence, such as scope of attention. For instance, researchers can insert a delay in between observing the event (of the car moving down the ramp) and retrieval. By doing so, researchers can manipulate the scope of attention, and perhaps with this modification, a link may be observed.
Chapter 5
Conclusions

The results of the two experiments presented here provide overwhelming support for the landmark-based account, demonstrating that this model provides the most comprehensive explanation for the search performance in a well-known object displacement task by children younger than three years of age. To the best of the author’s knowledge, this is the first study to directly examine beacon and landmark use on this particular task. And the findings show that the spatial relation between the cue and target is what drives search for a hidden object. If the cue directly marks the target location, it is more likely attended to and consequently used. If the cue does not, it will more likely be ignored. Properties of the cue (e.g., length, movement, direct connection to the target object) matter to the extent that they impact how well the cue marks its target. The development of cue use (from beacons to landmarks) guarantees that children will get better in utilizing indirect cues or landmarks, which is a useful skill to have, especially because not all cues are coincident to the target location. The fact remains though that the environment is rich with cues to help and guide people along the way. It is comforting to know that no matter how vast the world can be, we can always somehow find our way using various cues that the environment affords us.
References


Notes

i Using the same four barriers for each of the test conditions ensured that the barrier length visible above the occluding screen remained consistent across the trials for each of the test conditions. Because of this use though, the top of the barrier was visible above the occluding screen only for the conditions that employed Screen 1 (i.e., No cue & Short cue/short door). One could argue that the differences in the visibility of the top of the barrier across conditions may impact search in the present study. However, according to the landmark-based account, the top of barrier functions only as a landmark or indirect cue to object location, and children under three years of age less likely use this cue over a beacon or direct cue (i.e., pompom), as supported by previous work in this paradigm (e.g., Berthier, et al., 2000; Mangalindan & Schmuckler, 2011). Thus, differences to wall visibility were expected to not impact children’s search.

ii The apparatus used in Mangalindan & Schmuckler (2011) was slightly different from the one used in the current study because in the earlier study, it only had two doors compared to four doors in the present study. However, this should not be a significant difference because the presence or absence of doors had been shown to not impact children’s performance (Kloos & Keen, 2005) in this task. Moreover, the presence of two doors in Mangalindan & Schmuckler (2011) vs. the presence of four doors in the present study meant that based on chance alone, better performance (i.e., less likely to err in search) should have been expected in Mangalindan
& Schmuckler (2011) compared to the present study. However, this was actually not the case; better performance was observed in the present study.

iii Every effort was made such that the timing of pulling the pompom into position occurred almost immediately after the car stopped by the wall. Trials in which the pompom was not in the correct position (0.8%) were rare and were not included in the analyses.

iv To prevent potential fatigue effects, the total number of trials per condition was reduced from 12 (in Experiment 1) to 8 (in Experiment 2) because the children participated in both experimental conditions in Experiment 2. This change produced two (as opposed to three) repetitions at each door.

v It can be argued that the apparatus was not exactly the same for Experiments 1 and 2, with the difference being that there was no transparent window that ran across the occluding screen in Experiment 2. However, the conditions were still comparable in the sense that no tracking of the pompom can be made as the car rolled down the ramp.