SPATIAL REORIENTATION IN YOUNG CHILDREN: AN EXAMINATION OF THE USE OF GEOMETRIC AND FEATURAL CUES

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Spatial Reorientation in Young Children: An Examination of the use of Geometric and Featural Cues

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Abstract

In past experiments examining reorientation, young children may not have been given sufficient time to reorient and take all information in their environments into account in order to search accurately. In past studies, participants have begun searching for hidden objects immediately following the disorientation procedure. It was predicted that imposing a delay of 10 s between the time when participants stopped turning and began searching would increase search accuracy. Thirty children, aged 36 - 56 months, participated in the current study. Results suggest that allowing extra time between disorientation and searching leads to increased search accuracy. It is proposed that providing children with a small amount of extra time allows them to fully regain their sense of heading and direction. In turn, they are better able to make use of all the information in their environments to reorient and locate a hidden target.

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Spatial Reorientation in Young Children: An Examination of the use of Geometric and Featural Cues

An integral aspect of any animal's life is the navigation of its environment. Indeed, place-finding (finding and returning to a desired location) is one of the most common recurring adaptive problems faced by a diverse group of organisms in their daily lives (Cheng & Sherry, 1992; Cheng & Spetch, 1998; Collett, Cartright, & Smith, 1986). Such locations include homes, potential nest-sites, and food-sites (Cheng & Spetch, 1998; Kelly, Spetch, & Heth, 1998). A question that has sparked a great deal of both animal and human research is that of determining which properties of an organism's environment are used in the successful navigation of its environment. Research to date indicates that many organisms have two fundamental methods of exploring, learning, and finding their way around their surroundings (Learmonth, Newcombe, & Huttenlocher, 2001).

One of these methods is path integration, a self-referenced navigation system that relates the position of a desired location to the position of the self. In such a system, the distance and direction of self-movement are encoded and constantly updated to correct for self-movement (Gallistel, 1990; Learmonth et al., 2001; Newcombe, Huttenlocher, Drummey, Wiley, 1998; Redish, 1999). The second type of system animals use to remember the position of desired locations or objects is externally referenced. That is, the position of a desired location or object is directly related to some aspect of the external environment (i.e., a landmark (s)). Landmarks are any distinct features of an environment which may act as a guide in following a route, marking a boundary, or remembering the site of a desired location (Cheng, 1986, 1989, 1994; Cheng & Sherry, 1992; Cheng & Spetch, 1998; Collett et al., 1986; Gould-Beierle & Kamil, 1996; Newcombe et al., 1998; Spetch, Cheng, & MacDonald, 1996, 1997; Spetch, Cheng, & Mondloch, 1992).

Ideally, an animal will combine information gathered through both means to find its way. However, from time to time, situations arise in which the path integration system goes off-line, placing the animal in a state of disorientation. In these cases, it appears common for animals to use landmarks to correct the self-referenced, path integration system thereby reorienting the animal (Learmonth et al., 2001).

An area that has been gaining increasing interest concerns the different aspects of the external environment that animals will use as landmarks when their path integration mechanisms go off-line. That is, what is it about the different landmarks and their relationship to the target location that is used? Is it featural information such as color, size, or texture, or is it geometric information such as the shape of the environment that is important?

Investigations into questions of this nature have generally shown that animals can use multiple sources of external information (e.g., geometric relations, different types of landmarks) to locate a goal (Kelly et al., 1998). The primacy of the role played by any one type of cue will in all likelihood depend on the species being studied (Brodbeck, 1994) and/or the context in which the animal finds itself (Strasser & Bingman, as cited in Kelly et al., 1998).

Geometric properties, as defined by Gallistel (1990), are those properties of a surface, line, or point which can be described by virtue of their position in space relative to other surfaces, lines, or points. They include such measures as distance, direction, and angles. A non-geometric or featural property, in contrast, is any property which requires information other than relative position to successfully describe it. They include measures such as color, texture, or size (Cheng & Spetch, 1998; Gallistel, 1990).

Research with Animals

Rats

Investigators, using a number of different paradigms, have examined the role played by geometry and demonstrated its importance in a variety of species including rats, pigeons, chicks, monkeys, and humans (Cheng & Spetch, 1998). Of special relevance to the current study is a paradigm first developed and tested by Cheng (1986). Cheng designed a rectangular apparatus in which rats searched for hidden food whose position could be partially determined by the shape of the room but fully determined by a variety of different featural cues including the different brightness levels, odors, patterns at the corners of the apparatus as well as a distinctively colored wall. The primary assumption underlying this paradigm is that oriented rats store an internal representation of the location of the food and that disorientation disrupts this representation such that the disoriented rat needs to reorient itself in order to locate the hidden food. Cheng reasoned that the location where the rat searched would indicate which element(s) of the spatial array the rat used to reorient itself (Cheng, 1986; Cheng & Spetch, 1998; Gallistel, 1990; Gouteux, Thinus-Blanc, Vauclair, 2001; Hermer-Vasquez, Spelke, & Katsnelson, 1999; Margules & Gallistel, 1988).

Cheng's (1986) research revealed that it is primarily geometric information that is encoded and used in navigation tasks. That is, rats rely primarily on the geometric relations between the target location and the overall shape of the environment rather than non-geometric, featural information such as smell, texture, and brightness level. Featural information is not completely ignored; it simply plays a subordinate role in the animal's searching behavior (Cheng, 1986; Cheng & Spetch, 1998; Gallistel, 1990; Kelly et al., 1998; Vallortigara, Zanforlin, & Patsi, 1990; Zoladek & Roberts, 1978).

The rats in Cheng's experiments were placed in a rectangular apparatus with different features in each corner. On the first trial, the animals were shown the location of some highly desired food. After allowing the rats to eat some of the food, they were removed from the apparatus. The food was then buried in the same location. The rat's task was to find the food after a 75 second interval. In order to prevent the animals from relying on their innate sense of direction, the apparatus was periodically rotated during the 75 second delay. In addition, other, quite salient information was available. Panels with different, highly discriminable patterns were located in each of the four corners. Additionally, a different number of small lights shone in each corner, distinctive odors emanated from two of the corners, and in one of the experiments, one of the walls was white while the others were black (Cheng, 1986; Cheng & Spetch, 1998; Gallistel, 1990).

Evidence for the primacy of geometric information comes from a systematic rotational error made by the animals in their place-finding task (Cheng, 1986; Cheng & Spetch, 1998; Gallistel, 1990; Kelly et al., 1998; Margules & Gallistel, 1988). Within a rectangular environment, one other location stood in a geometrically equivalent location as the target. This rotational equivalent cannot be distinguished from the correct location on the basis of environmental shape alone. Rats confused these geometric equivalents and systematically searched in the geometrically equivalent, but incorrect location (located at a 180 degree rotation from the target location), most often at a similar frequency as the correct location. In addition, the rats almost never searched in the other two corners of the apparatus as these locations were quite different in terms of their geometric relations to the environment (Cheng, 1986; Cheng & Spetch, 1998; Gallistel, 1990; Kelly et al., 1998; Margules & Gallistel, 1988; Vallortigara et al., 1990).

Cheng concluded that the rotational error implied that the animals were making exclusive use of the shape of the apparatus to reorient, ignoring pertinent and obvious featural information. He believed this behavior to be indicative of a geometric module for reorientation which encodes only the overall shape of the environment (Cheng, 1986; Cheng & Spetch, 1998; Gallistel, 1990; Vallortigara et al., 1990).

Others have taken Cheng's lead and attempted to replicate his results with both rats and other animals. For example, Margules and Gallistel (1988) also provided evidence for the central role played by geometric cues in rats. Results from this series of experiments confirmed previous findings that rats rely on geometric information about the shape of their environment to establish their orientation in a place-finding task. Further, it was shown that rats ignore featural information that also defines environmental shape, even when the geometric information provided is insufficient to complete the task (Margules & Gallistel, 1988).

Geometric Module

The term geometric module requires further explanation. A module, the functional component of a multi-modular network, is a functionally specialized information processing program whose procedures are designed to solve a single type of problem faced by an organism in its environment. The term multi-modular representation is used to describe the evolutionary view that the mind is carved into a plethora of evolved information-processing programs specialized for solving different adaptive problems. This view is based on a basic engineering principle which states that a single machine is rarely capable of completing two distinct tasks with equivalent accuracy and precision. Modules are expert systems - designed to be furnished with all the tools necessary to solve one specific set of problems. These tools include specific procedures, rules, priorities, and assumptions that will be used to solve the particular adaptative problem an organism may be faced with in a given situation. Each module will be called into action depending on distinct environmental cues which signal the need for that module's particular brand of expertise (Cosmides & Tooby, 1987, 1994, 1995, 1997, 2000; Pinker, 1997). It should be noted that the above discussion was meant only to provide a basic understanding of the terms module and multi-modular representation. The complexity of interactions that are involved in this type of system should not be underestimated. For further reading on the modularity hypothesis see Cosmides & Tooby, 1987, 1994, 1995, 1997, 2000; Pinker, 1997.

In support of the geometric module proposition Gallistel (1990) offers an evolutionary argument. He suggests that it is useful to be sensitive to the shape of your environment as these aspects of an environment do not experience the same degree of change as do featural aspects of an environment. Maximizing reliance on the constancy provided by geometric properties of the natural world in which an organism operates makes a great deal of adaptive sense. A mountain will not move considerably, but the leaves of trees growing on the mountain will likely change colour or fall off, drastically changing its featural appearance. In addition, the kinds of spaces that are used in these experiments that are rotationally symmetric are few and far between in the natural environment so very few of the rotational errors that occur in these experiments (Gouteux & Hermer, 2001; Hermer & Spelke, 1994, 1996; Wang et al., 1999) actually occur in real life (Learmonth et al., 2001).

However, the noted difference between the enclosed areas used for experimental purposes and areas in a natural environment also pose a problem for the geometric module explanation. The utility of such a module is questionable when one considers that in the natural environment there is not always a large extended surface from which organisms can gain necessary, even vital information. In fact, in most circumstances it would seem much more adaptive to have the ability to use featural information or at least the geometric information provided by an arrangement of objects such as boulders or trees etc. (Learmonth et al., 2001). This fact challenges an adaptive argument. It is obviously not adaptive to rely on a way-finding system that, in all likelihood, will result in a sizeable amount of confusion due to the inability of a particular environment to provide the very specific type of information required by the organism to find its way.

Chicks

Vallortigara et al. (1990) also provided support for the use of metric properties in landmark based place-finding tasks. The chicks in these experiments were placed in a rectangular apparatus, based on the one used in Cheng's (1986) study with rats, and tested in a reference memory task. When tested in a featureless environment, chicks encoded geometric information as indicated by the fact that they searched at the correct location or its rotational equivalent but made no other systematic errors. When featural information was present, geometric information was still encoded, but played a subordinate role to the featural information provided. However, the chicks did continue to encode the geometric information even when it was not necessary to complete the task. This compounded with the fact that the chicks could not see outside of the box and were rotated to prevent the use of their inherent sense of direction, led the authors to suggest the possibility of a geometric module in chicks as well (Cheng & Spetch; Vallortigara et al., 1990).

Monkeys

Gouteux, Thinus-Blanc, and Vauclair (2001) also attempted to replicate the results of Cheng (1986) using Rhesus monkeys. They completed a series of eight experiments and determined that, like the chicks in the Vallortigara et al. (1990) study, Rhesus monkeys can and do use the geometry specified by the large-scale spatial relations of their environments. However, they also made use of any featural information which was present as long as that information was salient enough for them to detect. It should be noted that rats have relatively poor vision in comparison to the visual capabilities of chicks and monkeys (Cheng, 1986; Vallortigara et al., 1990; Gouteux et al., 2001). This may partially contribute to the success of these two species on reorientation tasks.

When tested in a rectangular environment devoid of featural information, the disoriented monkeys in these experiments behaved in ways in keeping with that of the rats and chicks of earlier studies (Cheng, 1986; Margules & Gallistel, 1998;

Vallortigara, 1990). That is, the monkeys also relied on the geometric information specified by the shape of the enclosure to reorient and locate the hidden target (thereby making the rotational error) (Gouteux et al., 2001).

Monkeys were also tested with features present. When tested in a room with one featural cue (a colored wall) the results indicated that they were able, like chicks, to make use of both the geometric and featural information available in order to reorient and subsequently locate the hidden target. Since the featural information was not directly associated with the target it can also be concluded that this is not merely a simple case of associative learning. Rather, it is clear that the monkeys completed their task by utilizing all pertinent information offered by the environment - geometric and featural (Gouteux et al., 2001).

Gouteux et al (2001) conducted other experiments to test specific spatial ability - i.e., whether the monkey's ability was subject to any size and/or distance constraints. Experiments 4 and 5 investigated the monkeys' ability to use small, distal, and proximal featural cues associated either directly or indirectly with the target in a rectangular environment. Experiments 6 through 8 focused on the effect of featural landmark size (again, in a rectangular environment). The major conclusion from these experiments was that size matters. Monkeys can make use of featural landmarks in any position (i.e., near or far from the target location) as long as they are large enough to be detected. If the featural cues in the environment are too small, monkeys will be unable to detect and use them in their search efforts

(Gouteux et al., 2001).

Research with Humans

Evidence of the sort found in Cheng's (1986) study has also been reported in experiments with human children. Indeed, extensive research into the use of geometric versus non-geometric cues in the reorientation processes of human children has been conducted (Gouteux & Hermer, 2001; Hermer, 1997; Hermer & Spelke 1994, 1996; Learmonth et al., 2001; Learmonth et al., 2002; Wang, Hermer, and Spelke, 1999). The procedures and findings of these studies are discussed below.

Procedures

The basic procedural elements from all studies examining the use of geometric versus featural cues in the reorientation processes of human children were based on the procedures developed by Hermer and Spelke (1994). Their procedures were adapted from a similar study involving rats developed by Cheng (1986) discussed earlier in this paper. Children aged 16-24 months in some studies (Hermer & Spelke, 1994, 1996; Learmonth et al., 2001; Wang et al., 1999), 3-4 years in others (Gouteux & Hermer, 2001; Learmonth et al., 2001; 2002) were shown an object (a toy brought from home by the child's parents). Children watched as the toy was hidden in a corner of a rectangular (Hermer & Spelke, 1994, 1996; Learmonth et al., 2001, 2002), square (Wang et al., 1999), or cylindrical (Gouteux & Hermer, 2001) enclosure. The enclosures used in these studies not only varied in shape but also in size. Most of the studies tested children in an enclosure measuring 4 ft X 6 ft or corresponding sizes for square and cylindrical enclosures (Gouteux & Hermer, 2001; Hermer & Spelke, 1994, 1996; Wang et al., 1999). However, two studies (Learmonth et al., 2001, 2002) employed a larger enclosure measuring 8 ft X 12 ft - four times the area of the original enclosure.

Next, children in disoriented conditions underwent a disorientation procedure. The parent picked up the child, covered his or her eyes, and turned him or her for at least four full revolutions. Other, older, children simply closed or covered their eyes and completed the required number of revolutions without parental assistance. Children in oriented conditions simply turned in place with their eyes open (either by themselves or with the help of their parents). The experimenter signaled the parents or the participants to stop turning facing a randomly predetermined wall at which point children were free to open their eyes and begin searching for their toy. During these experiments care was taken to avoid dizziness in the child. Participants were instructed to turn slowly. In addition, care was taken to ensure that children did not begin searching until they were able to stand stabile (Gouteux & Hermer, 2001; Hermer, 1997; Hermer & Spelke 1994, 1996; Learmonth et al., 2001; Learmonth et al., 2002; Wang, Hermer, and Spelke, 1999).

Critics of Hermer and Spelke (1994) suggested that the disorientation procedure itself was affecting children's disuse of featural information. The notion that the disorientation procedure itself caused the children's failure to use the non-geometric information was, therefore, tested by Hermer and Spelke (1996). Disoriented children were presented with a spatial task which researchers believed required no reorientation. After children were successfully disoriented, the children and the hiding containers were removed from the original testing area and placed side by side in a new room just outside the experimental chamber. This lateral positioning of the boxes was randomized across trials. Because of the new environment in which children found themselves they could not reorient by comparing current surroundings to those experienced prior to disorientation. In addition, because the box containing the hidden toy had moved there was no need for the child to reorient and return to the object's previous location. Instead, the child was simply required to search out the correct box. If the disorientation procedure was the cause of failure to use featural cues as a result of disruptions in memory processes then children should not find the object in this task. This, however, was not the case. Results showed that children performed successfully in this instance, using featural information regarding the hiding location to find the hidden object (Hermer & Spelke, 1996).

Finally, some of the experiments in these studies involved testing in a featureless environment where all walls of the enclosure were white (Gouteux & Hermer, 2001; Hermer, 1997; Hermer & Spelke 1994, 1996; Learmonth et al., 2001; Learmonth et al., 2002; Wang, Hermer, & Spelke, 1999). Others (Gouteux & Hermer, 2001; Hermer, 1997; Hermer & Spelke 1994, 1996; Learmonth et al., 2001; Learmonth et al., 2002; Wang, Hermer, & Spelke, 1999) involved the use of enclosures with large-scale features (e.g., one blue wall, 3 white walls). More (Hermer & Spelke, 1994, 1996; Gouteux & Hermer, 2001) used small-scale features (e.g., a featurally distinct box), while others still (Gouteux & Hermer, 2001; Learmonth et al., 2001; Wang et al., 1999) used different sorts of geometric cues (e.g., a distinctive geometric arrangement of boxes or a distinctively shaped wall).

Results

Hermer, Spelke, and colleagues have provided us with a wealth of information regarding children's reorientation abilities. Specifically, they have shown that children aged 18 months to four years rely exclusively on geometric information about the permanent, continuous, surfaces of a spatial layout (e.g. walls) in order to reorient. Other types of geometric information are not used by children in these situations. For example, while children will make use of a distinctively shaped wall (a continuous surface) they will not use a geometric pattern of boxes. This proves to be the case in rectangular, square, and cylindrical shaped environments. It is also the case when children are purposely familiarized with the testing environment and its associated landmarks. The degree of familiarity with the environment and landmarks apparently makes little difference to the ability of children to use non-geometric information to reorient and locate displaced objects (Gouteux & Hermer, 2001; Hermer & Spelke, 1994, 1996; Wang et al., 1999).

Perhaps most striking is children's object localization performance in an environment where featural and geometric cues uniquely specified both the child's own position and the position of the target object. When disoriented children are in situations in which the room is transformed while their eyes are covered they demonstrate striking evidence of their heavy reliance on geometry. To transform the room each container was shifted directly across the room so that one search location corresponded to the original location with respect to shape (geometry) but not with respect to featural cues, and one location corresponded to the original location with respect to featural cues but not to shape. Disoriented children almost always searched in the location with the appropriate geometry (Hermer & Spelke, 1996).

Featural, non-geometric cues, on the other hand, are used only in the absence of such geometric information in an associative learning process. That is, featural cues, in those instances when they are utilized, are not used to reorient. Instead, they are associated directly with the target object. This allows for the successful completion of the object localization task but not in a reorientation process. Instead of reorienting themselves first, and then localizing the target object (as is the case when using geometric information) subjects make a direct association with the target object and the non-geometric properties of its hiding location (Gouteux & Hermer, 2001; Hermer & Spelke, 1994, 1996; Wang et al., 1999).

Hermer and Spelke (1994) concluded that their findings indicated the presence of an encapsulated mechanism for reorientation that is based on recognition of the geometric properties of shape - a geometric module. They proposed that their work is suggestive of distinct problem solving processes for reorientation and object localization memory tasks (Hermer & Spelke, 1996).

As exhaustive as the research conducted by Hermer, Spelke, and colleagues may seem, it has not gone uncontested. Indeed, in an attempt to replicate the results of Hermer and Spelke (1994; 1996), Learmonth et al. (2001; 2002) found that children in their experiments were, in fact, able to utilize both geometric and non-geometric information to locate a hidden target. It appears, from this work (Learmonth et al., 2001; 2002), that previous findings in the area of children's reorientation (Gouteux & Hermer, 2001; Hermer & Spelke, 1994, 1996; Wang et al., 1999) abilities only occur when children are tested in the relatively small-scale enclosures used in these studies. When children from the ages of 16 months to 4 years are tested in a larger enclosure they are more than capable of utilizing both geometric and featural information (both small and large scale features) to help them to reorient and locate a hidden target. The size of the navigable space had a clear impact on children's ability to use a featural cue to aid in reorientation (Learmonth et al., 2001, 2002).

This finding casts serious doubt on previous claims made by Hermer and Spelke regarding children's reorientation capacities and the existence of a geometric module. Such a module, if it existed, would have to be completely impenetrable to any and all non-geometric, featural information. This obviously is not the case.

Learmonth et al. (2002) also tested children in an enclosure mirroring those of past studies. From this they were able to determine exactly when children become able to use featural information in the smaller space. It appears that the ability to use featural landmarks in the smaller space increases with age. The inability of young children to use a colored wall as a landmark for reorientation purposes in a small space such as the one used by Hermer and Spelke disappears as children move beyond their fifth year.

Delay

Some of the studies reported in the preceding discussion (Hermer and Spelke, 1994; 1996) also looked at the use of geometric versus featural cues for reorientation in adults. In general, adults demonstrate greater flexibility than children and rodents. Adults are able to incorporate and use both types of information simultaneously. In past experiments examining the reorientation abilities of young children, participants, like their adult counterparts have been instructed to search out the hidden object immediately following the disorientation procedure (Gouteux & Hermer, 2001; Hermer & Spelke, 1994, 1996; Wang et al., 1999). In the majority of circumstances this has led to situations in which disoriented participants have overwhelmingly showed a pattern of responding indicating that they are unable to make use of any featural information provided in their testing environments. Indeed, only geometric information has seemingly been encoded and used to help the children reorient and successfully locate the target object (Gouteux & Hermer, 2001; Hermer & Spelke, 1994, 1996; Wang et al., 1999).

This has been the case in all but one experiment reported in Hermer & Spelke (1996). This experiment tested whether the disorientation procedure could have caused the seeming inability of participants to use featural information. Participants were required to move from one room into another before embarking on their search. Hermer and Spelke (1996) suggested that this would remove any need for reorientation. They found that children in these circumstances had no problems using featural information to find their hidden toys. However, it is possible to interpret this result in a slightly different manner. For example, this result is also consistent with the idea underlying the present experimental hypothesis which suggests that a short delay before searching would result in increased response accuracy. Participants in the experiment testing the effects of the disorientation procedure (Hermer & Spelke, 1996) were delayed from searching. Perhaps their increased ability to complete the task using all information available was not because reorientation was not required. Perhaps, instead, participants were accurate because they were provided with extra time to fully reorient.

In addition, other researchers (Learmonth et al., 2001, 2002) have designed studies in which children have had no problems incorporating both featural and geometric information into their reorientation efforts. They have tested children in a larger experimental enclosure and suggested this as the cause of increased search accuracy. Children tested in a larger room than that used in the original studies were able to successfully incorporate all information provided in the enclosure in their efforts to reorient and locate a hidden target.

Several lines of evidence suggest that modifying the procedure used on adults often reveals capabilities in children that others had previously believed were absent (Baillargeon, 1987; Bukato & Daehler, 1995; Fernald, Swingley, and Pinto, 2001; Gelman, 1969). For example, Baillargeon (1987) in a study looking at object permanence designed an experiment that allowed him to look at the abilities of infants as young as four months in this area. Using an age-adapted method Baillargeon (1987) was able to show a rudimentary understanding of the object permanence concept in children as young as four months of age.

Gelman (1969) achieved a similar feat in testing five year old children on a number conservation task. Participants were provided with training sessions. After each training period participants were tested on a conservation of number task. A significant number of participants performed correctly even when tested several weeks after the training period. In fact, in later work Gelman (as cited in Gelman, 1969) was able to demonstrate that, under some circumstances, even three to four year olds are able to utilize training sessions and learn to conserve number.

In an examination of the speech processing capabilities of infants, Fernald, Swingley, and Pinto (2001) were also able to tailor their study to fit the cognitive capacities of their participants. Past researchers have concluded that children and adults have fundamentally different ways of processing speech. Fernald et al. (2001) were not convinced that this was the case. They believed that infants and children were simply not being tested in a way that was adjusted to their capabilities. Instead of using words drawn from a random list they used an innovative instrument that helped them to determine words with which the sample children were familiar. Using this instrument allowed them to show that children as young as 18 months of age process speech in the same, continuous, manner as adults.

That children sometimes require that they be treated differently than adults in experimental situations is the driving premise behind the current examination. While it may be appropriate for adults to begin searching for a displaced target immediately following disorientation, it is plausible that allowing children extra time before they begin to search may improve performance on the reorientation task. Potential explanations for any improvements in performance will be considered in the general discussion. In a small space such as the one used by Hermer, Spelke, and colleagues in earlier studies in this area there would have been no real way for participants to take a small amount of extra time, without appearing uncooperative, unless specifically asked to do so. However, the larger space used in the Learmonth et al. (2001, 2002) studies may have inadvertently provided participants with the extra time they needed by virtue of the longer time it would have taken them to move about the room. It is hypothesized that if a short period of time, perhaps 10 seconds, is allowed to pass before participants begin their search they will be able to take featural information into account and successfully locate the target object.

It is suggested that, in the present circumstances, tailoring the experiment to the capabilities of the participants being tested means imposing a delay - giving our young participants just a little more time to demonstrate behavior that adults demonstrate with ease. While this may seem obvious, even simple, it has not previously been taken into consideration. Many researchers have taken children's behavior in these situations to be indicative of a geometric module for reorientation behavior. However, it is currently held that the fact that children behave so differently from their adult counterparts and so similarly to rats tested on similar reorientation tasks does not necessarily mean that the human mind is organized according to a modular framework. It is likely that, instead, testing circumstances have not been adjusted to meet the cognitive capabilities of the participant population.

Other studies that have examined the effect of delay on young children's memory indicate that imposing a delay of approximately 10 seconds, as in the present study, will not prove detrimental to their memory. For example, DeLoache (1986) looked at the effect of imposing a 30 second delay on 21 and 27 month old's memory of the location of a hidden object. The young children tested in these experiments were not adversely affected by the 30 second delay. Some of the younger children did experience some difficulty in remembering the location of the hidden toy. However, it was shown that this was not related to the delay but to the type of cues given to help children remember where the object was hidden.

Relatedly, DeLoache and Brown (1997) reported findings from a research project examining young children's memory for object location. Children aged 18 - 30 months were tested in a task resembling a game of hide-and-go-seek. As in the previous study a delay of 30 seconds was imposed. Children performed competently in these tasks indicating that a delay of 30 seconds did not appear to have substantial effects on the memories of these young children.

Children have also been tested at delays of 2 and 4 weeks. Deocampo and Hudson (2003) tested 24 and 30 month olds memory after 2 and 4 week delays. Children who saw pictorial reminders of the activities they had previously experienced demonstrated excellent recall even after 4 weeks had passed. Indeed, young children's memory for some events shows no decline after three months in some circumstances, e.g., if the child re-enacts the event a short time later, (Fivush & Hammond, 1989) or even longer - up to 18 months for certain kinds of events, e.g., trip to Disneyland, (Hammond & Fivush, 1991). Given this information, there is no reason to anticipate any negative effects on children's memory for the location of the hidden object in the current experiment as a result of a 10 second delay.

Symbolic Representation - An Alternative Performance Measure

An alternative probe or performance measure was added to the procedure. Participants were asked to look at a model of the experimental enclosure and point to the model box that corresponded to the larger box in which their toy was hidden during the experiment. This addition was included in order to help determine whether children who had performed with low search accuracy in the reorientation task would be able to use a symbolic representation of the enclosure to indicate that they were indeed aware of their toy's hiding location in the larger enclosure.

Research in the area of symbolic representation suggests that children at the ages of 3 to 4 years are capable of basic representational thought. That is, they are capable of grasping the basic relationship between a model and its referent - that the model represents or "stands for" another, separate object (DeLoache, 1987; DeLoache, Miller, & Rosengren, 1997; DeLoache & Smith, 1999; Flavell, Miller, & Miller, 2002).

Given this information children should experience little difficulty in using the model to indicate that they were aware of the hiding location of their toy during the reorientation trials. In doing so, participants who are predicted to perform poorly (those of the disoriented no delay condition) will help to confirm that a short delay is necessary to improve performance on the reorientation task.

The Current Study

The current study examined an alternative explanation for previous findings in the area of childhood reorientation capacities. Past studies have explained the puzzling results of some of these studies by claiming (a) that children possess a geometric module for reorientation that is impenetrable to featural information thereby causing children to ignore such information (Hermer & Spelke, 1994;1996) or (b) that children cannot make proper use of all cue types in small spaces such as those used by Hermer, Spelke, and colleagues but have no problem in larger spaces as smaller spaces somehow interfere with a child's ability to understand that their task is to reorient (Learmonth et al., 2001; 2002). The driving premise behind the current study is that participants in past studies have not been given sufficient time to reorient. It is hypothesized that imposing a delay of approximately 10 seconds between the time when participants stop turning and begin searching will result in increased search accuracy. Such an increase in search accuracy would necessarily require that participants make use of all information in their environments. It was predicted that participants in the oriented conditions would perform with greater accuracy than those in the disoriented conditions and that participants in the delay conditions would perform with greater accuracy than those in the no delay conditions. More specifically, an interaction between these variables (delay vs. orientation) was predicted. Participants in the disoriented no delay group were expected to perform with significantly lower search accuracy than all other groups which should not have differed from each other.

Participants also completed a model task in which they were asked to look at a model of the experimental enclosure and choose the small box in the model that corresponded to the box in the larger enclosure where their toy was hidden during the experimental trials. The model was simply a different type of performance measure to help determine whether participants who had performed poorly in the experimental enclosure for the reorientation task were actually aware of their toy's hiding location. It was predicted that all participants would perform accurately on the model task. Specifically, it was hypothesized that even children who had been unable to correctly identify the box that concealed their toy in the reorientation task would then indicate that they were indeed aware of its location. This would support the hypothesis that children need extra time to make use of all information available to them inside the enclosure in order to make a comprehensive search choice.

Method

Participants

Participants included 30 children (n = 19 males, n = 11 females) aged 36 - 56 months with no known health problems, developmental delays or learning disabilities. Parents accompanied children to the laboratory on all visits. Participants were randomly assigned to one of the four experimental groups: disoriented delay, disoriented no delay, oriented no delay, and oriented delay. Data from 8 participants (n = 6 males, n = 2 females) were excluded from the analyses due to procedural difficulties (problems turning, general uncooperativeness, problems keeping eyes closed, problems paying attention to task, etc.).

Participants were recruited from two separate daycares. Recruitment letters (see Appendix A) were delivered to each of the daycares and placed in each child's mail pouch. Recruitment letters contained details concerning the purpose of the study and its procedure as well as an informed consent form. Parents were asked to return consent forms (which asked parents to provide a telephone number for scheduling purposes) to their child's daycare if they chose to volunteer their child for the project. In one of the daycares, second and third recruitment reminder letters were delivered. Once consent forms were collected from the daycares, parents were contacted and appointments to take part in the experiment were scheduled.

Parents were informed that their participation was completely voluntary and that they could withdraw their child from the study at any point. Informed, written consent was obtained from the parents of the children who participated in the study. Parents were provided with further details regarding the experimental hypothesis after their child had completed the experiment. After the study was completed parents were sent a certificate bearing their child's name indicating that he or she had participated in a psychological research project at Memorial University of Newfoundland. In addition, a brief outline of the results of the study was included.

Materials

Participants were tested in a rectangular, room-like, enclosure measuring 6 ft wide x 10 ft long x 7.5 ft high. The enclosure was set up inside a larger room measuring 8 ft wide x 12 ft long x 8 ft high which served to completely isolate the experimental enclosure from the outside environment and any distracting landmarks. The enclosure was illuminated by one incandescent light mounted in the center of the enclosure's ceiling. A video camera used to record experimental trials was mounted inconspicuously in the center of the ceiling nearest the cue wall to provide an overhead view of the enclosure. However, video data for 14 participants was lost due to accidental destruction of the first videotape. Four featurally indistinct, opaque, identical containers were placed inside the enclosure (one in each of the four corners). One of the walls of the enclosure was covered with a blue curtain (measuring 6 ft wide x 7.5 ft high) which served as the featural cue. The enclosure for the present study was quite similar to the one used by Hermer and Spelke (1994; 1996). That is, the present enclosure was also rectangular in shape and used a single blue wall as the featural cue. The only major difference was in the size of the room. The present enclosure measured approximately one and one half times larger of the original enclosures used in the Hermer and Spelke (1994; 1996) studies as opposed to the Learmonth et al. (2001, 2002) studies which used an enclosure four times larger than the Hermer and Spelke enclosures.

Each participant searched for a toy brought from home by the child's parents which was placed inside one of the four plastic containers on each trial. The option of using a child's own toy was chosen to increase motivation to complete the task and decrease time necessary to familiarize the child with a new toy. Parents were asked to bring a toy that the child was fond of and which was of an appropriate size. Supplementary age appropriate toys were available in the event that parents failed to bring a suitable toy.

Finally, a mock up of the experimental enclosure was created for use in the model task. The model, an approximation of the larger enclosure was fashioned from a box measuring 6 inches x 12 inches. Three of the "walls" were covered in grey construction paper while the fourth cue "wall" was covered in blue construction paper to match the colors of the larger enclosure. In addition, four featurally indistinct boxes were placed in each of the four corners of the model.

Procedure

Participants entered the enclosure accompanied by the experimenter. Once inside the enclosure, each child watched the experimenter hide his or her toy. The toy was placed inside the same box on each trial for individual participants. Toy location was chosen randomly for each participant. Following this, participants were disoriented or not depending on the group to which they were assigned. Disoriented groups were instructed to cover their eyes while slowly turning in place in a clockwise direction for at least four full revolutions. Each child was instructed to stop turning facing a different wall on each trial. To guard against dizziness, children were instructed to turn slowly. In addition, if children were unable to maintain their balance while turning or while moving to a search location, that trial was discarded and children were instructed to turn at a slower rate. While each child was turning, the experimenter slowly moved around him or her in a counter-clockwise direction so as not to provide any type of directional cue that would potentially aid the child's search performance. Oriented children simply turned in place with eyes open for four revolutions as the experimenter moved around them.

Children in the oriented no delay condition were instructed to search for their toy after turning in place for at least 4 full revolutions while participants in the oriented delay group were required to wait for approximately 10 seconds before beginning their search. Participants in the disoriented no delay group began searching immediately following the disorientation procedure. Finally, children in the disoriented delay group were instructed to wait for a period of approximately 10 seconds following the disorientation procedure before beginning to search out their hidden toy. To achieve the delay children in the delay groups were prevented from rushing off to begin searching. The delay was implemented by asking the child to count to ten with the experimenter who used a stop watch to make sure the delay period did not go beyond or below the required 10 second period. Once a child had successfully located his or her toy he or she was instructed to return it to the experimenter so that they could "play the game again".

Most participants entered the enclosure and completed the required trials with only the experimenter in the enclosure with them. However, a number of children were not comfortable with this arrangement and requested that their parent be present. In these cases, the parent entered the experimental enclosure with the child and the experimenter. Parents were then required to pick up their child and simply do the necessary turning for him or her. Parents stood in the center of the room and either slowly turned in place while the child kept his or her eyes open (for the oriented trials) or turned in place while the child's eyes were closed (for the disoriented conditions). Parents were instructed to place the child on the floor after they had finished turning, place their arms at their sides and remain facing the wall they were facing when they had stopped turning. They were also instructed to avoid giving their child any clue as to the location of the toy.

Although only the child's first choice was included in the data analysis, children were allowed to continue searching until they had successfully located their toy. Other than the successful location of the hidden toy no purposeful reinforcement was given for search performance. Each child completed at least four trials in their respective groups with an inter-trial interval of approximately 30 seconds. At times it was necessary to have a participant complete more than four trials due to failure to follow proper procedure (e.g., failure to keep eyes closed or failure to complete turning properly). After the child located the hidden object, he or she returned it to the experimenter and the original procedure was repeated.

Once the participant had successfully completed four trials he/she was led out of the experimental enclosure. At this point, the child was asked to look at the model of the experimental enclosure. Participants were told that they were looking at "a little room just like the big one they had just played a game in" made by the experimenter. The similarities between the two rooms were pointed out (both had four small boxes, one blue wall and three grey walls). Participants were then asked if they could point out the little box in the small room that was in the same place as the big box in the big room where the experimenter was hiding his/her toy. Participant responses were recorded and they and their parents were thanked for their participation. At this point, the experimenter reviewed the videotape of the experimental trials and recorded a hard copy of the data on individual data sheets.

Therefore, although video data from several of the participants is unavailable due to accidental destruction of a videotape all hard copies of the data remained intact.

Results

It was predicted that imposing a delay between the time when participants stopped turning and began searching would result in increased search accuracy. The data supported this prediction. Participant age did not play a role in this effect. An analysis testing for patterns in errors made by participants was completed and revealed no discernable patterns in the location of errors made by participants in any of the experimental conditions. An analysis of response latencies for the disoriented no delay conditions did not reveal a significant difference between the correct and incorrect responses. A similar analysis could not be completed for the oriented no delay condition since there were very few errors. Analysis of the model task revealed that a participant's ability to successfully complete this task is affected only by his or her age - 4 year olds were more accurate than their three year old counterparts. Success with this task was not affected by degree of accuracy on the reorientation task or experimental condition.

Reorientation Task

Treatment Effects

Table 1 contains the means and standard deviations for response accuracy where response accuracy is reported as the percentage of correct container choice over all four trials and treatment conditions. A 2 x 2 (orientation x delay) independent measures ANOVA indicated a significant main effect of orientation, F $(1, 18) = 10.85$, $MSE = 283.57$, $p < .05$. Accuracy was greater in oriented participants (M=86%, SD=17%) than in disoriented participants (M=61%, SD=23%). The main effect of delay was also significant, F $(1, 18) = 8.02$, MSE = 283.57, $p < .05$. Participants in the delay conditions (M=85%, SD=17%) were more accurate than those in the no delay conditions (M=65%, SD=25%). The interaction effect approached significance, F $(1, 18) = 3.64$, $MSE = 283.57$, $p = .07$. In dealing with proportional or percentage data using ANOVA models there is often a relationship between the group mean and the group variance. To guard against problems of this nature data were transformed using the arcsin transformation and the test was repeated. Results mirrored those of the initial test.

As shown in Figure 1, the data demonstrate a pattern which indicates the presence of the predicted significant interaction between orientation and delay. Therefore an analysis of simple effects was undertaken in order to tease apart the specific relationships in the data. Results of this analysis are shown in Table 2.

As can be seen in Table 2, the disoriented no delay group differed significantly from all other treatment conditions which did not differ from each other. This is consistent with the experimental hypothesis which maintained that imposing a delay after disorientation would result in greater accuracy among disoriented children.

Next, the number of correct choices made in each of the experimental conditions were compared with the number of correct choices expected by chance alone. The subsequent chi-square tests revealed the following: χ^2 (1, N = 18) = 2.00, $p > .05$ - Disoriented No Delay; χ^2 (1, N = 26) = 7.54, $p < .05$ - Oriented No Delay; χ^2 (1, N = 21) = 5.76, $p < .05$ - Disoriented Delay; χ^2 (1, N = 23) = 7.35, $p < .05$ - Oriented Delay. See Table 3 for the number of correct choices made in each of the experimental conditions versus the number of correct choices expected by chance alone. This analysis further supports the hypothesis which maintained that imposing a delay after disorientation would result in greater accuracy among disoriented children. Previous analyses compared the participant response accuracies in each of the four conditions against one another. The current analysis answers the question of whether the experimental groups know something about the feature independently of how they perform relative to each other. The results of the chi-square analysis reported above indicate that this is indeed the case for all groups barring the disoriented no delay group. Every group but this one appear to have benefited from the presence of the featural cue. This implies that the delay worked. Those participants in the disoriented delay condition performed significantly better than chance thereby indicating that participants in this condition were able to make use of the featural cue top enhance their performance.

Age Effects

Three and four year olds were compared to determine whether the two age groups demonstrated any differences in terms of their ability to successfully complete the reorientation task. The degree of success achieved by participants on the reorientation task was not affected by their age. There were no age effects, χ^2 (3, N = 22) = 1.47, $p > .05$. See Table 4 for the distribution of responses in the analysis examining reorientation task success versus participant age.

Error Analysis

A series of analyses were completed in an attempt to uncover potential patterns in participant errors. An integral component of an argument supporting Hermer and Spelke's claim that the human mind is organized into a modular network is a very specific pattern of responding. Disoriented participants should make approximately equivalent numbers of choices in the correct and rotationally equivalent search locations while making few, if any, errors at the other corners. We did not find this pattern of errors. That is, there was no discernible pattern of errors in the oriented no delay condition (χ^2 (1, N = 4) = 1.00, $p > .05$), the disoriented no delay condition (χ^2 (1, N = 13) = .08, $p > .05$), or the disoriented delay condition (χ^2 (1, N = 4) = .00, $p > .05$). Errors in all conditions (aside from the oriented delay condition which could not be similarly analysed due to an insufficient number of errors) were evenly distributed. See Figure 2 for the distribution of choices made in each search location for each of the four experimental conditions.

Latency Analysis

Latencies (period between the time when a participant was instructed to stop turning and began searching) of the oriented no delay and disoriented no delay conditions were examined. A paired samples t-test comparing the mean latencies of the correct and incorrect responses of the disoriented no delay participants did not reveal a significant difference in the latencies of correct and incorrect responses. The time taken by participants before making a correct ($\underline{M}$ = 5.09 sec, $\underline{SD}$ = 4.60) or incorrect ($\underline{M}$ = 2.15 sec, $\underline{SD}$ = .83) response was not significantly different, $\underline{t}$ (3) = 1.39, $\underline{p}$ >.05. Due to accidental destruction of one of the videotapes used to document the experiments data from two of the six participants in this experimental condition could not be included in the analysis. A similar test examining the latencies of correct and incorrect responses in the oriented no delay condition was not completed as there were too few incorrect responses. However, means and standard deviations of the latencies of correct and incorrect responses in the oriented condition are presented in Table 5 and show that response latencies were higher for incorrect as opposed to correct choices.

Model Task

Treatment Effects

Participant accuracy on the model task was not affected by whether they were in the oriented or disoriented conditions, χ^2 (1, $\underline{N}$ = 22) = 0.75, $\underline{p}$ > .05. See Table 5 for the distribution of responses in the analysis examining the effects of orientation on model task accuracy. A separate chi-square test was carried out to determine whether there was a significant effect of delay implementation on model accuracy. This analysis also failed to find significant results. Whether a participant was in the delay or no delay conditions had no effect on model accuracy, χ^2 (1, N = 22) = 0.13, $p > .05$. See Table 7 for the distribution of responses in the analysis examining the effects of delay implementation on model accuracy. The chi-square test requires an expected value of at least 5 in each cell. This expectation was not met in the results reported above. Therefore, the values reported here reflect Yates' correction for continuity.

Effects of Reorientation Accuracy

A third chi-square was carried out to examine potential effects of reorientation task response accuracy on model task response accuracy. Model accuracy was not affected by accuracy on the reorientation task, χ^2 (3, N = 22) = 3.19, $p > .05$. See Table 8 for the distribution of responses in the analysis examining the effects of reorientation task performance on model accuracy.

Age Effects

Finally, the effect of age on model accuracy was examined. Model accuracy was significantly affected by participant age, χ^2 (1, N = 22) = 4.40, $p < .05$. Four year olds were more accurate than three year olds on the model question. The chi-square test requires an expected value of at least 5 in each cell. This expectation was not met in the results reported above. Therefore, the values reported here reflect Yates' correction for continuity. See Table 9 for the distribution of responses in the analysis examining model accuracy versus participant age. However, while the three year olds experienced difficulty in completing the model task (reasons for which will be discussed in the general discussion) it is clear that four year olds did not experience similar difficulties. Indeed, when one examines the (admittedly small) remaining sample it is clear that four year olds experienced little difficulty correctly identifying the model container that corresponded to the container used to hide their toy in the reorientation task. As predicted, this proved to be the case even when participants, such as those in the disoriented condition, performed with poor search accuracy in the reorientation task. Please see highlighted portions of Appendix B for raw data from four year old participants.

Discussion

Reorientation Task

It was predicted that imposing a delay of approximately 10 seconds between the time when participants stopped turning and began searching would result in increased search accuracy. Specifically, it was hypothesized that participants in the oriented conditions would perform with greater accuracy than those in disoriented conditions and that participants in the delay conditions would perform with greater accuracy than those in the no delay conditions. Both hypotheses were confirmed in the ensuing analysis. It was also anticipated that the data would reveal a significant interaction between these two variables (orientation versus delay) thereby revealing a clear difference between the disoriented no delay group and all other groups. For the most part, the present results supported this prediction. While the interaction was not statistically significant, it approached significance ($p = .07$) and the anticipated pattern appeared to be present. The resulting power analysis indicated that additional participants (approximately 38 per group) would have been necessary to achieve the desired interaction effect (Keppel, 1991). Post-hoc analyses were carried out and revealed that participants in the disoriented no delay condition performed with significantly decreased search accuracy relative to those in the disoriented delay, oriented no delay, and oriented delay conditions, which did not differ from each other.

The data were further analysed to determine wether participant response accuracy in each of the experimental conditions significantly differed from chance performance. The results were affirmative. That is, all groups but the disoriented no delay group performed better than predicted by chance. Every group but this one appeared to have benefited from the presence of the featural cue. It is suggested that the present results indicate that providing children with a small amount of extra time allows them to regain their sense of heading and direction. In turn, they are able to make better use of all the information (both geometric and featural in nature) in their environments to reorient and locate a hidden target.

Age Effects

Subsequent analyses probing for potential age effects revealed that there were no such effects. The degree of success achieved by participants on the reorientation task was not affected by their age.

Error Analysis

An integral component of the argument for the existence of the geometric module responsible for reorientation activity is a very specific pattern of errors that should occur. Specifically, disoriented participants should perform at chance levels choosing the correct and incorrect locations with relatively equal frequency. In addition, the great majority of these errors must occur at the location that is the rotational equivalent of the correct location. The rotational equivalent has exactly the same geometric properties as the correct location. It differs only in terms of featural information. An analysis of participant errors did not reveal such a pattern in any of the experimental conditions - most notably in the disoriented no delay condition. Participant errors were evenly distributed amongst the three incorrect locations. This may serve to cast further doubt on the modular explanation of reorientation behavior. On the other hand, this result also questions the validity of the present experiment. All other accounts of the reorientation abilities of young children have demonstrated this very particular pattern of errors. The fact that this was not the case in the present study may indicate that our results reflect, in part or in full, a flaw (s) in the study's design as opposed to valid effects. Further study is necessary to determine whether the results of the present study were affected by some unknown factor. For example, our results may have been affected by the dimensions of our rectangular enclosure. While the dimensions of the experimental enclosure used in the present study were comparable to those used in previous studies, they were not identical. The current enclosure formed an elongated rectangle as compared to the shape of enclosures used in the past. This may have inadvertently affected results in ways not examined in the literature to date. Of course it should be kept in mind that this discussion is purely speculative. No conclusive tests have been undertaken to determine whether the shape of the rectangle has a definitive effect on performance in reorientation tasks.

While the results of the current study make it clear that imposing a delay is an effective means of improving multiple cue use by young children in reorientation activities, the current explanation is not conclusive. The delay may have worked because young participants need extra time to fully reorient. However, it may be that the delay allowed children the necessary time to focus and pay attention to the task at hand. Perhaps young children simply need time to remember that they have a purpose. They are in this situation to solve a problem (find the hidden toy). The extra time may allow them to focus on the problem and more actively engage their problem solving skills to remember and use all pertinent information that is available in the testing environment.

This is a feasible explanation if one considers children as novice (as compared to adults) in dealing with the demands of a reorientation/object localization task. Adults, by sheer virtue of the time they have spent roaming the earth over the course of their lives would necessarily have a great deal of experience in solving reorientation/object localization tasks. As such, they can be considered experts in this field. Experts often solve problems automatically - they require less time than a novice to engage in the complex judgements and inferences that are required to solve the problem at hand (Flavell et al., 2002; Glasser & Chi, 1988; Gobbo & Chi, 1986; McPherson & Thomas, 1989). Thus children, as novices with these types of tasks as compared with adults, may require extra time to successfully solve the problem using all pertinent information.

In addition, expert knowledge about a given area has the potential to speed-up problem solving by freeing mental capacity. When the necessary data used to solve a problem are very familiar, as they are in the case of the expert, they require less mental capacity. This serves to effectively increase short term memory capacity. This means that more information can be held in focal attention at the same time so that the information and its different sources can be compared and related to one another (Flavell et al., 2002; Glasser & Chi, 1988; Gobbo & Chi, 1986; McPherson & Thomas, 1989). It is highly probable that as novices in dealing with reorientation/object localization tasks children, if not given sufficient time, will depend only on geometric information simply because they do not have enough short term memory capacity to hold, compare, and process all of the information that is at their disposal. Or, as is the case in the current study, children may not make successful use of any of the information in their environments.

The delay may also have given children more time to focus their vision after disorientation, possibly providing them with the opportunity to gain a fuller appreciation of all the information available to them in the experimental enclosure.

This, in turn, may have allowed them to pay attention to and use featural information that had not been used by participants of previous studies. However, this explanation is unlikely given the fact that the visual system of human children appears to reach adult-like maturity by 12 months of age (Flavell et al., 2002; Kellman & Arterberry, 1998; Hainline, 1998). Thus, children who participated in the present study (none of whom were under the age of 3 years) should not have experienced any difficulties in focussing after disorientation. There is no reason to suspect that they would require extra time to focus their vision.

Latency Analysis

Throughout the course of the experiment it became apparent that participants in the no delay conditions would, at times, impose their own delay before beginning their search. That is, they would pause after they were instructed to stop turning, look around the room, and then begin their search. Subsequently, it was anticipated that an examination of the latencies (period between the time when a participant was instructed to stop turning and began searching) of the disoriented no delay and oriented no delay conditions would reveal a pattern supporting the idea that imposing a delay after disorientation would increase search accuracy. It was thought that participants would have longer latencies (which were the result of a kind of self-imposed delay) when making correct choices than when making incorrect choices.

Results for the disoriented no delay condition did not support this prediction.

However, it should be noted that due to accidental destruction of one of the videotapes used to document the experiments not all of the already limited number of participants could be included in this analysis. In addition, a power analysis revealed that approximately 72 participants would have been necessary to achieve significant results with this analysis (Keppel, 1991). Obviously, we did not come close to approaching this number. However, it should be noted that the mean length of the self-imposed delay (5.09 sec) was approximately half as long as the experimental delay. Perhaps this is simply not enough time to achieve the desired result of multiple cue use for reorientation regardless of the number of subjects.

A similar analysis for the oriented condition could not be completed as there were too few incorrect observations. Interestingly, the pattern shown by the limited data that is available indicates that participants in this condition actually had longer latencies when making incorrect as opposed to correct choices. This is in direct opposition to what would be expected given the fact the earlier results indicated that imposing a delay improves performance. From this line of thinking one would not assume that individuals would self-impose longer delays for incorrect choices. However, with such a small number of observations conclusive statements about this peculiar outcome is not possible.

Model Task

A series of analyses on the model task were completed. Results confirmed the prediction that children who performed poorly in the disoriented no delay condition would then perform accurately on the model task indicating that they were indeed aware of the hiding location of their toy. Success with the model task was not significantly affected by either of the experimental manipulations (orientation, delay implementation) nor by success with the reorientation task. Participants were no better at the model task as a result of being oriented or disoriented, delayed or not delayed, highly accurate or poorly accurate on the reorientation task.

Age was the only significant factor affecting successful completion of the model task. As it turned out, three year old participants experienced a larger degree of difficulty with this task. The three year olds' grip on representational thought is still somewhat tenuous. That is, different manipulations can interfere with a three year old's ability to "dually represent" an object as both an object in and of itself as well as a symbol of the referent object. Apparently, increasing an object's nature as an object in and of itself decreases a three year old's ability to also use that object as a symbol of something else (DeLoache, 1987; DeLoache, Miller, & Rosengren, 1997; DeLoache & Smith, 1999; Flavell et al., 2002).

Further examination of this task has indicated that it is highly likely that the wording of the question children were asked when they were presented with the model task may have contributed to our results. Participants were asked to "look at the little room" that the experimenter had built that was "just like the big room" they had just vacated. The wording of the model presentation very likely caused the children to think of our enclosure mock up as more than a model. It is likely that it also encouraged them to think of the mock up as a little room in and of itself that just happened to be similar to the bigger room in which they had just played a game. Thus, the "objectness" of the model had been increased thereby undermining the ability of our younger participants to perform successfully on the model task.

Conclusion

As previously noted, when experimenting with children, situations often arise which require slight modifications to experimental methods and procedures to suit the needs and abilities of younger populations. Overall, the present data suggest the past experimentation in the area of early childhood spatial reorientation has not fully considered the cognitive capacity of the participants under examination. A number of experimental variables are in need of examination. The present study examined the effect of allowing children extra time before beginning to search for a hidden object. Resulting data suggest that this was an effective manipulation. It is suggested that the delay allowed children to take the opportunity to fully regain their sense of heading and direction before embarking on their search. Further study examining competing alternative explanations for this result is necessary before making conclusive statements.

While the results of the present study are promising, further study is necessary and would contribute to a fuller understanding of the reorientation processes of young children. For example, research continuing in the line of the latency analyses conducted in the current study could provide further insight into the idea that children need more time to reorient than their adult counterparts. Perhaps in the future experimental procedures could be altered in such a way as to encourage children to exercise better judgement under these types of circumstances so that they are able to more successfully take the time they need to fully reorient before beginning to search. In addition, while much research has been generated regarding the types of cues used by children in their efforts to reorient there is very little research available discussing the cognitive structures underlying this behavior that need to mature to allow children to reach adult like performance.

The present study also had a number of limitations. The limited number of participants available to take part in the current study was problematic on several grounds. A larger study using a larger pool of participants may lead to more robust results. Another limitation of the current study was the lack of a pilot study. It is likely that more initial practice interacting with participants and exercising the procedures would have resulted in fewer cases of discarded data. In the present situation, however, this was not possible due the restricted number of participants.

However, aside from noted limitations, the results of the present study show a great deal of promise. The finding that imposing a 10 second delay between the time when participants stop turning and begin searching improves multiple cue use not only adds to the existing knowledge base in this area but also serves to cast further doubt on any claims regarding the existence of a geometric module for reorientation in human spatial representations. An impenetrable, encapsulated module like that described by Hermer and Spelke (1994; 1996) requires that disoriented children be incapable of using featural landmarks to reorient and locate a hidden object under all circumstances. The work of Learmonth et al. (2001; 2002) and the present research have both demonstrated conditions under which children demonstrate this very behaviour with apparent ease.

With this said, one must take care to avoid taking the current results past their boundaries. That is, the present results only challenge claims of a geometric module in human spatial representation. They do not call into question the theories and arguments supporting the concept of modular organization of other aspects of human or animal behaviour as a whole. However, at this point, modularists are challenged with the task of providing specific, testable descriptions of these innate, domain-specific mechanisms designed to solve different problems faced by organisms in their natural environments. Until that time modularity remains simply an intriguing idea with the possibility of generating potentially exciting research.

References

Baillargeon, R. (1987). Object permanence in 3 and 4 month old infants. Cognitive Development, 23, 655-664.

Brodbeck, D. R. (1994). Memory for spatial and local cues: A comparison of a storing and a non-storing species. Animal Learning and Behavior, 22, 119-133.

Bukatko, D., & Daehler, M.W. (1995) Child Development. Boston: Houghton Mifflin Company.

Cheng, K. (1986). A purely geometric module in the rat's spatial representation. Cognition, 23, 149-177.

Cheng, K. (1989). The vector sum model of pigeon landmark use. Journal of Experimental Psychology: Animal Behavior Processes, 15, 366-375.

Cheng, K. (1994). The determination of direction in landmark-based spatial search in pigeons: A further test of the vector sum model. Animal Learning and Behavior, 22, 291-301.

Cheng, K. & Sherry, D. (1992). The use of edges and distances to represent spatial positions. Journal of Comparative Psychology, 106, 331-341.

Cheng, K. & Spetch, M. L. (1998). Mechanisms of landmark use in mammals and birds. In S. Healy (Ed.) Spatial representation in animals (pp. 1-17). London: Oxford University Press.

Collett, T. S., Cartwright, B.A., & Smith, B.A. (1986). Landmark learning and visuo-spatial memories in gerbils. Journal of Comparative Physiology A, 158, 835-851.

Cosmides, L. & Tooby, J. (1987). From evolution to behaviour: Evolutionary psychology as the missing link. In J. Dupre (Ed.), The latest on the best: Essays on evolution and optimality (pp.277-306). Cambridge, MA: Cambridge University Press

Cosmides, L., & Tooby, J. (1994). Origins of domain specificity: The evolution of functional organization. In L. A. Hirchfeld & S. A. Gelman (Eds.), Mapping the mind: Domain specificity in cognition and culture (pp.85-116). Cambridge, MA: Cambridge University Press.

Cosmides, L. & Tooby, J. (1995). Mapping the evolved functional organization of mind and brain. In M. S. Gazzaniga (Ed.), The cognitive neurosciences (pp. 1185-1197). Cambridge, MA: Cambridge University Press.

Cosmides, L. & Tooby, J. (1997, January 13). Evolutionary psychology: A primer. Retrieved September 15, 2000 from the World Wide Web: http://www.psych.ucbs.edu/research.cep/primer.html

Cosmides, L. & Tooby, J. (2000). Evolutionary psychology and the emotions. In M. Lewis & J. M. Haviland-Jones (Eds.), Handbook of emotions (2nd ed.). Cambridge, MA: MIT Press.

DeLoache, J. S. (1986). Memory in very young children: Exploitation of cues to the location of a hidden object. Cognitive Development, 1, 123-137.

DeLoache, J. S. (1987). Rapid change in the symbolic functioning of very young children. Science, 238, 1556-1557.

DeLoache, J. S., & Brown, A. L. (1997). Looking for Big Bird: Studies of memory in very young children. In M. Cole and Y. Engestroem (Eds.), Mind, culture, and activity: Seminal papers from the laboratory of Comparative Human Cognition. NY: Cambridge University Press.

DeLoache, J. S., & Smith, C. M. (1999). Early symbolic representation. In I. E. Sigel (Ed.), Development of mental representation: Theories and applications. New Jersey: Earlbaum.

DeLoache, J. S., Miller, K. F., & Rosengren, K. (1997). The credible shrinking room: Very young children's performance in symbolic and non-symbolic tasks. Psychological Science, 9, 205-210.

Deocampo, J. A., & Hudson, J. A. (2003). Reinstatement of 2-year-olds' event memory using photographs. Memory, 11, 13-25

Fernald, A., Swingley, D., & Pinto. J. P. (2001). When half a word is enough: Infants can recognize spoken words using partial phonetic information. Child Development, 72, 1003-1015.

Fivush, R., & Hamond, N. R. (1989). Time and again: Effects of repetition and retention interval on 2 year olds' event recall. Journal of Experimental Child Psychology, 11, 259-273.

Flavell, J. H., Miller, P. H., & Miller, S. A. (2002). Cognitive development (4th ed.).

New Jersey: Pearson Education.

Gallistel, C. R. (1990). The organization of learning. Cambridge: MIT Press.

Gelman, R. (1969). Conservation acquisition: A problem of learning to attend to relevant attributes. Journal of Experimental Child Psychology, 7, 31-33.

Glaser, R., Chi, M.T.H., Farr, M. J. The nature of expertise. Hillsdale, NJ: Erlbaum.

Gobbo, C., & Chi, M.T.H. (1986). How knowledge is structured and used by expert and novice children. Cognitive Development, 1, 221-237.

Gould-Beierle, K. & Kamil, A. C. (1996). The use of local and global cues by Clark's Nutcrackers. Animal Behavior, 52, 519-528.

Gouteux, S. & Hermer, L. (2001). Children's use of geometry and landmarks to reorient in an open space. Cognition, 81, 119-148.

Gouteux, S., Thinus-Blanc, C., & Vauclair, J. (2001). Rhesus monkeys use geometric and non-geometric information during a reorientation task. Journal of Experimental Psychology: General, 505-519.

Hainline, L. (1998). The development of basic visual abilities. In A. Slater (Ed.), Perceptual development: Visual, auditory, and speech perception in infancy. Hove, UK: Psychology Press.

Hammond, N. R., & Fivush, R. (1991). Memories of Mickey Mouse: Young children recount their trip to Disneyworld. Cognitive Development, 6, 433-448.

Hermer, L. (1997). Internally coherent spatial memories in a mammal. Neuroreport, 8, 1743-1747.

Hermer, L. & Spelke, E. (1994). A geometric process for spatial reorientation in young children. Nature, 370, 57-59.

Hermer, L. & Spelke, E. (1996). Modularity and development: The case of spatial reorientation. Cognition, 61, 195-232.

Hermer-Vazquez, L., Spelke, E. S., Katsnelson, A. S. (1999). Sources of flexibility in human cognition: Dual-task studies of space and language. Cognitive Psychology, 39, 3-36.

Kellman, P. J., & Aterberry, M.E. (1998). The cradle of knowledge: Development of perception in infancy. Cambridge: MIT Press.

Kelly, D. M., Spetch, M. L., & Heth, C. D. (1998). Pigeons encoding of geometric and featural properties of a spatial environment. Journal of Comparative Psychology, 112, 259-269.

Keppel, G. (1991). Design and analysis: A researcher's handbook. New Jersey: Prentice Hall.

Learmonth, A. E., Nadel, L., & Newcombe, N. S. (2002). Children's use of landmarks: Implications for modularity theory. Psychological Science, 13, 337-341.

Learmonth, A. E., Newcombe, N. S., & Huttenlocher, J. (2001). Toddlers' use of metric information and landmarks to reorient. Journal of Experimental Child Psychology, 80, 225-244.

Margules, J. & Gallistel, C. R. (1988). Heading in the rat: Determination by environmental shape. Animal Learning and Behavior, 16, 404-410.

McPherson, S.L., & Thomas, J.R. (1989). Relation of knowledge and performance in boys' tennis: Age and expertise. Journal of Experimental Child Psychology, 48, 190-211.

Newcombe, N., Huttenlocher, J., Drummey, A. B., & Wiley, J. G. (1998). The development of spatial location coding: Place learning and dead reckoning in the second and third years. Cognitive Development, 13, 185-200.

Pinker, S. (1997). How the mind works. NY: Norton

Redish, A. D. (1999). Beyond the cognitive map: From place cells to episodic memory. Cambridge, MASS: MIT Press.

Spetch, M. L., Cheng, K., MacDonald, S. E. (1996). Learning the configuration of a landmark array: I. Touch screen studies with pigeons and humans. Journal of Comparative Psychology, 110, 55-68.

Spetch, M. L., Cheng, K., & Mondloch, M. V. (1992). Landmark use by pigeons in a touch screen spatial search task. Animal Learning and Behavior, 20, 281-292.

Vallortigara, G., Zanforlin, M., & Patsi, G. (1990). Geometric modules in animals' spatial representations: A test with chicks. Journal of Comparative Psychology, 104, 248-254.

Wang, R. F., Hermer, L., & Spelke, E. (1999). Mechanisms of reorientation and object localization by children: A comparison with rats. Behavioral Neuroscience, 113, 475-485.

Zoladek, L, & Roberts, W. A. (1978). The sensory basis of spatial memory in the rat. Animal Learning and Behavior, 6, 77-81.

Table 1

Descriptive Statistics for the Observed Response Accuracy (% of Correct Container Choice over all Four Trials) in each Treatment Condition

	Delay Implementation		
Orientation	Delay	No Delay	Overall
Oriented			
M	90.00	83.33	86.36
SD	13.69	20.41	17.19
n	5	6	11
Disoriented			
M	80.00	45.83	61.36
SD	20.92	10.21	23.35
n	5	6	11
Overall			
M	85.00	64.58	73.86
SD	17.48	24.91	23.75
n	10	12	22

Table 2

Critical F Values for All Possible Pairwise Comparisons for the Interaction Between Orientation and Delay

	Oriented No Delay	Disoriented No Delay	Oriented Delay	Disoriented Delay
Oriented No Delay	–	F = 14.88*	F = 0.43	F = 0.11
Disoriented No Delay	–	–	F = 18.76*	F = 11.23*
Oriented Delay	–	–	–	F = 0.88
Disoriented Delay	–	–	–	–

* Significant at .05 level

Table 3

Actual Versus Chance Performance (the Number of Correct Choices in each of the Experimental Conditions Versus the Number of Correct Choices Expected by Chance Alone

	Disoriented No Delay	Oriented No Delay	Disoriented Delay	Oriented Delay
Number of Correct Choices	12	20	16	18
Number of Correct Choices Expected by Chance	6	6	5	5

Table 4

Reorientation Accuracy (% of Correct Responses Across Trials) Versus Participant Age.

Age	25%	50%	75%	100%
3 yrs	1	4	2	6
4 yrs	0	3	4	2

Table 5

Descriptive Statistics for the Response Latencies of the Oriented No Delay Condition.

	Response	
	Correct	Incorrect
M	1.52	3.44
SD	.78	2.08
n	13	3

Table 6

Model Accuracy Versus Participant Orientation (Number of Incorrect and Correct Responses in the Oriented and Disoriented Conditions)

Model	Oriented	Disoriented
Correct	8	5
Incorrect	3	6

Table 7

Model Accuracy Versus Delay Implementation (Number of Incorrect and Correct Responses in the Delay and No Delay Conditions)

Model	No Delay	Delay
Correct	8	5
Incorrect	4	5

Table 8

Reorientation Task Accuracy (% Correct Corner Choice) Versus Model Task Performance (Number of Correct and Incorrect Responses).

Model	25%	50%	75%	100%
Correct	1	4	2	6
Incorrect	0	3	4	2

Table 9

Model Accuracy (Number of Correct and Incorrect Responses) Versus Participant Age.

Model	3 years	4 years
Correct	3	10
Incorrect	7	2

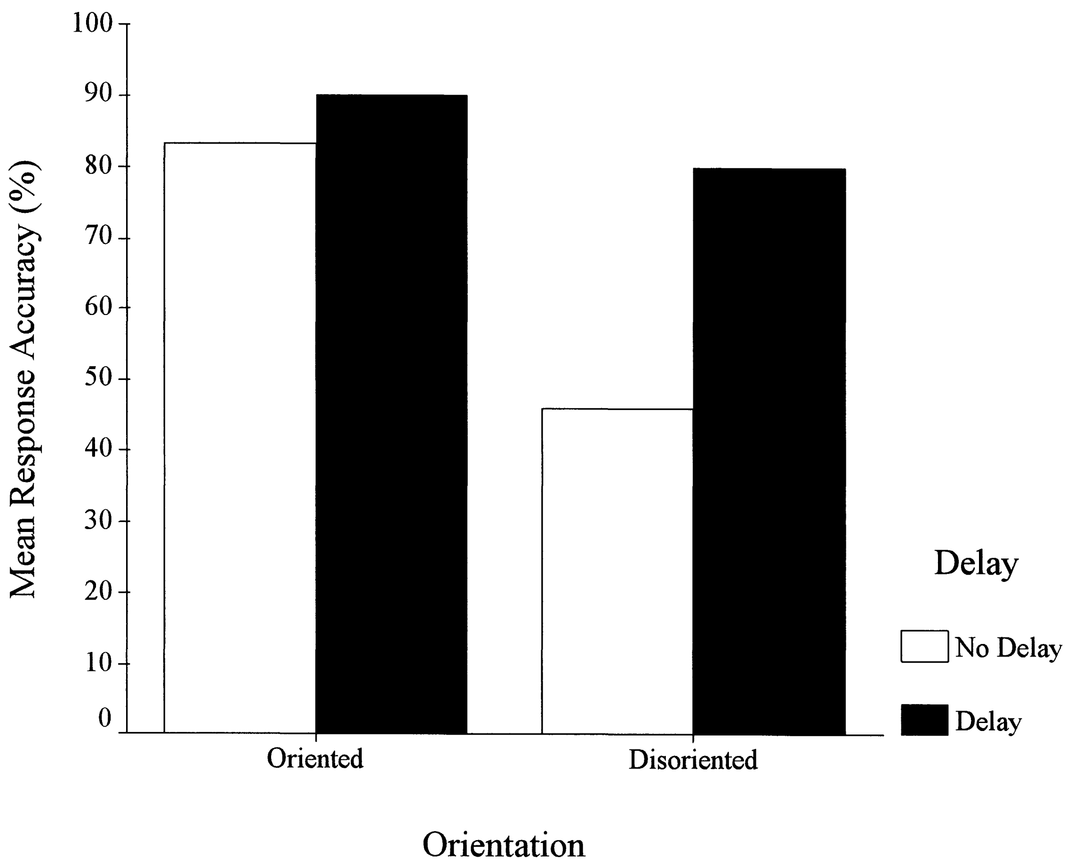

Figure 1. Mean response accuracy (% correct choices) for the four experimental conditions.

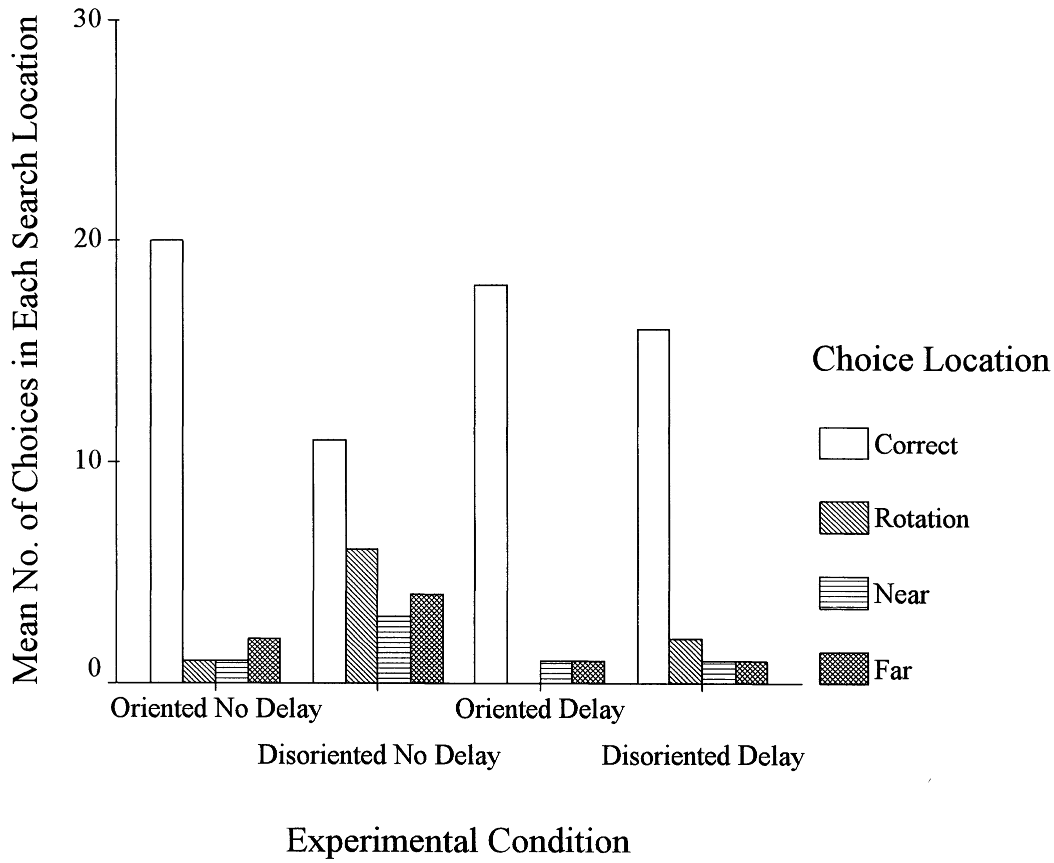

Figure 2. Mean number of choices at each of the four search locations (Correct Corner, Rotational Equivalent, Near Corner and Far Corner) in each experimental condition. See diagram below for layout of choice locations.

Correct	Far
Near	Rotation

Appendix A

Participant Recruitment Letters
Consent Form

Dear Parent (s),

My name is Andrea Pike, I am a Masters student in Psychology at Memorial University of Newfoundland and am currently doing research for my Masters thesis under the supervision of Dr. Gerard Martin. I am writing to request the participation of your child in my project.

I want to see the type of information (e.g. shapes, colors) young children use to help them remember where objects are after children become disoriented. Disorienting the child simply involves having him/her slowly turn in place 4 times with his/her eyes covered. The child then has to find a hidden toy. By finding the toy it is thought that the child has reoriented, or figured out which direction he/she was facing relative to where the toy was hidden. I want to know how the child reorient him/herself.

I would like to take a few moments to address some of the concerns you may have regarding your decision to volunteer your child for this project. First of all I would like to stress that the study takes only about **15 minutes** and most children enjoy themselves in what is essentially a game of hide-and-go-seek. I realize that your schedule may be quite hectic. Please know that I will make every effort to make **flexible scheduling arrangements** that work best for you. In addition, **free parking in a convenient location** is available. Finally, as a token of our appreciation your child will receive a certificate bearing his or her name indicating that he or she participated in a research study at MUN that helped to broaden the existing knowledge base regarding spatial learning. This will be sent to you along with an outline of the study's results after the study has been completed.

The experiment will be conducted at Memorial University of Newfoundland. Your child will not be discomforted in any way or coerced to participate if he or she does not want to take part. A common practice that has developed for these types of studies is the use of video taping to help the researcher follow children's searching behavior (e.g. where they searched, what wall they were facing when they started or finished, etc.). After the tapes have been watched they will be destroyed. The results of the study are confidential and no child will be identified in any public report of the results.

Thanks for your consideration. If you wish to allow your child to participate in this study please fill out the attached consent form and return it to your child's preschool/daycare at your earliest convenience. There are no consequences of a choice not to participate and you are free to withdraw your child from participation at any time. This project has been approved by Memorial University's Interdisciplinary Committee on Ethics in Human Research.

Andrea Pike, BA. Gerard Martin, Ph.D

Dear Parent (s),

Hello again, my name is Andrea Pike and I am a Master's student at Memorial University of Newfoundland. About a month ago I wrote you a letter asking for your child's participation in my research project. Since that time, I have received several letters of consent, however, I am still in need of your participation. I would like to take this opportunity to remind you of the study and what will be involved. I have included a copy of the original letter which highlights the procedures to be used in the study. In addition, I would like to address some of the concerns which may be causing your hesitation to volunteer your child for this research.

First of all I would like to stress that the entire study will only require approximately one half hour of your time. I realize that your schedule may be quite hectic. Please know that I will make every effort to make flexible scheduling arrangements that work for you. In addition, while not indicated in the original letter, your child will receive a certificate bearing his or her name indicating that he or she participated in a research study at Memorial University of Newfoundland that helped to broaden the existing knowledge base regarding spatial learning. This will be sent to you along with an outline of the study's results after the study has been completed.

If you have already agreed to participate, I thank you for your support and I will be contacting you within the next week to make scheduling arrangements.

In the event that you have any questions regarding this project please feel free to contact me at 726-3604 or email me at ______________

Once again I ask that you consider my request and thank you for your time.

Sincerely,

Andrea Pike, BA

Gerard Martin, Ph.D.

Dear Parent (s),

Hello, my name is Andrea Pike and I am a Master's student at Memorial university of Newfoundland. Some time before the Christmas holidays I wrote asking for your child's participation in the research project I am in the process of completing in order to obtain my degree. Since that time I have received approximately 20 letters of consent. However, I am still in need of your participation. In order for my project to be a success I must have the participation of approximately 45 participants. I would like to take this opportunity to remind you of the study and what will be involved. I have included a copy of the original letter which highlights the procedures to be used in the study. In addition, I would like to address some of the concerns which may be causing your hesitation to volunteer your child for this project.

First of all I would like to stress that the study takes only about **15 minutes** and most children enjoy themselves in what is essentially a game of hide-and-go-seek. I realize that your schedule may be quite hectic. Please know that I will make every effort to make **flexible scheduling arrangements** that work best for you. In addition, **free parking in a convenient location** is available. Finally, while not indicated in the original letter, your child will receive a certificate bearing his or her name indicating that he or she participated in a research study at MUN that helped to broaden the existing knowledge base regarding spatial learning. This will be sent to you along with an outline of the study's results after the study has been completed.

If you have any questions please contact me by phone: 726-3604 or by email: ______________ If you choose to allow your child to take part in this project please fill out and return the attached consent form and return it to the daycare.

For those who have already participated, I thank you sincerely for you cooperation. If you know someone who may be interested in taking part, please feel free to pass along a copy of the original letter and my contact information.

Thank you for your time and consideration.

Andrea Pike, BA Dr. Gerard Martin, Ph.D

Declaration of Consent

Please detach and return this portion of the document to your child's daycare/pre-school.

I consent to my child ______________________________________ (please print name) participating in this study on the reorientation and object localization processes of young children conducted by Andrea Pike and her supervisor, Dr. G. Martin, according to the procedures that have been explained above.

Child's Birth Date: ______________________________
Parent's Name (printed): __________________________
Parent's Phone Number: __________________________*
Parent's Signature: ______________________________
Date: ____

*Your telephone number is required in order to make scheduling arrangements. If you would like to contact me for any reason please feel free to do so by telephone at: 726-3604 or email me at _____________

Appendix B

Raw Data

Sex	Age	Discarded?	Condition	Trial	Good/Bad	Response	Error Loc	Parent?	Latency	Model
M	54 mos	No	OND	1	bad	-	-	Not Present	-	✓
				2	bad	-	-	Not Present	-	
				3	bad	-	-	Not Present	-	
				4	good	✓	-	Not Present	1.06	
				5	good	✓	-	Not Present	0.87	
				6	good	✓	-	Not Present	0.88	
				7	good	✓	-	Not Present	0.66	
F	38 mos	No	OND	1	good	×	Far Corner	Not Present	5.84	×
				2	bad	-	-	Not Present	-	
				3	good	✓	-	Not Present	1.94	
				4	good	✓	-	Not Present	0.89	
				5	good	✓	-	Not Present	1.32	
M	53 mos	No	OND	1	good	✓	-	Present	1.99	✓
				2	good	✓	-	Present	1.28	
				3	good	✓	-	Present	1.72	
				4	good	✓	-	Present	1.06	
F	36 mos	No	OND	1	good	✓	-	Not Present	3.49	✓
				2	good	✓	-	Not Present	2.18	
				3	good	×	Near Corner	Not Present	2.18	
				4	good	×	Rotational	Not Present	2.29	
F	52 mos	No	OND	1	good	✓	-	Not Present	-	✓

				2	good	✓	-	Not present	-	
				3	good	✗	Far Corner	Not present	-	
				4	good	✓	-	Not Present	-	
M	56 mos	No	OND	1	good	✓	-	Not Present	-	✓
				2	good	✓	-	Not Present	-	
				3	good	✓	-	Not Present	-	
				4	good	✓	-	Not Present	-	
M	57 mos	No	DND	1	good	✗	Rotatio nal	Not Present	-	✓
				2	good	✓	-	Not Present	-	
				3	good	✓	-	Not Present	-	
				4	good	✗	Far Corner	Not Present	-	
F	38 mos	No	DND	1	good	✓	-	Not Present	-	✗
				2	good	✓	-	Not Present	-	
				3	good	✗	Rotatio nal	Not Present	-	
				4	good	✗	Far Corner	Not Present	-	
M	39 mos	No	DND	1	bad	-	-	Not Present	-	✗
				2	good	✓	-	Not Present	4.64	
				3	bad	-	-	Not Present	-	
				4	bad	-	-	Not Present	-	
				5	good	✓	-	Not Present	2.84	
				6	good	✗	Rotatio nal	Not Present	2.75	

				7	good	✗	Far Corner	Not Present	2.94	
F	57 mos	No	DND	1	bad	-	-	Not Present	-	✓
				2	good	✓	-	Not Present	15.16	
				3	good	✗	Far Corner	Not Present	1.74	
				4	good	✗	Near Corner	Not Present	1.45	
				5	good	✗	Near Corner	Not Present	2.75	
									-	
M	41 mos	No	DND	1	good	✗	Rotatio nal	Not Present	0.56	✗
				2	good	✗	Rotatio nal	Not Present	1.78	
				3	good	✓	-	Not Present	1.93	
				4	good	✓	-	Not Present	2.16	
M	57 mos	No	DND	1	good	✗	Near Corner	Not Present	3.06	✓
				2	good	✗	Rotatio nal	Not Present	2.28	
				3	good	✓	-	Not Present	3.75	
				4	good	✓	-	Not Present	5.16	
M	42 mos	No	OD	1	good	✓	-	Not Present	-	✓
				2	good	✓	-	Present	-	
				3	good	✓	-	Present	-	
				4	good	✓	-	Present	-	
M	48 mos	No	OD	1	good	✗	Near Corner	Not Present	-	✗
				2	good	✓	-	Not Present	-	
				3	good	✓	-	Not Present	-	
				4	good	✓	-	Not present	-	

F	46 mos	No	OD	1	good	✓	-	Not Present	-	✓
				2	good	✓	-	Not Present	-	
				3	good	✓	-	Not Present	-	
				4	good	✓	-	Not Present	-	
F	41 mos	No	OD	1	good	✓	-	Present	-	×
				2	good	✓	-	Present	-	
				3	good	✓	-	Present	-	
				4	good	✓	-	Present	-	
									-	
M	56 mos	No	OD	1	good	✓	-	Not Present	-	✓
				2	good	✓	-	Not Present	-	-
				3	good	✓	-	Not Present	-	-
				4	good	✓	-	Not Present	-	-
M	38 mos	No	DD	1	good	✓	-	Not present	-	×
				2	good	✓	-	Not Present	-	-
				3	good	✓	-	Not Present	-	-
				4	good	×	rotational	Not Present	-	-
F	48 mos	No	DD	1	good	✓	-	Present	-	✓
				2	good	×	far corner	Present	-	-
				3	good	✓	-	Present	-	-
				4	good	×	near corner	Present	-	-
M	46 mos	No	DD	1	bad	-	-		-	-
				2	good	✓	-	Not Present	-	×
				3	good	×	rotational	Not Present	-	-

				4	good	✓	-	Not Present	-	-
				5	good	✓	-	Not Present	-	-
M	53 mos	No	DD	1	good	✓	-	Not Present	-	✓
				2	good	✓	-	Not Present	-	-
				3	good	✓	-	Not Present	-	-
				4	good	✓	-	Not Present	-	-
F	54 mos	No	DD	1	good	✓	-	Not Present	-	✕
				2	good	✓	-	Not Present	-	-
				3	good	✓	-	Not Present	-	-
				4	good	✓	-	Not present	-	-
M	40 mos	Yes	OD	-	-	-	-	Present	-	✕
M	55 mos	Yes	OND	-	-	-	-	Not Present	-	-
F	56 mos	Yes	OND	-	-	-	-	Not Present	-	✕
M	56 mos	Yes	DD	-	-	-	-	Not Present	-	-
M	40 mos	Yes	DD	1	bad	-	-	Present	-	-
F	47 mos	Yes	OD	1	bad	✕	far corner	Not Present	-	✕
				2	bad	✕	rotation al	Not Present	-	-
				3	bad	✕	near corner	Not Present	-	
M	41 mos	Yes	DND	1	bad	✕	near corner	Not Present	-	
M	49 mos	Yes	DND	-	-	-	-	Present	-	-