Wesleyan University The Honors College

Children's use of landmark information in maps

by

Christian Hoyos

Class of 2011

A thesis submitted to the

faculty of Wesleyan University

in partial fulfillment of the requirements for the

Degree of Bachelor of Arts

with Departmental Honors in Psychology

Middletown, Connecticut April, 2011

Acknowledgments

I'd like to thank my advisor, Anna Shusterman, for her wonderful guidance and invaluable insight during this whole process. Thanks to Joanna Schiffman, Sam Melvin, Talia Berkowitz, and everyone in the Blue Lab for making it possible to collect so much data in a short period of time. I greatly appreciate the generosity of the families in the Middletown area for bringing their children into the lab. Thanks to my fellow thesis writers, Julia Leonard and Lauren Feld, for their edits, stress-reducing encouragement, and positive touch. A special thanks to my family (Mom, Dad, Nico, and Grandma), friends, and Chuck, for providing inspiration and loving support. And finally, thanks to the Ronald E. McNair and Howard Hughes Fellowships for funding this research.

Table of Contents

Abstract 4

Introduction 5

Methods 19

Results 25

Discussion 33

Conclusion 51

References 51

Appendix 55

Abstract

Past research has shown that spatial language has been related to navigation abilities in children. The purpose of this study was to explore another symbolic domain beyond language, particularly a map, to assess the influence it may have on landmark use. Children aged 4 to 7 years old were brought into a sparsely marked room with three white walls and one red wall to see how they encode spatial relations among objects with relation to the colored landmark. Children were placed in one of two orders, either receiving a map-to-room or room-to-map task first, where they had to place objects in corresponding locations between the map and the room. Younger children benefited from receiving the map first, suggesting that maps allow for a better understanding of spatial relations compared to initially encoding these relations from within the space. Measures of spatial language were not correlated with performance, suggesting that navigation tasks with maps may be tapping into different cognitive capacities than the disorientation tasks typically used in similar studies.

Children's Use of Landmark Information in Maps

How are maps related to children's landmark use? Landmarks are integral to navigation. Whether it is the position of the sun and stars, or signs in the street, they let the navigator know where they are situated in the world. Maps, too, can aid in navigation by providing an abstract, easily accessed representation of a space.

In cultures that do not possess maps, adults may rely more heavily on landmark information to navigate through their surroundings (Uttal, 2000). In the case of certain groups of aborigines in Australia, mnemonic devices are used to memorize paths solely via landmark information (Lewis, 1976). Adults in the West, however, tend to think about space in map-like form, and take a survey-based perspective of space (Taylor & Tversky, 1992). Both of these examples show that symbolic representations of space, whether they are visual or linguistic, are used across cultures to navigate.

For preschool aged children, both landmark use (Hermer & Spelke, 1994) and map use (Liben & Yekel, 1996; Herman, Shiraki, & Miller, 1985) are difficult. When asked to transfer information between a map and a larger sparsely marked space, children understood the geometric relations between locations in small, but not large, spaces (Vasilyeva & Huttenlocher, 2004). However, it has been shown that maps help with the ability to represent large space (Uttal, 2000; Liben, Kastens, & Stevenson, 2002). Therefore, the goal of this study is to elucidate the relationships between map use and the understanding of spatial relations among objects and landmarks in a large space. Since the spaces used in several studies looking at map use and landmark use were rectangular (Vasilyeva & Huttenlocher, 2004; Hermer & Spelke, 1994), the

current study utilized a square space, without any informative geometry that could have provided additional cues guiding children's navigation.

Given that children are attuned to both landmark and configural information in real space and in maps, we ask 1) are there differences in the cognitive processes associated with encoding a location on a map and identifying the corresponding location in a room, versus encoding locations in real space and identifying the analogous locations on a map? And 2) in using a map depicting a square room with no informative geometry and a single landmark, what kinds of landmark-target relations can children use?

Landmark Use

Children have demonstrated some difficulty using landmarks in rectangular rooms with a single colored wall (Hermer & Spelke, 1994). The same protocol is used across many disorientation studies, where children were brought into a rectangular space where there were containers in each corner in which objects could be hidden. One of the short walls was colored in comparison to the other unmarked walls. This acted as a landmark and made it possible to distinguish between each corner. Children then watched as an object was hidden in one of these corners. Then they were blindfolded, spun around to induce disorientation, and then the blindfold was removed and they were asked to search for the object. Children were attuned to the geometric layout of the space, but could not successfully find the object based on wall color (Hermer & Spelke, 1994).

A closer look reveals differing levels of landmark use. Making direct associations between a landmark and a target (direct landmark use) arises before the

ability to associate landmarks some distance away from a target (indirect landmark use; Lee, Shusterman, & Spelke, 2006; Hoyos, Nuzzi, & Shusterman, 2011). Therefore, directly connecting a landmark to a target may be easier than there being some distance between the two. In the current study, the emergence of these two types of landmark use was assessed, along with children's knowledge of left-right language, given that previous research has shown that left-right language is causally related to children's use of landmarks in various settings (Hermer-Vasquez, Moffet, & Munkholm, 2001; Pyers, Shusterman, Senghas, Spelke, & Emmorey, 2010; Hoyos et al., 2011).

By using symbols such as spatial language, children have been able to use landmarks to navigate. Given that maps are symbolic representations of space, successful map use requires both symbolic and navigational abilities. The current study explored the role of symbolic representations of space in landmark use by assessing how children navigate using a map.

Symbolic Development

How does symbolic development unfold in children? Many argue that symbolic development is one of the most important hallmarks of human cognitive development (DeLoache, 2004; Uttal, Liu, & DeLoache, 2005; Huttenlocher, Vasilyeva, Newcombe, & Duffy, 2008). Children that learn symbols also learn that they have communicative intentions, and that there are reasons behind using certain symbols (Tomasello, 2000). Thus, the use of symbols is related to the understanding of intention.

The processing of intention arises early, as it is necessary at an early age to understand the intentional gaze of the mother during word-learning (Baldwin, 1995) and some research has shown that 6 to 10 month old infants were able to understand the intentions of even non-human social entities (Hamlin, Wynn, & Bloom, 2007).

Understanding intentionality remains important later in development, as it is around age 3 that children become aware of the intentional uses of objects (Wohlgelernter, Diesendruck, & Markson, 2010). In terms of maps, intentionality is important as children need to understand "what the map-maker is telling the map-reader" (Tomasello, 2000, p. 131). Children who understand the intentions behind maps are subsequently better at using maps, and it is around age 4 that this skill emerges (Leyva & Wiser, 2006). In this study, children who could create a map from a layout of objects were subsequently better at reading and processing another map to create an array of objects; this was not true for the reverse, where children who built the array of objects based on a map were not subsequently better at creating a map out of a set of objects. The map-making experience allowed children to be better map-readers.

Could this be related to a realization of intentionality? In making a map, one chooses the features of a space that one wants to convey to the map-reader. Certain features are chosen because they create explicit links between the real-life objects and their referents on the map. Past research has shown that preschool aged children have displayed difficulty with the understanding of irrelevant features of a map, such as thinking that a road was actually painted red because it was represented by a red line on the map (Downs & Liben, 1987). It may be that understanding the intention behind

choosing specific colors for certain representations (e.g., knowing that a red line was intended to highlight a particular route, rather than believing the road is actually red) helps children decide which features are important and which are not.

Models and Maps

This basic processing of intentionality is broadly related to symbol-use. But in order to use a symbol, do children need to know that a given object was *intended* to be used a symbol? Must children learn that a map is intended to guide navigation? Through her extensive research on the symbolic abilities of children, Judy DeLoache has explored the factors that influence how children begin to use and understand symbols. The classic studies that assessed children's ability to associate a symbol to its referent were conducted utilizing a search task with a scale model of a room. Children were shown the relationship between a scale model and a room, both with the same layout of objects and types of furniture, and were then shown where a small stuffed animal was hidden in the model. Then they were asked to find the larger version of the stuffed animal in the actual room. There is a rapid change in performance from 2.5 to 3 years old, where they begin to associate the objects in the model with the objects in the room (DeLoache, 1987).

DeLoache has argued that it must be a single realization that occurs within this short time that allows the child to understand the relationship between the scale model and the room, because of the stark differences in performance with the model task between 2.5 and 3 year olds. (DeLoache, 1987). A similar pattern emerges in experiments that have used pictures instead of a model, shedding light on an intermediate stage in this type of development; 2 year olds did not understand the

relationship between a photo and its referent, whereas 2.5 year olds understood this relationship with photos and thus do so before they begin to understand models (DeLoache, 1991; DeLoache & Marzolf, 1992).

Achieving this representational insight may be tied to the concept of dual representation, or understanding that an object is both a tangible entity and a symbol that refers to something else. Since a picture is by definition a representation of some other thing, children more easily appreciate its symbolic intention compared to a model, which is a visually appealing object that may be difficult to think about as representing something other than what it is. Children may believe it is intended to be played with, rather than intended to stand for some other space. However, prior experience with a picture in these tasks allowed for better subsequent performance with a model, showing the importance of incremental symbolic experience to developing these capacities (DeLoache, 1991).

One of the most compelling reasons in support of the dual representation hypothesis comes from a study where 2.5 year olds were significantly more successful in the model task through one crucial manipulation: a “magical” shrinking room (DeLoache, Miller, & Rosengren, 1997). These young children were led to believe that a special device was able to shrink the hidden object and the room, essentially eliminating the need for a symbol-referent relationship. If children believed that the scale model was just the actual room in a smaller form, it became a memory task, and there was no symbol or referent because in the child’s mind, the symbol was the referent. Since they performed better in this task, then it is possible that their poor performance without the shrinking device is due to their inability to

achieve representational insight. This insight was impeded by the objects themselves; the salience of a concrete and tangible object prevented the child from realizing that it was capable of representing something else, in other words, that it was simultaneously an object and a symbol.

In another study, they presented half of the children with the model behind a glass, to prevent any interaction with the model. The other half of the children were allowed to play with the model for a period of time before the experiment began. They found that those who did not play with the model achieved greater insight into the model-room relation than those that played with the model (DeLoache & Burns, 1993). This shows that treating the model like an object, through play, impeded the ability to consider it as a symbol. On the other hand, not being able to touch or get close to the model increased the ability to represent the object as a symbol, supporting the idea that dual representation allows the object to be understood as representing something else.

How is it that a picture of a space is more easily understood as a symbol compared to a concrete object? Children were explicitly shown that the model was the small version of the room, and still failed the task. While it may be that they failed to achieve representational insight, or failed to understand that the model was intended to be a symbol for the room, there are other elements of maps and symbols that must be taken into consideration. The benefits of maps for representational insight may be approached in an additional two ways: 1) It may be that there is an inherent benefit of abstract representations that lend themselves to an easier transfer of spatial information or 2) it may be that maps present a highly useful perspective of

the space, beyond what may be gleaned by navigation alone, that is useful for understanding spatial relations.

Abstract Representations

Maps are abstract representations of space. They condense the multifaceted, multicolored, 3-D world into a 2-D array of lines and shapes. Maps provide the basis from which abstract concepts of space can emerge. This is especially true for conceiving of large-scale spaces, such as a country or state, the representations of which cannot be accessed by normal means (Uttal, 2000). But is it the abstractness of a map that allows children more insight into the spatial relations among entities?

Sloutsky, Kaminski, and Heckler (2005) explored these possible advantages to learning by using abstract representations. Since the goal of learning is to transfer relevant knowledge to new situations, they believed that an abstract, generalized representation of a concept could provide more “portable knowledge” compared to concrete examples that contain too much irrelevant information. They found that the most abstract and perceptually sparse symbols aided in better learning of mathematical and scientific concepts, compared to perceptually rich concrete symbols. It is counter-intuitive to think that the use of perceptually rich symbols could negatively affect learning, but they argued that these representations lend themselves more to be thought of as actual objects, or they interfere with learning by engaging the perceptual senses.

Subsequent studies explored this notion further, and suggested that although one may still learn a concept across several concrete representations, it was still better to receive a simpler more generalized abstract representation (Kaminski, Sloutsky, &

Heckler, 2008). Concrete examples contain more information beyond the the deep to-be-learned structure of a concept, and therefore interfere with the acquisition of knowledge. Their hypothesis was that having one generic instantiation of a concept helped transfer knowledge to new situations better than multiple concrete examples, and they found this to be true with one, two, and three concrete examples (Kaminski et al., 2008). Concrete examples are not completely useless, however, and they suggested that having concrete examples initially may be more engaging and can facilitate initial learning.

Maps help with the ability to represent space (Uttal, 2000; Liben et al., 2002), but is a highly abstract map more useful to creating this representation? Given the above evidence, it may seem like a perceptually sparse map may be the most useful for children in understanding the spatial relations among objects. This view is supported by DeLoache's findings, in that abstract pictures of space allowed for more transfer of information than concrete objects (DeLoache, 1991; DeLoache & Marzolf, 1992).

Perspective

Abstract representations may provide spatial information that is easily transferred to other settings compared to concrete representations. In maps, however, this abstractness is confounded with perspective. Maps are usually presented from a survey-view, above the space, which condenses the array into a much smaller scale. This reduction to a smaller scale reduces the salience of specific features (increasing abstractness) and in doing so, places less focus on individual features of objects and highlights the spatial relations among objects (Uttal, 2000).

Is this survey perspective providing different information than if one were to move about the space? When looking at a map or looking down from above the space, one can see the spatial relations among objects in a single glance. When one is within the space, the relations between objects in the array are not visible in one glance which requires more integrative thinking in order to understand the spatial relations. One of the main questions being addressed in this study is seeing how these differences in the ways that one experiences the array can affect the encoding of the spatial relations among objects. One study showed an advantage to being "inside" the space when attempting to search for an object following disorientation (Lourenco, Huttenlocher, & Vasilyeva, 2005), showing that children benefited from an internally-acquired representation of the space. This however is counter-intuitive, considering that seeing the entirety of an array in one glance is easier than having to think about the relations from inside a space. But if being inside the space actually helped more than being outside of it, it could be that observing the entire array in a single glance did not help one to realize the spatial relations among objects; it may be more useful and helpful to be able to take in each part of the array individually instead of all at once. In integrating each individual part of the space, it could have allowed for a "higher quality" representation than if one were encoding the array all at once.

On the other hand, there may be benefits to survey-based representations. Uttal (2000) argued that these perspectives were better than a route-based representation, given that during navigation, one's position relative to landmarks and objects is constantly changing (Tversky, 1996). A map provides a fixed point of view

from which navigation decisions can be made; it is an abstract representation of the space, focusing on spatial relations, and reduces the potential interference from individual salient features that may be present during navigation. Taylor and Tversky (1992) found that adults intuitively formed survey-like representations of a hypothetical space even from non-survey-based sources of information. But this is not limited to those with life-long experience with maps. Other studies have found that infants did better in a maze task when given a survey-view prior to navigation (Rieser, Doxsey, McCarrell, & Brooks, 1982) and the same survey-view advantage was shown in older children (Gauvain & Rogoff, 1986). A survey-view of a space leads to a better representation of the space, and allows the encoding of multiple relations among multiple locations.

However, the advantage of the oblique view in Liben and Yekel's study (1996) went against these findings. In this study, one type of map, the oblique map, showed more features of the objects in a room, such as the legs of tables and chairs and the frames of windows. The other type of map, the plan map (survey-view) showed the room from overhead, and the aforementioned features were not displayed on the map. An overhead view could be arguably more abstract, given that the tables have turned into circles on the map, since the legs are hidden underneath. Children performed better on a map-reading task with the oblique map compared to the plan map, and using the oblique map first aided in subsequent performance on the plan map (Liben & Yekel, 1996). It may be that the extra features shown in an oblique view (i.e., legs of a table) could actually still be considered a survey-view representation, simply with more features and information about the objects that were

presented. It may have been that the strictly survey-view map that they used was too perceptually sparse given the complexity of a classroom setting. Regardless of these possible differences in perspective that a map can produce, one study supported the idea that exposure to a map could help children create mental representations that maintain the relations among multiple objects (Uttal & Wellman, 1989), an ability which is very difficult for preschool-aged children (Herman et al., 1985).

Studying map use in children is important because it demonstrates the mastery of a variety of cognitive faculties, and sheds light on what types of reasoning are culturally imposed versus innate. The fact that adults can easily conceive of survey-view perspectives is related to the presence of survey-view maps everywhere in Western societies. Adults in other cultures use different strategies to conceive of space, such as more landmark-based or allocentric strategies (Uttal, 2000). Assessing children's map use in the current study's design showed the development of landmark use, the use of abstract symbols, and possible benefits of survey-based perspectives.

Current Study

In this study, we explored children's use of maps by implementing a task similar to that of DeLoache's studies. However, instead of a space with distinct furniture, we used a symmetrical room, stripped of any important visual cues other than a single red wall. Each corner contained a box, which were the target locations where objects were placed. Instead of the extensive training conducted in DeLoache's studies, we simply showed the child the room and the map together, and pointed out the relationship between the circular boxes in the corners of the room with the circles on the map. In order to test how children realized the relationship between the map

and the room on their own, we provided minimal instruction during training. In fact, studies conducted after the initial model-room tasks have shown that these extensive practice trials had no beneficial effect on children's performance and were consequently dropped from the standard task (DeLoache & Sharon, 2005). However, since the training in the current study was significantly less instructive than the methods used in these studies, we also utilized a slightly older population of children so as to account for any difficulty with this less instructive training. Additionally, in order for the red wall to have served its full potential as a landmark, we utilized each corner as a target location. And in order to make sure that no single corner was ignored as a hiding location, we used 4 points of entry to the space via each corner so that across subjects, no corner could be ignored because it lied outside of their visual field once they were inside the room.

Considering that mental rotation is very difficult for children, we expected that some corners could be more intuitive than others. The map was presented outside of the room in the same orientation with every participant; however, different participants entered the room at different corners. Thus, some points of entry did not require a rotation of their mental representation of the array in order to have it aligned correctly with the room. Furthermore, we expected that the map-room relation would be very difficult for younger children to realize. It may have been more difficult than using DeLoache's space because instead of distinct items of furniture, there were four identical objects that served as target locations. Therefore in order to successfully pass the task, one needed to appreciate the overall relations between objects and the

landmark. Simply knowing that an object was “at the box” was not helpful, but it was better to know that it was at the box “by the red wall” or “left of the red wall.”

Given the research on the advantages of abstract representations and survey-based perspectives, we expected that the abstract-to-concrete task (map-to-room) could be easier for children to understand. On the other hand, starting the experiment in the room with the room-to-map task could have allowed children to think about the map much more easily, because one would have understood what features of the room the map was intended depict. These differences could have been grounded in the abstract-concrete distinction; however, any differences in performance could also have been attributed to the differences in experience between the two arrays: survey-based or route-based representations. Additionally, we ensured that any problems with moving between arrays were not attributed to memory by having one memory trial per task. This was done in order to make sure that if children were failing the task, it was due to representational failures, and not failures of memory. This was also done to make sure that children were actively engaged and interested in the task.

In order to test the effects of spatial language on accurate placements within the room, we assessed children’s knowledge of left and right. Prior studies using a disorientation task in similar spaces have shown a correlation between successful use of the landmark and stable representations of left and right (Hermer-Vasquez et al., 2001; Shusterman & Spelke, 2005; Pyers et al., 2010; Hoyos et al., 2011). In order to differentiate between two identical corners, having this spatial language could vastly improve the decisions that children made in the task. Having stable representations

for left and right could be related to children's ability to use the landmark and successfully place the object on the correct side of the wall.

The current study addressed several issues. Firstly, we wanted to know how children begin to understand the object relations displayed on a map and how it relates to their real life experience. At what age does this ability arise and how successful are children in associating real objects with their referents on a map? Secondly, would reading a map influence the extent to which children could integrate landmarks into their navigation? In other words, would a map allow greater access to a landmark and help children overcome their difficulty in using landmarks in certain contexts (Hermer & Spelke, 1994)? We measured children's left/right knowledge, as this may be closely related to children's ability to use landmarks. Thirdly, does mental rotation play a role in the ability to associate the map with the room? We wanted to know if children "update" their representation of the room as they entered the space from a different orientation than was originally presented to them. In other words, would certain points of entry differ in their difficulty based on how much mental rotation is required in order to align the space with the initial presentation of the array? And finally, we looked for direction of transfer effects, or differences when moving from map-to-room or room-to-map. Were there differences when transferring knowledge from abstract-to-concrete or concrete-to-abstract arrays?

Methods

Participants

A total of 40 children between 4 and 8 years old participated in the experiment (mean age = 66 months, range = 43 – 95 months). An additional four children were

run, but their data was excluded from the analyses: One for experimenter error (the map was placed in the wrong orientation), and three who decided to discontinue the task. All participants were contacted through a database of families recruited from the central Connecticut area. The study was conducted in the Cognitive Development Lab, in the Department of Psychology at Wesleyan University. The study and its procedure were explained to the caregivers and they agreed to participate by signing a consent form. They received $5 as a travel reimbursement and their child received a small toy as a thank-you gift at the end of the study. This study received approval through Wesleyan University's Institutional Review Board. All procedures and protocols for obtaining informed consent were in accordance with IRB policies.

Stimuli

The experiment was conducted in a 10 ft. by 10 ft. square room. The experimental space was surrounded by curtains, which left about a 1 ft. gap between the wall and the curtains. This allowed for absolute symmetry of the space. The door could not serve as an additional landmark since it was concealed by the curtains during the experiment. The gap around the curtains allowed for entry to the space at each of the four corners. The curtains, one red and three white, were suspended on the ceiling and hung to the floor. Ceiling tiles, vents, recessed lights, and the carpet pattern were all completely symmetrical so that there were no spatial cues to guide a child's navigation other than the red curtain. A camera in one corner allowed us to record the sessions, and symmetry was maintained by fake "cameras" placed in each of the other corners. Each corner had open circular containers on the floor, which allowed children to easily place objects inside. Sitting right outside of the "hiding

room" was the "picture table", a small square table where the map was used and presented to the child.

The map (see Appendix) was a laminated 8.3 by 8.3 inch square, depicting the red wall, the three white walls, and the four containers on the ground, mounted on a magnetic base, so that magnetic figures of animals could be placed onto the map easily. Two types of animals, a pig and a turtle, were used in the task. We used two versions of those animals between the room and the map: magnets for the map, and stuffed animals for the room.

Experimental Design

The experiment employed a 2 (task order) x 4 (orders of hiding locations) x 4 (corners of entry: A, B, C, or D, see Appendix) design.

Tasks. There were two tasks, one of which was the room-to-map task, where children were shown where to hide an object in the room and then had to place it correctly on the map. In the map-to-room task, children were shown where to hide an object on the map and then had to place it correctly in the room. All children received both tasks, but in different orders. Children began with either the room-to-map or map-to-room task and then subsequently received the other task.

Placement trials. Each task utilized each of the four corners as a hiding place, giving each task 4 placement events. Thus each child performed 8 placement events over the two tasks. They received one of four different possible hiding orders. The same hiding order was used for each task within each participant. All the containers were used as hiding places once. Each order alternated between wall color, leading to a combination of white-red-white-red or red-white-red-white.

In the first task, they were introduced to one of two stuffed animals as the object used in the placement trials. The second stuffed animal was used in the 2nd task in order to highlight the change in procedure between the two tasks.

Corner of entry. A single entry point was used for all of the 8 trials within each participant. There were four possible entry points, one at each corner, made possible by the gap between the curtain and the walls of the room. The entry points were counterbalanced across participants.

Procedure

Regardless of which condition the child was first participating in, the child was first introduced into the space via the predetermined corner of entry. The child was told that they would be playing a hide-and-seek game by helping some of the experimenter's friends play hide-and-seek. After explaining that they would be playing hide-and-seek with the stuffed animal, the experimenter went over and pointed to each box to explicitly show the child each of the four hiding locations. Then the child was told, "There's also a picture of the room that we can use to pick some hiding places for the stuffed animal." The picture was then placed on the floor in front of the child, aligned with the room. The experimenter explained to the child that there were hiding places on the picture as well, and then pointed to each corner on the picture.

Map tasks. In the room-to-map task, the child was told that they were going to choose a hiding place in the room first, and then they would go outside to the picture table and put the animal in the "right spot." The stuffed animals were used in the room, but the magnet animals were used on the map. No verbal distinction was

made between the stuffed animal and their magnetic counterparts in order to facilitate the association between the objects; they were both referred to as “Tim the Turtle,” or “Pat the Pig.”

Once a location in the room was selected, the experimenter then explained that it was time to go outside of the room to the picture table so that the child could put the animal on the “right spot” on the picture. They were told that this was important, so that the animal’s friends could find them. Before leaving the room to go out to the picture table, the experimenter removed the stuffed animal from the container, unbeknownst to the child, in order to set up the memory trial upon their return to the room.

Once at the picture table, the child was given the magnetic version of the animal and asked “Where is the right place for Pat/Tim to go?” The child chose a location and was not corrected if the placement was wrong. The experimenter then told the child that the animal’s friends were able to find them now, but they should go back into the hiding room and pick a new hiding spot for Pat or Tim. Upon returning to the hiding room, the animal was no longer in the container because the experimenter had picked it up. The experimenter then asked the child where they had put the animal when they were in the room the last time. If the child recalled an incorrect location, they were then corrected and reminded where the animal was initially placed, and the memory trial was repeated once again on the next trial. If the child was successful, then the memory trial was not repeated until they switched tasks. The placement events were repeated 3 more times to complete all four hiding locations.

Once the room-to-map task was completed, the child was then told that they were going to play a different game with a different animal. The child was introduced to the new animal, Pat or Tim, and then the map-to-room task was explained. They were told that this animal played the game in a different way and they were going to choose a hiding place on the map first, and that they would have to go into the room and place the animal in the right place. The child was given the magnetic version of the animal to "choose" a hiding place on the map. After a location was selected, the child and experimenter headed into the hiding room and the child placed the animal in a container. They were not corrected if they made an incorrect selection. Before entering the room, the experimenter took the magnet off of the map in order to set up the first memory trial. Once the child made this first placement, the child and experimenter returned to the picture table to choose a new hiding place. For the memory trial, the child was then asked where the animal was the last time they had picked a hiding spot. If a child was unsuccessful they were corrected and the memory trial was repeated after the second trial. There were three more test trials to complete all four hiding locations.

The previous order of procedures refers only to the condition when a child started with the room-to-map condition, but the other half of the children started with the map-to-room condition in which case the order of these procedures are reversed.

Left-right language task. After the two map games, the child was told that there was one more game to play inside of the room. This "dancing" task measured children's representations of left and right and was the same task used by Shusterman and Spelke (2005). There were 12 left-right trials and filler trials to keep children

motivated in case they did not know their left and right. After every 3 trials, the experimenter changed the direction that the child was facing so that they were not mapping left and right to particular sides of the room. After the child finished this task, they were given a small toy.

Results

Participants

Twenty-four females and 16 males participated in the experiment. Children were divided into two groups based on age. Group 1 comprised children aged 3.5 to 5.5 years old (N = 19, M = 54 months, SD = 6.8 months, range = 22), and Group 2 comprised children aged 5.5 to 8 years old (N = 21, M = 76 months, SD = 6.7 months, range = 25).

All Participants

A repeated-measures omnibus ANOVA with block as the within-subjects factor, order of tasks and age group as the between-subjects factors, and sex as a covariate, revealed main effects of age group, $F(1, 35) = 23.95$, $p < .001$, and order of tasks, $F(1, 35) = 4.88$, $p = .034$. There was also an interaction of age group and order of tasks, $F(1, 35) = 9.03$, $p = .005$, and an interaction between block and age group, $F(1, 35) = 8.31$, $p = .007$. No effects of sex were found, $F(1, 35) = 0.79$, $p = .380$, and sex was thus dropped from subsequent analyses.

Follow-up t-tests on the main effects of order revealed significant differences between order of tasks in the second block of trials, $t(38) = -2.57$, $p = .014$, but not the first, $t(38) = -0.23$, $p = .820$. This suggests that, taking all participants into account, performance on the first task did not vary based on the type of task, but

performance in the second block was influenced by the type of task. Those who received the map-to-room task first (M = 2.63) performed subsequently better in the room-to-map task (M = 3.05), compared to those who received the room-to-map task first (M = 2.52) and then performed subsequently worse in the map-to-room task (M = 2.14). This is preliminary evidence for the benefits of receiving the map-to-room task first, however, given the three interactions of age group, the subsequent analyses are divided along these lines.

Age Group 1 (4 – 5 Year Olds)

A repeated-measures ANOVA with block as the within-subjects factor and order of tasks as the between-subjects factor revealed a marginal effect of block, $F(1, 17) = 3.10$, $p = .096$, and a main effect of order of tasks, $F(1, 17) = 12.92$, $p = .002$.

Follow-up t-tests revealed an effect of position with performance in the room-to-map task, but not the map-to-room task (see Appendix, Figure 2). It did not matter whether the map-to-room task was first or second in order of tasks (first M = 2.11, second M = 1.60), $t(17) = -0.82$, $p = .424$. However, performance in the room-to-map task was higher when it followed the map-to-room task (M = 3.11) compared to when it preceded the map-to-room task (M = 1.10), $t(17) = -4.28$, $p = .001$. This suggests that the map-to-room task provided the experience necessary to succeed in the room-to-map task. Without this experience, children did not perform well in the room-to-map task, suggesting that the abstract-to-concrete transfer allowed for a better realization of the concrete-to-abstract transfer.

To further explore these position effects, performance within each task was tested against chance. For those that received the map-to-room task first, performance

in the map-to-room task was marginally above chance (M = 2.11), $t(8) = 2.30$, $p = .051$. In the subsequent room-to-map task, children were above chance (M = 3.11), $t(8) = 6.01$, $p < .001$. For those that received the room-to-map task first, performance in the room-to-map task was not above chance (M = 1.10), $t(9) = 0.32$, $p = .758$. In the subsequent map-to-room task, children were not above chance (M = 1.60), $t(9) = 1.50$, $p = .168$. This is further evidence for the benefits of abstract representations, since there is not a general effect of experience, but rather a specific benefit of receiving the map-to-room task first.

Age Group 2 (5 – 8 Year Olds)

A repeated-measures ANOVA with block as the within-subjects factor and order of tasks as the between-subjects factor revealed a within-subjects effect of block, $F(1, 19) = 6.67$, $p = .018$, and an interaction of block and order of tasks, $F(1, 19) = 4.75$, $p = .042$.

Much like the younger group, follow-up t-tests revealed position effects for the room-to-map task but not the map-to-room task (see Appendix, Figure 3). It did not matter whether the map-to-room task was first or second in the order of tasks (first M = 3.10, second M = 2.64), $t(19) = -1.05$, $p = .307$. However, unlike the younger group, these effects go in the opposite direction. Older children were at near perfect performance when the room-to-map task was first (M = 3.82), compared to lower performance when it followed the map-to-room task (M = 3.00), $t(19) = 2.21$, $p = .040$. Despite these differences, both tasks in both positions were significantly above chance, all $p < .001$, showing that the older children were very successful in both tasks.

Comparisons Between Age Groups

We compared performance in the tasks between the two groups in order to see where there was an effect of age. For those that received the room-to-map task first, performance in the room-to-map task was higher in the older group (M = 3.82) compared to the younger group (M = 1.10), $t(19) = -7.66$, $p < .001$. In the subsequent map-to-room task, performance was also higher in the older group (M = 2.64) compared to the younger group (M = 1.60), $t(19) = -2.16$, $p = .044$.

For those that received the map-to-room task first, no differences in performance in the map-to-room task were found between the older group (M = 3.10) and the younger group (M = 2.11), $t(17) = -1.68$, $p = .111$. In the subsequent room-to-map task, there were no differences in performance between the older group (M = 3.00) and the younger group (M = 3.11), $t(17) = 0.23$, $p = .821$.

These data show that age did not affect performance when the map-to-room task was received first; there were no differences in performance between both groups in this order of tasks. Since the younger children had difficulty throughout the whole task when receiving the room-to-map task first, it may be that receiving the map-to-room task first enabled the younger children to perform better. The older children were able to successfully transfer from the room to the map without difficulty, whereas the younger children needed the map-to-room experience in order to perform like the older children (see Appendix, Figure 4).

Correctly Colored Placements

Some children may not have made completely correct placements, but still could have been using the wall colors less accurately to cue their placements. In order

to examine this type of performance, we measured whether children were making correctly colored placements, or in other words, when an object was at a red corner, did they go to the red wall, and when an object was at a white corner, did they go to the white wall.

In the younger group, those that received the map-to-room task first were above chance at choosing the correctly colored corners in the map-to-room task (M = 2.67) and in the subsequent room-to-map task (M = 3.67), $t(8) = 2.31$, $p = .05$, $t(8) = 7.07$, $p < .001$, respectively. Those that received the room-to-map task first, were not above chance in the room-to-map task (M = 1.90), $t(9) = -0.36$, $p = .726$, but were subsequently above chance in the map-to-room task (M = 2.70), $t(9) = 2.69$, $p = .025$. This is similar to the performance seen across the tasks with regard to correct placements, where the position of the room-to-map task affected performance; performance on the room-to-map task is enhanced by having it follow the map-to-room task. There were significant differences in performance between the room-to-map tasks when it came first (M = 1.90) compared to when it followed the map-to-room task (M = 3.67), $t(17) = -4.80$, $p < .001$. The position of the map-to-room task did not influence performance, $t(17) = 0.09$, $p = .932$.

In the older group, children were making correctly colored placements above chance in both tasks, regardless of order, $p < .01$. There were ceiling effects when the room-to-map task came first (M = 4). This shows that older children are more attuned to the colored cues than younger children, regardless of task or position. Similar to their pattern of correct placements, older children were making more correctly colored placements when the room-to-map task was first (M = 4) compared to when it

followed the map-to-room task (M = 3.2), $t(19) = 2.58$, $p = .019$. The map-to-room task showed slightly better performance when it came first (M = 3.50) than when it came second (M = 2.91), $t(19) = -1.75$, $p = .097$.

Age comparisons. Older and younger children were not significantly different in their correctly colored placements in the map-to-room task (younger group M = 2.68, older group M = 3.19), $t(38) = -1.96$, $p = .058$. However, there were significant differences between the groups in the room-to-map task (younger M = 2.74, older M = 3.62), $t(38) = -2.76$, $p = .009$. This suggests that both groups of children are able to understand the demands of the map-to-room task, but only the older children understand the room-to-map task. The younger children require the map-to-room task first to successfully complete the room-to-map task.

Comparisons to correct placements. When comparing to correct placements, the initial map-to-room task is not only helping the younger children succeed in the room-to-map task, but it also aids in better landmark use. In the younger children, those that received the map-to-room task first displayed marginal differences between correct placements (M = 2.11) and correctly colored placements (M = 2.67), $t(8) = -2.29$, $p = .051$. In the subsequent room-to-map task, there were no differences in the amount of correct (M = 3.11) and correctly colored placements (M = 3.67), $t(8) = -1.64$, $p = .139$, thus showing that they were more accurate. However, when the younger children received the room-to-map task first, there were significant differences between correct (M = 1.10) and correctly colored placements (M = 1.90) in the room-to-map task, $t(9) = -2.45$, $p = .037$, as well as correct (M = 1.60) and

correctly colored placements (M = 2.70) in the subsequent map-to-room task, $t(9) = -3.97$, $p = .003$, showing that they were less accurate in their placements.

For the older group, there were no differences between correct and correctly colored placements across both tasks in both positions, all $p > .08$. Therefore, the gap in performance seen in the younger children between complete accuracy and choosing correctly colored locations is attributed to the idea that choosing wall color emerges before successfully choosing the correct corner. Or in other words, that direct landmark use arises before indirect landmark use.

These data also suggest that the initial map-to-room task experience allowed for better landmark use. Those that received the initial room-to-map experience displayed significant differences between their correct and correctly colored placements, suggesting that they were able to make placements less accurately based on wall color. Those that received the initial map-to-room experience had similar rates of correct and correctly colored placements, showing that they were more accurate in their placements. This is further evidence that the map-to-room task allows younger children to perform like the older children.

Left-Right Knowledge

Knowledge of left and right was assessed to see how it might be related to performance. Passing the left-right language task was considered to be getting seven out of eight trials correct. A correlation was computed to assess the relationship between overall success and left-right knowledge. There was a positive correlation between the two variables, $r = .454$, N = 39, $p = .004$. However, there was no correlation between the two variables within Group 1, $r = .328$, N = 18, $p = .184$, or

Group 2, r = .227, N = 21, p = .322. This effect, however, seems to be driven largely by age. A partial correlation controlling for age did not reveal any effect of left-right language on performance, r = .198, N = 39, p = .233. Likewise, a partial correlation controlling for left-right language revealed a strong effect of age, r = .501, N = 39, p = .001.

Past Experience in the Space

We had the unique opportunity to use participants that once participated in a prior experiment in the same space. We wanted to see if this experience had any effect on performance. A Pearson correlation revealed no significant relationship between prior experience and overall performance (with experience M = 5.64, SD = 2.21, no experience M = 4.73, SD = 2.22), r = .198, N = 40, p = .222. However, with correctly colored placements as the dependent measure, the correlation approached significance, with those having no prior experience in the space having a mean of 5.85 correctly colored placements and those having prior experience having a mean of 6.71 correctly colored placements, r = .306, N = 40, p = .055. A t-test confirmed the same pattern, $t(38) = -1.98$, p = .055. However, a linear regression showed that this effect may also be largely driven by age, $\beta = .402$, $t(39) = 2.74$, p = .009, and not prior experience in the space, $\beta = .215$, $t(39) = 1.47$, p = .151.

Mental Rotation

Since children are entering the room from different points of entry, we wanted to see if these differences had any effect on performance for two possible reasons. One, it could be that the landmark was more salient at certain corners compared to others (i.e., entering across from the red wall). Two, it could be that some corners are

more difficult to use; the map is always presented in the same orientation across participants, but since the corners of entry differ, some corners require rotating the mental representation of the array. A multivariate ANOVA with corner of entry as the between-subjects factor, overall correct and correctly colored placements as the dependent variables, and age as a covariate, showed no differences between the entry points in overall success, $F(3, 36) = 0.23$, $p = .877$, or in correctly colored placements, $F(3, 36) = 0.61$, $p = .614$ (correct placements across all trials at corner A: M = 5.21, N = 14, SD = 2.39, corner B: M = 5.43, N = 7, SD = 2.30, corner C: M = 4.56, N = 9, SD = 2.60, corner D: M = 5, N = 10, SD = 1.83).

Discussion

The data presented in this study show a developmental trajectory of children's ability to use maps and utilize landmarks to guide navigation. Age was consistently related to success across the map tasks, beyond the effects of left-right language and prior experience in the space. The order of the tasks was also strongly related to performance, both within and across the two age groups.

Firstly, taking all participants into account, there was more success seen in the map-to-room to room-to-map transition, suggesting that abstract representations may be beneficial to successful navigation. The position of each task, whether they came first or second in order, also had a strong effect on performance within each age group and supported the abstract-first advantage.

In the younger group, these position effects were found with the room-to-map task but not the map-to-room task. Performance did not vary in the map-to-room task based on whether it came first or second. But performance in the room-to-map task

was better when it followed the map-to-room task rather than when it came first. This is in line with the trend seen over both groups overall, that children who received the map-to-room to room-to-map transition were more successful than those who received the reversed order. In the younger children, only the map-to-room to room-to-map transition was above chance, providing further evidence for the abstract-first advantage. The better performance seen in the abstract-to-concrete transfer extends the benefits of abstract representations beyond learning mathematical concepts (Sloutsky et al., 2005; Kaminski et al., 2008), to aiding navigational abilities in young children.

In the older group, both tasks in both positions were above chance, showing that the older children were very successful at understanding the map-room relation. Position effects were also found in the older group for the room-to-map task but not the map-to-room task. These effects were in the opposite direction than that of the younger group. Older children showed near-perfect performance in the room-to-map task when it was presented first, but were not as successful when the room-to-map task followed the map-to-room task.

Comparing performance between age groups showed that older children were much better than the younger children in the room-to-map to map-to-room transition. However, there were no differences in performance in the map-to-room to room-to-map transition between the two groups. This shows that unlike the older children, the younger children had difficulty with the room-to-map task. Given that there were no differences between the two groups in the map-to-room to room-to-map transition, it may be that the initial map-reading experience allowed the younger children to

perform like the older children. This map-reading experience allowed the younger children to understand the map-room relation similar to that of the older children, in a manner that was not observed in the opposite order of tasks. This is further evidence supporting the benefits of abstract representations in navigation.

The benefits of receiving the map-to-room task first were also observed when correctly colored placements were assessed. Younger children were making more accurate placements in the map-to-room to room-to-map transition compared to the reversed order. Both age groups had similar rates of correctly colored placements in the map-to-room task, but the older children performed better than the younger children in the room-to-map task. This supports the notion that the room-to-map task was more difficult for the younger children and was thus more prone to position effects.

No other variables that were measured, including left-right knowledge, past experience with the space, and differences between corners of entry, had an effect on performance, especially when age was considered as a factor. Unlike the current study, a previous study using a disorientation task in the same space showed a strong correlation with left-right language tasks (Hoyos et al., 2011). For prior experience in the space, there were marginal effects on correctly colored placements, suggesting that perhaps children who have been in the space before were more likely to distinguish between wall colors.

Landmark Use

The ability to use landmarks in this study mirrors previous findings related to landmark use (Lee et al., 2006; Hoyos et al., 2011). They suggest an intermediate

level of landmark use before complete success in these kinds of tasks, in that color may be used as a landmark to a limited extent before full use of the landmark is realized. These differences were highlighted by the order of the tasks. The older children were very accurate overall, and had high rates of correct placements along with high rates of correctly colored placements. The younger children had lower rates of correct placements but high rates of correctly colored placements, showing that they had some ideas about the locations of objects, but their ability to accurately choose the completely correct location was still limited.

We consider two ways in which one can use a landmark to navigate. Lee and colleagues (2006) have framed it in terms of direct and indirect landmark use. Direct landmark use is creating an association between the landmark and target when the landmark directly marks the location of the target. Indirect landmark use is using the landmark as a reference point to the location of the target, which could be at some distance away from the landmark. In this study, direct landmark use was measured by correctly colored placements, and indirect landmark use was measured by correct placements.

In the current study, we distinguished high rates of correct placements (indirect landmark use) from low rates of correct placements coupled with higher rates of correctly colored placements (direct landmark use). The gap between the two measures showed that while some children were not making completely accurate placements, they were making placements based on wall colors. In the younger children, the differences between correct and correctly colored placements was much larger in the room-to-map to map-to-room transition, showing that they had difficulty

in choosing the correct corner but were still attuned to wall color. When they received the room-to-map task first, they were able to connect the colored wall to the location of the object, but were choosing at chance between either corner on the colored wall. They demonstrate nascent notions about landmarks, but it is only the older children that understand the demands of the task and successfully place the object in the correct locations. Despite their lower performance compared to older children overall, the map-to-room task did aid in the younger group's ability to use landmarks more accurately.

We hypothesized that the ability to choose the correct corner was related to spatial language, or having stable representations for left and right, since a disorientation task in the same exact space showed these effects (Hoyos et al., 2011). However, we did not find a strong effect linking left-right knowledge to success on the task, while age itself is what seems to have been the most important factor in successful landmark use. The previous study showed the complete opposite pattern; left-right language predicted performance beyond the effects of age (Hoyos et al., 2011). Despite being conducted in the exact same setting with the same experimenter, they show very different patterns of performance related to age and spatial language. It may be that map use requires a different cognitive operation than spatial memory and reorientation.

While spatial language seems to allow spontaneous use of landmarks, it is not the only way that children have been shown to use landmarks. In one study, Shusterman and colleagues (accepted) explicitly told children in one of their tasks that they could use the colored wall to guide their search. Successful landmark use

was improved by this simple cue, showing that spatial language is not the only way to successfully complete the task. In fact, having left-right knowledge may be influenced by a variety of factors. For example, some children participate in extracurricular activities like dance or gymnastics classes where having knowledge of spatial language is necessitated. This could account for some of the variation in left-right knowledge across individuals, given that the importance of having these words may be very different from child to child. The development of left and right knowledge as a function of having specific experiences should be further explored.

Since we did not find a relationship between left and right knowledge and success in the task, it remains unclear how it is that age allows one to successfully utilize landmarks or a map. Is it simply an increase in experience with the world and more opportunities to move around in it, or is it the further development of symbolic capacities that influences this ability? Age may be used as a proxy for size, but what if larger children are able to notice more features of their surroundings? Older children may attend to specific features in the environment more than younger children.

If it is not an increased awareness of the world, then age may be strongly correlated with symbolic development more so than left-right language. Left-right language may be more related to actual landmark use and reorientation, whereas the current map tasks show that it may be more focused on understanding the symbolic relations between both arrays rather than landmarks alone.

Age-Related Effects on Performance

Since it was the older children that were able to engage in full landmark use, this ability seems to emerge around age six, which is around the same time that children are able to mentally rotate their representations of space (Peter, Gluck, & Beiglbock, 2010). This is not to say that map use arises at this time as well, since the younger children were successfully utilizing the map (in the sense that they could detect and use the correspondence between the color of the landmark and target locations). However, it may be that around age 6, children attain a group of abilities related to spatial reasoning that enable them to pass these tasks.

Map use is very difficult for preschool aged children (Herman et al., 1985; Liben & Yekel, 1996). Liben and Yekel's (1996) experiment used an actual classroom as the experimental space, complete with tables, windows, shelves, etc., displayed on the map. They claimed that children had difficulty with accurately targeting locations on the map. However, in their study, the children had to place stickers on a map to identify locations in the room. This assessment is similar to the room-to-map task in this study, as children had to place the magnets on the map. Since children in the current study displayed a difficulty with this particular task in comparison to the map-to-room task, the results of the Liben and Yekel study may only be limited to tasks where children must make placements on a map. It may be that children benefit from the abstract depiction of space in a map-to-space task, and the results of the current study show that preschool aged children do demonstrate the ability to use maps. By using the map in the map-to-room task, it subsequently allowed them to perform like older children. The claim that preschool aged children

have difficulty with maps is limited to a specific type of task, and there is reason to believe that children would perform better in Liben and Yekel's setting if they were asked to use the map to travel to locations in the space. Although the current study was conducted in a small space, similar benefits of going from a map to a space versus going from the space to the map were found in larger arrays (a college campus) with much older children (9 and 10 year olds; Christensen & Liben, 2011).

Liben and colleagues (2002) argued that preschool-aged children perform poorly on a task where there are multiple symbols of the same kind. The results of the current study show that younger children can perform well when there are multiple identical targets, once they have received an initial map-reading experience. This supports the idea that abstract representations help children understand the spatial relations among multiple identical objects, in addition to the benefits to more accurate landmark use.

The initial motivation for using the 4 to 8 age group was the fact that we anticipated the tasks to be more difficult than the traditional map/model tasks used by Judy DeLoache, given that this study was more about the higher order spatial relations among objects rather than a simple one-to-one correspondence between objects. The children tested in this study were capable of understanding the spatial relations among objects. In the future, younger children should be tested as well, in order to see the full trajectory of no landmark use to full landmark use. It would be valuable to have a group of children that fail both the map-to-room to room-to-map and room-to-map to map-to-room transitions, in order to paint a complete picture of map and landmark use. It may be that by age 2.5, children can understand pictures as

representations of space (DeLoache, 1991; DeLoache & Marzolf, 1992). By age 3, children can understand one-to-one correspondences between a model and a space (DeLoache, 1987). And as this study shows, somewhere between ages 4 and 6, children begin to understand higher order spatial relations among identical objects. This performance is facilitated by initially encoding the array via the map.

Differences Between the Two Map Tasks

The most striking finding of this study is the effect of the initial map-to-room task on performance in the younger group. When children started with the room-to-map task, their performance was at chance. When this task followed the map-to-room task, their performance was much more accurate, and was even similar to that of the older children. The map-reading experience aided in their ability to make more accurate placements in the subsequent task. This provides support for the benefits of abstract representations to navigation, because the differences found between the tasks are not related to gaining overall experience with the room and the map. If children were getting more accustomed to using the map and the room through experience, we would have seen significant rises in performance both across the map-to-room to room-to-map and room-to-map to map-to-room transitions. The initial room-to-map experience lacked what the initial map-to-room experience provided, and we hypothesized that it was the abstract nature of the map that allowed for better performance.

There were no differences between age groups with regard to performance in the map-to-room to room-to-map transition. This showed that between ages four and five, children could transfer information from a map to a space just like the six, seven,

and eight year olds. This subsequently helped the younger children overcome their difficulty with the room-to-map task, and thus allow them to perform just like the older children. This is further evidence for the idea that symbolic capacity is incremental; performance in one symbolic task aided performance in a more difficult task. When the younger children received the room-to-map task first, their performance was worse compared to the older children who received the room-to-map task first. Therefore, the abstract properties of the map could have allowed children to gain insight into the task that was otherwise inaccessible to them without the initial map-to-room task.

Performance in the map-to-room task was stable, regardless of position, for both age groups. The room-to-map task was much more variable based on position for both groups. However, these effects go in entirely different directions. The younger children benefited from receiving the initial map-to-room experience, but it seems as though the older children benefited the most from having no prior experience with any array with regard to performance in the room-to-map task. The older children performed the best in the room-to-map task when it was presented first. The younger children performed the best in the room-to-map task when it came second.

There may be other factors at play in terms of the differences between the tasks, since each task actually has different demands. The room-to-map task requires one to hold more spatial information about the array since one must think about the spatial relations in a large room, but the placement event in this task is quite easy; one can just extend the hand and place the magnet anywhere on the map. On the other

hand, the map-to-room task may be easier to hold the spatial information since it was all presented in a single glance on the map, but the placement event here requires more effort and energy; one must actually walk over to the corner and place the object in the correct location. The consideration of these corners is also arguably more difficult, since it requires the turning of the head or body to consider each option. On the map, however, all the options are displayed in one glance, allowing each one to be considered with ease.

These differences in difficulty may explain the patterns displayed by the older children, in that they may have been less motivated over time to make accurate placements because of the demands of the tasks. Nonetheless, they were above chance with correct placements across both orders and both tasks, showing that they did have greater insight into the map-room relation than the younger children.

The map may have been helpful because of its abstractness, but it is possible that these benefits may be explained by this easy/difficult framework between the two tasks. Going from map-to-room to room-to-map may be the easier order, and correct placements across both tasks were significantly higher than the reverse order in younger children. The map-to-room task, which arguably requires more energy, came before the easier task, the room-to-map task. This means that the experiment in this condition got easier over time, and could have impacted the motivation and energy that the children had when participating in the experiment. When the order was reversed, it may be considered the more tiring order; the child began with room-to-map, which is the easier task, and if they were tired or unmotivated with the

experiment at this point, it became even harder with the map-to-room task following thereafter.

However, these differences in difficulty do not fully account for the findings. When young children received the room-to-map task first, their performance was much lower than if they received it after the map-to-room task. If the room-to-map task is indeed easier than the other, it does not explain why they are not performing with the same ease when it occurs in both positions. It is even counterintuitive to think that they are performing better in the second block if they are in fact losing motivation as the experiment goes on. The older children show the opposite trend and this may be better explained by the motivational concerns, as those receiving room-to-map first are much better than those receiving the task after the map-to-room task.

What is it about the map-to-room task that allows the younger children to perform better in the subsequent room-to-map task? This could be explained by the two different frameworks discussed in the introduction. The first is the abstract-first advantage, or the idea that abstract representations are more intuitive for transfer of learning. It may be the abstractness of the map that allows for a higher quality representation of the array that is transferred more easily to the room, than the concreteness of the room transferring information to the map. The second is the role of perspective-taking, and because the map presents the entire array in a single glance from a survey-view, it may be easier to think about the spatial relations when given the map.

Before any experience with either array, it seems that the abstract-to-concrete transfer helps in the subsequent concrete-to-abstract task. The concrete-to-abstract

task (room-to-map) is aided by the prior experience, and performance is lower without this prior experience when it is presented first. The difference in difficulty between the two orders of tasks may even amplify this difference, given that the demands of the tasks are easier in the abstract-to-concrete to concrete-to-abstract transfer.

The issue of perspective still remains confounded in this sense. The map presented its information in a single glance while the room required one to integrate each corner into a complete mental representation of the array. Therefore, it may be that the map-to-room task was just easier in the sense that it packaged the information very efficiently. The room-to-map task was affected by the position in which it was presented in. It could be that the initial survey-view given by the map in the map-to-room task aided the younger children in performing better in the room-to-map task, because they now possessed this highly useful survey-view of the array. When the room-to-map task was presented first, this benefit of the survey-view perspective was not present, and therefore younger children had difficulty thinking about the space. The fact that the older children could perform so well without any survey knowledge of the array in the initial room-to-map task shows that they perhaps already conceive of spatial relations in a survey-view perspective.

The effects of position were much stronger in the younger children. Older children across both tasks and both positions were highly successful, despite some minute differences between tasks. The transfer from map-to-room to room-to-map may be more intuitive than the room-to-map to map-to-room transfer, and this may be related to the abstractness of the map, the perspective of the map, or the difficulty

between the tasks. Future research should attempt to tease these concepts apart to get a better picture of the factors that have led the map-to-room task to produce more success. For example, to test the potential benefits of abstract representations, the abstractness of the map can be varied to see if more abstract maps show better performance compared to more concrete maps. To test the role of perspective-taking, perhaps a more route-based map can be presented compared to the survey-view map presented in this study. If performance is still higher with the survey-view map, then this would provide further support for the benefits of survey views for navigation.

Strategies Used to Complete the Tasks

There are several possible strategies one can use to successfully complete the tasks. One strategy is to think about each corner relevant to its position to the red wall, in other words, thinking about “white-white” or “red-white” corners. Another strategy is to think about the corners in terms of left and right, considering corners that are “left of the red wall” or “right of the white wall.” Yet another strategy would not require thinking about the relationships between wall color and corner, but rather maintaining the spatial orientation of the space with relation to the self when moving between the map and the room. In other words, it may require thinking egocentrically about “near” corners versus “far” corners.

Since children were using wall color to guide their placements, it suggests that landmark-based strategies were being used rather than maintaining a mental representation of the space with relation to the self. However, this would not explain why left and right knowledge is not implicated in success in the task. It may be that all of these strategies are being used to varying degrees, and the children using their

left and right are washed out by the presence of other strategies. Perhaps the measure of left and right could have benefited from a much stricter assessment.

It may also be that left and right are not related to map-reading tasks. The visual nature of the map may induce a richer mental representation of the array, and children may have been able to consult this much more reliably than maintaining a sense of left and right. In other words, children could have kept a mental picture of the array in mind when they read the map, rather than thinking about complex linguistic constructions like “left of the red wall” to accurately place the object.

In addition, since the colored wall was perpendicular to the location of the child when she was looking at the map, left and right perhaps is not the correct way to think about the differences between the two corners. Left and right may have been related to disorientation tasks because the child was always at the center of the room; when they approached any of the walls, the differences between corners are either to the left or right. However, the way in which the map was presented and the corners from which the children entered the room did not lend themselves to this distinction between walls (see Appendix for map, Figure 1). It could be impacted by the fact that their initial representation of the colored wall on the map was not in a left-right framework. It would be more appropriate to distinguish between “near” and “far” corners on the colored wall, which would support the idea that children were using egocentric representations of the space to navigate through the room or read the map. In any case, these results show that map use requires a different cognitive operation than the disorientation task.

Mental Rotation

Assessing children's mental rotation abilities is important, given that it may be the basis from which the ability to use maps arises (Peter et al., 2010). We hypothesized that different corners would present different patterns of performance since they require a rotation of the array that was initially presented by the map. We found no differences in performance between corners. There may not be sufficient data for each corner to make meaningful conclusions about children's mental rotation abilities, and as such, more data points should be collected for entry at each corner. However, if the current finding still holds, then it may be that all children encoded the map-room relations independent of perspective, or that they encoded these map-room relations geocentrically. This approach might be limited to the older children, given that younger children tend to think about space with relation to the self (Uttal, 2000; Piaget & Inhelder, 1960).

Limitations and Future Directions

Further studies should be conducted in order to account for the limitations and confounds that this study presents. There was an initial concern about the fact that children were able to see some of the red cloth from where the picture table was placed, meaning that they could associate the red wall much more easily to the map. This should be controlled for in future studies, perhaps because it may impact the differences between the map-to-room and room-to-map tasks.

The order of corners used in the placement events within each task should also be considered. Since every corner is used at least once, there may be another strategy that children could use in making placements. They could keep track of which corners were already used, thereby making conclusions towards the end of each task on which

corners to put the object. This is a major difference with the typical disorientation tasks that utilize a subset of all possible corners. This also means that there are more potential choices, other than the target. Perhaps this could be solved by adding boxes at the center of each wall in addition to those already at the corners, so that there would be more targets than the ones being used, in order to create similar conditions to that of the disorientation task.

Furthermore, the red wall could be eliminated in order to truly assess the ability of children to use the orientation-based, egocentric strategy. Without the red wall, the only tool children have to correctly place the object is maintaining the orientation of the array. This would also be a stronger measure of mental rotation abilities if children are still entering the room at different corners, which would require them to update their mental representation of the space depending on where they are entering the space. If they can align these sparse arrays, then this would be in strong support for geocentric alignment, where the locations of objects are associated with their position in the world, rather than to the self.

However, entering at different corners is still confounded by the length of time that it takes to get to each corner. Corner A is the fastest because children are entering the space right away, however, traveling to B, C, and D take more time, and thus extend the amount of time that children need to think about the spatial relations (see Appendix). Because the door to the room has to stay open behind one of the curtains, corner B actually takes the longest to get to because one needs to go past A, D, and C, in that order. Perhaps corner B is the most difficult not only because it rotates the space by a full 180 degrees but it could also be due to the length of time it

takes to travel there. Having memory trials for every single trial within each task could remedy this problem, since it shows that children have been actively thinking about the spatial relations and have maintained the correct location in their memory.

In order to truly address direction-of-transfer effects, the demands between each task must be equal. Perhaps a long hook or arm could be added to the placements made in the room so that children do not have to walk to each corner but rather just have to put it in the corner via the extended arm. In addition, children could also stand at the opposite wall, instead of in the center of the room, so that all the possible choices of placements are in view and can be considered with minimal need to turn the body or head. The addition of a long arm could also make the task more interesting or fun, improving the potential motivational issues seen in the older group. The tasks should be improved in some way to be more engaging for the older children. Alternatively, much younger children need to be tested in order to see the full trajectory of landmark use from little to no direct landmark use to full indirect landmark use.

The role of perspective remains confounded with these results. Perhaps studies that examine the effect of rotating the map to various degrees could show if they are maintaining a perspective-independent representation of the array. If perspective still has influence on their performance, then the perspective with which the array is shown on a map can be varied. There can be a pure survey-view map, and then a more route-view map that depicts the locations from inside the space. Performance across these two tasks would show whether or not the survey-view is more beneficial than the route-view.

And finally, as previously discussed, perhaps different kinds of maps with differing levels of abstraction may be compared across subjects. A more abstract map with fewer colors (or intentionally altered colors), or a less abstract map with more features and details may be compared in order to assess which is more useful to complete the task. This approach would combine children's spatial and symbolic reasoning.

Conclusion

The current data show that the abstract-to-concrete task provided children with greater insight into the map-room relation than the concrete-to-abstract task. In the younger children, the initial map-to-room experience allowed them to perform like the older children in the subsequent room-to-map task, compared to their poor performance in the reverse order. Older children were successful across both tasks in both positions, showing that they had attained insight into the map-room relation. Age was the strongest predictor of performance, showing how age is implicated in successful map and landmark use beyond the influence of other variables. The beneficial effects of abstract representations have thus been extended to include the successful transfer of spatial information. Further research should tease apart these factors in order to arrive at a clearer picture of landmark use, map use, mental rotation, and other possible advantages of abstractness to learning in the spatial domain.

References

Baldwin, D. A. (1995). Understanding the link between joint attention and language. In C. Moore & P.J. Dunham (Eds.). *Joint attention: Its origins and role in development* (pp. 131-158). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Christensen, A. E., & Liben, L. S. (2011). Not all map use is created equal: Effects of task demands on children's environmental learning. Poster presented at the Biennial Meeting of the Society for Research on Child Development, March 31 – Apr 2, Montreal, QC.

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

DeLoache, J. S. (1991). Symbolic functioning in very young children: Understanding of pictures and models. *Child Development, 62,* 736-752.

DeLoache, J. S. (2004). Becoming symbol-minded. *Trends in Cognitive Sciences, 8*(2), 66-70. doi:10.1016/j.tics.2003.12.2004

DeLoache, J. S., & Burns, N. M. (1993). Symbolic development in young children: Understanding models and pictures. In C. Pratt & A. Garton (Eds.) *Systems of representation in children: Development and use.* (pp. 91 – 112). Oxford, England: John Wiley & Sons.

DeLoache, J. S., & Marzolf, D. P. (1992). When a picture is not worth a thousand words: Young children's understanding of pictures and models. *Cognitive Development, 7,* 317-329.

DeLoache, J. S., Miller, K. F., & Rosengren, K. S. (1997). The credible shrinking room: Very young children's performance with symbolic and non-symbolic relations. *Psychological Science, 8,* 308-313.

DeLoache, J. S., & Sharon, T. (2005). Symbols and similarity: You can get too much of a good thing. *Journal of Cognition and Development, 6*(1), 33-49.

Downs, R. M., & Liben, L. S. (1987). Children's understanding of maps. In P. Ellen & C. Thinus-Blanc (Eds.), *Cognitive processes and spatial orientation in animal and man: Vol. 2. Neurophysiology and development aspects.* Dordrecht: Martinus Nijhoff.

Gauvain, M., & Rogoff, B. (1986). Influence of the goal on children's exploration and memory of large-scale space. *Developmental Psychology, 22,* 72-77.

Hamlin, J. K., Wynn, K., & Bloom, P. (2007). Social evaluation by preverbal infants. *Nature, 450,* 557-560.

Herman, J. F., Shiraki, J. H., & Miller, B. S. (1985). Young children's ability to infer spatial relationships: Evidence from a large, familiar environment. *Child Development, 56,* 1195-1203.

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

Hermer-Vasquez, L., Moffet, A., & Munkholm, P. (2001). Language, space, and the development of cognitive flexibility in humans: The case of two spatial memory tasks. *Cognition, 79,* 263-299.

Hoyos, C., Nuzzi, L., & Shusterman, A. (2011). Left-right language predicts children's landmark use in a disorientation task. Poster presented at the Biennial Meeting of the Society for Research on Child Development, March 31 – Apr 2, Montreal, QC.

Huttenlocher, J., Vasilyeva, M., Newcombe, N., & Duffy, S. (2008). Developing symbolic capacity one step at a time. *Cognition, 106,* 1-12.

Kaminski, J. A., Sloutsky, V. M., & Heckler, A. F. (2008). The advantage of abstract examples in learning math. *Science, 320,* 454-455.

Lee, S. A., Shusterman, A., & Spelke, E. (2006). Reorientation and landmark-guided search in children: Evidence for two systems. *Psychological Science, 17*(7), 89-96.

Lewis, D. (1976). Observations on route finding and spatial orientation among the aboriginal peoples of the western desert region of central Australia. *Oceania, 46,* 249-282.

Leyva, D., & Wiser, M. (2006). *Drawing and reading simple maps in four-year-olds: Exploring a new symbolic domain.* Poster presented at the Annual Meeting of the Jean Piaget Society (JPS). Baltimore, MD.

Liben, L. S., Kastens, K. A., & Stevenson, L. M. (2002). Real-world knowledge through real-world maps: A developmental guide for navigating the educational terrain. *Developmental Review, 22,* 267-322.

Liben, L. S., & Yekel, C. A. (1996). Preschoolers' understanding of plan and oblique maps: The role of geometric and representational correspondence. *Child Development, 67,* 2780- 2796.

Lourenco, S. F., Huttenlocher, J., & Vasilyeva, M. (2005). Toddler's representations of space : The role of viewer perspective. *Psychological Science, 16*(4), 255-259.

Peter, M., Gluck, J., & Beiglbock, W. (2010). Map understanding as a developmental marker in childhood. *Journal of Individual Differences, 31*(2), 64-67 doi:10.1027/1614-0001/a000011

Piaget, J., Inhelder, B., & Szeminska, A. (1960). *The child's conception of geometry.* New York: Norton.

Pyers, J. E., Shusterman, A., Senghas, A., Spelke, E. S., & Emmorey, K. (2010). Evidence from an emerging sign language reveals that language supports spatial cognition. *PNAS, 107*(27), 12116-12120.

Rieser, J. J., Doxsey, P. A., McCarrell, N. S., & Brooks, P. H. (1982). Wayfinding and toddlers' use of information from an aerial view of a maze. *Developmental Psychology, 18,* 714-720.

Shusterman, A., Lee, S. A., & Spelke, E. S. (accepted). Cognitive effects of language on human navigation. *Cognition.*

Shusterman, A., & Spelke, E. (2005). Language and the development of spatial reasoning. In P. Carruthers, S. Laurence, and S. Stich (Eds.), *The Structure of the Innate Mind.* Oxford University Press.

Sloutsky, V. M., Kaminski, J. A., & Heckler, A. F. (2005). The advantage of simple symbols for learning and transfer. *Psychonomic Bulletin & Review, 12*(3), 508-513.

Tomasello, M. (2000). *The Cultural Origins of Human Cognition.* Cambridge, MA: Harvard University Press.

Taylor, H. A., & Tversky, B. (1992). Spatial mental models derived from survey and route descriptions. *Journal of Memory and Language, 31,* 261-292.

Tversky, B. (1996). Spatial perspective in descriptions. In P. Bloom, M. A. Peterson, L. Nadel & M. F. Garrett (Eds.), *Language, speech, and communication* (pp. 463 – 491). Cambridge, MA: MIT Press/Bradford Books.

Uttal, D. H. (2000). Seeing the big picture: Map use and the development of spatial cognition. *Developmental Science, 3*(3), 247-286.

Uttal, D. H., Liu, L. L., & DeLoache, J. S. (2005). Concreteness and symbolic development. In L. Balter & C. Tamis-LeMonda (Eds.), *Child psychology: A handbook of contemporary issues* (2nd Ed.) (pp. 167-184). Philadelphia, PA: Psychology Press.

Uttal, D. H., & Wellman, H. M. (1989). Children's mental representation of spatial information acquired from maps. *Developmental Psychology, 25,* 128-138.

Vasilyeva, M., & Huttenlocher, J. (2004). Early development of scaling ability. *Developmental Psychology, 40*(5), 682-690.

Wohlgelernter, S., Diesendruck, G., & Markson, L. (2010). What is a conventional object function? The effects of intentionality and consistency of use. *Journal of Cognition and Development*, *11*(3), 269 – 292.

Appendix

Figure 1. The map of the space (letters were not included when shown to children).

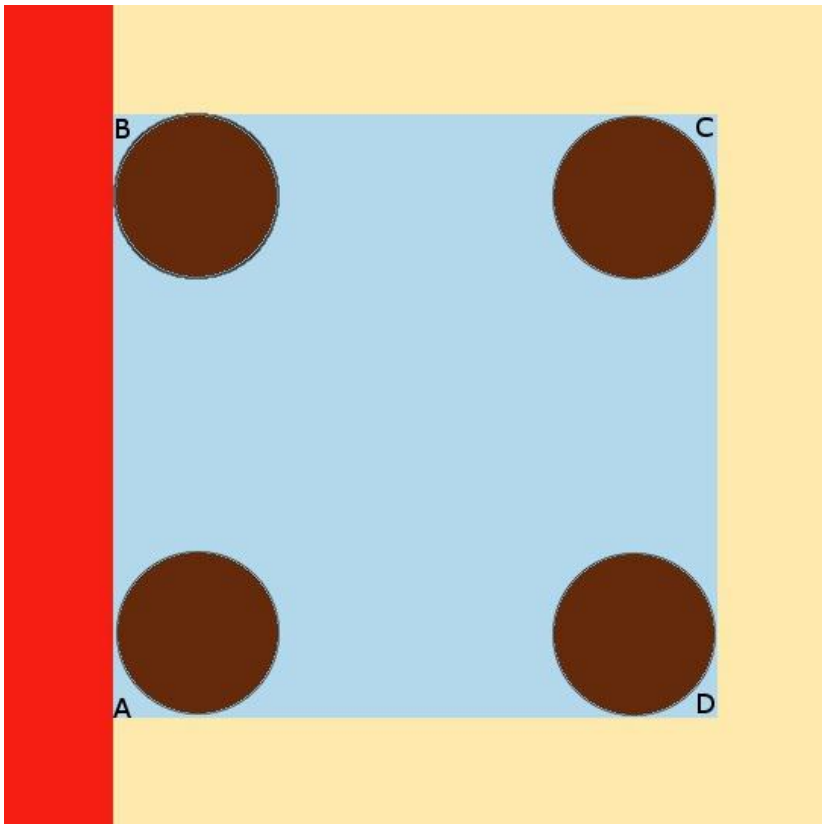

Figure 2. Younger children's performance across tasks modulated by the position of the room-to-map task.

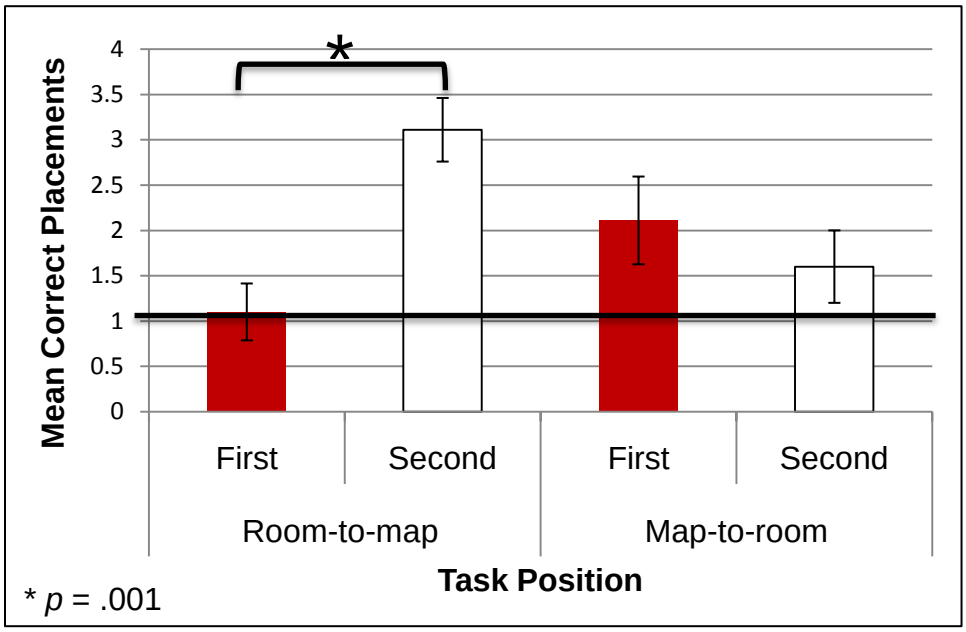

Figure 3. Older children's performance across tasks modulated by the position of the room-to-map task.

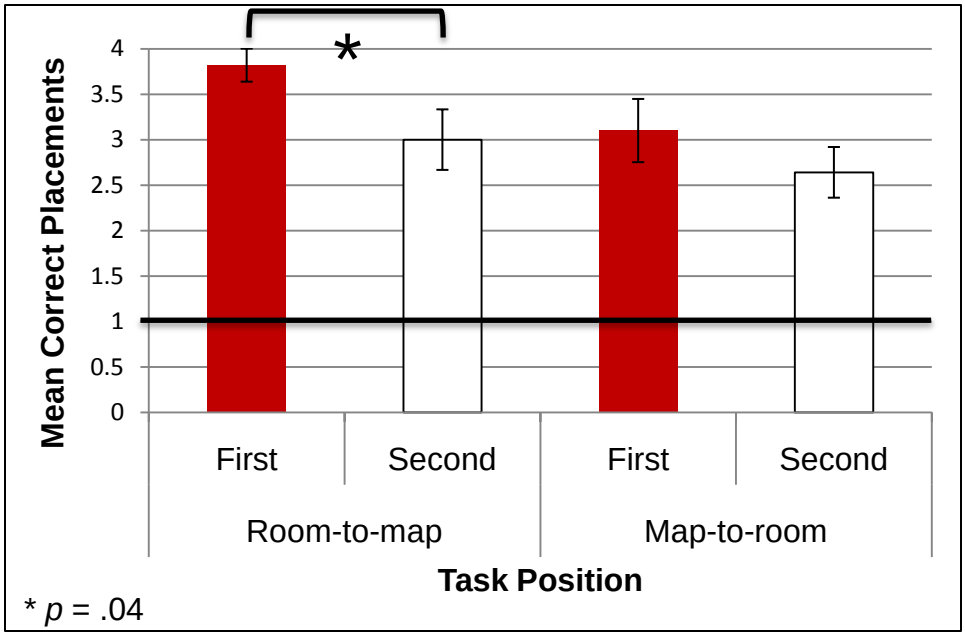
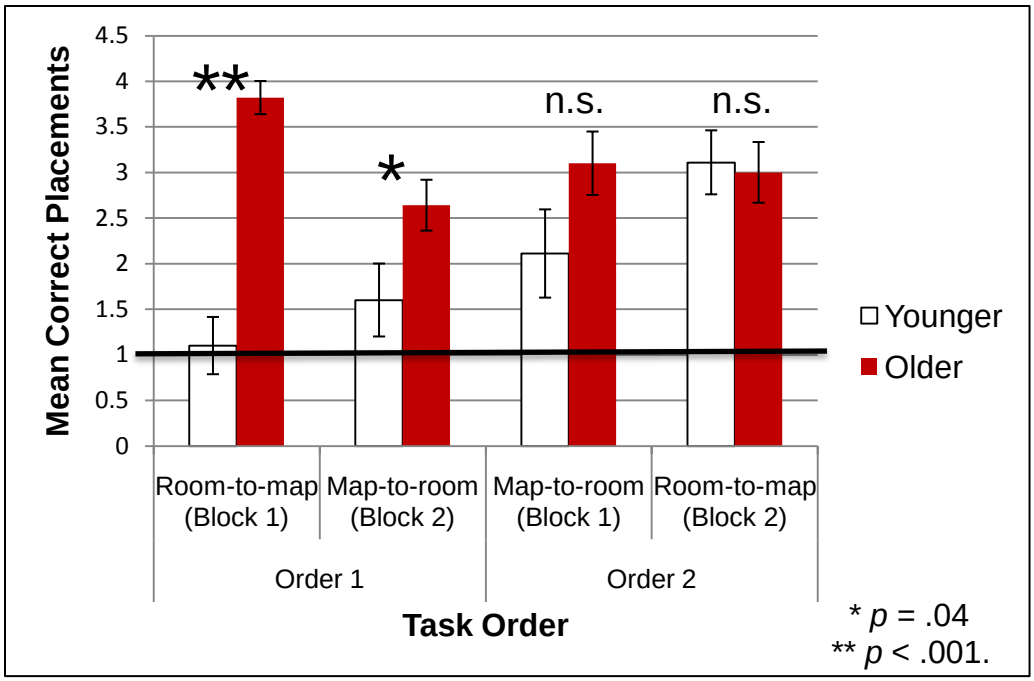
Figure 4. Younger children perform like older children when they received the map-to-room task.