Children's Comprehension Of Spatial Location In Different Spaces

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Research in geography education must be inspired by the elements and standards outlined in Geography for Life, National Geography Standards. The first essential element, "The world in spatial terms" outlines the analysis and internal and external representation of geographic and spatial information as a primary goal of geographic educators. Before this is possible it is important to understand how geographic and spatial knowledge is acquired in the variety of spaces in which children learn and in which geographic information is presented. This experiment examines the geographic understanding of space by 3rd grade students in two distinctly different geographic spaces, as expressed through their recall of spatial location. A desktop space is used to simulate the space at which the majority of school learning occurs while an outdoor environment (laid out on the school playground) is used to simulate the more extensive space of everyday geographic interactions. Results of this study will improve our understanding of how size and scale affect geographic and spatial knowledge acquisition and will inform geographic educators who are interested in developing curriculum involving different types of spaces.

Keywords: *geography education, spatial cognition, scale.*

INTRODUCTION

For the benefit of the geography teacher *Geography for Life, National Geography Standards*, outlines the essential elements of the geographically informed person. It does so through 18 standards that when met will lead to a comprehensive understanding of these elements (Geography Education Standards Project [U.S.], American Geographical Society of New York, Association of American Geographers, National Council for Geographic Education, & National Geographic Society [U.S.], 1994). The first element, The World in Spatial Terms, includes the representation of space, both externally (maps, Geographic Information System, descriptions, diagrams, etc.) and internally (mental models), and the analysis of the spatial organization of the Earth's surface (Geography Education Standards

Project (U.S.), American Geographical Society of New York, Association of American Geographers, National Council for Geographic Education, & National Geographic Society (U.S.), 1994). From this we can safely conclude that mental models of space are an essential element in the discovery of geography. The goal of this paper is to present research that helps us better understand how children process spatial information at different scales. Specifically, it examines whether spatial and geographic information in small and large spaces is encoded, stored, and recalled differently. The outcome of this research is important for a number of reasons. The majority of external spatial representations are presented (and most useful) in small desktop size spaces (either paper maps or diagrams, or screen displayed GIS maps), while the spaces they represent exist at a much larger size. Ignoring for the moment the relationships inherent between a representation of a space and the space itself, if spatial knowledge acquired in large and small spaces is different, then the way a child learns about geography in those two spaces may be affected. Additionally, many geographic processes and concepts that are taught in the classroom (with or without the use of maps and models) occur in dramatically larger spaces on the Earth's surface. Therefore, it is essential that we understand the differences between mental models produced for geographic information in different size spaces.

Are human behavior and knowledge acquisition affected by spatial scale? As suggested by Lockman and Pick (1984), this is an important question for revealing how spatial information is processed. Answering this question will help reveal the relationship between scale, spatial behavior and development, as well as help us better understand the development of spatial skills and abilities. All of these elements are essential to developing geographic curriculum. The pervasiveness of scale in geography and other spatial sciences demonstrates the important role it plays in human spatial behavior and that its role must be understood to evaluate effectively our general knowledge of spatial behavior.

Space can be subdivided and categorized in many different ways. That we must develop skills for dealing with varied spaces implies that we have a wide variety of tools and abilities for dealing with spatial information and for making spatial decisions. Evidence suggests that spatial behavior in different scale (size) environments is driven by different cognitive processes of encoding, internal manipulation, and decoding (Lockman & Pick, 1984). If this is the case, it is important that geographers develop a better understanding of how spatial knowledge is acquired in different size spaces.

The developmental importance of these issues should not be ignored. A clearer understanding of how children process spatial information can provide critical information relating to how well they understand spatial concepts and what they may or may not understand about different spaces at different ages. The majority of developmental spatial research has focused on what is generally called small-scale space, or the space of manipulation. Furthermore, when "large" spaces are used, they are generally nothing more than a functionally small space (a single room) subdivided such that portions of the environment are occluded from view (Weatherford, 1981). Although these spaces require different modes of integration in order to develop a comprehensive mental model of the space, they are not different in size (Ittelson, 1973; Montello, 1993). Integrating spatial knowledge through different modes of interaction (single perspective vs. requiring navigation) has been shown to affect the accuracy and flexibility of the knowledge, but is not the only characteristic of a space that determines how that space is understood (Presson, DeLange, & Hazelrigg, 1989; Richardson, Montello, & Hegarty, 1998; Thorndyke & Hayes-Roth, 1982). This research will examine how changing the size of the environment affects the accuracy and nature of spatial and geographic knowledge.

It is important for many reasons to understand how different size spaces are internally represented. Geography, cognitive science, and education all stand to benefit from an improved understanding of the impact of size and scale on spatial cognition. The purpose of this research is to examine how location recall of objects is affected by changes in the size of the space in which the locations are presented. This is examined by having children encode and recall spatial locations in two different size spaces; one small desktop space and one large environmental space. The patterns of their recall error will help uncover how accurately children represent these two different size spaces. If size affects how space is understood and internally represented, then the manner in which the spatial information is coded and recalled should also be different.

Background

Children and adults interact with their surrounding environment in many ways. Many of our day-to-day activities require complex skills and knowledge, including spatial knowledge acquisition and decision-making. Not only do we participate in activities in formal settings (school and work), we also engage in many informal activities that require similar skills and abilities. In particular, children are faced with many different opportunities and environments that have received very little attention in quantitative developmental research. It is the goal of this research to explore the nature of some of these environments and how children acquire spatial knowledge at different scales.

Classroom activities occur in constrained built spaces that include authority relationships, not only between the teacher and student, but also with respect to the space and the student. The child has little control over the space and its character. Even within the classroom there are diverse spatial experiences available to children. Whether working individually or working in an open space with others, a child's experience and the spatial decisions that are made are shaped by the space in which the activity takes place. Educational activities pursued in the classroom space and during outdoor free play exist on opposite ends of a continuum along which children's spatial experiences can be categorized. In between exist numerous activities and experiences that make up a child's daily lives and contribute to his or her social, intellectual, and psychological development.

Children encounter spatial information in a variety of situations. Individual situations can be dramatically different although on the surface they may seem similar. Perhaps the most eagerly anticipated time for children is when school is out of session and they are afforded time for free play. Hart (1979) spent many months with a community of children observing them in this situation and learned a great deal about how children interact with one another and with their environment during their free play time. This study revealed that children experience space and the environment in a variety of situations, many of them beyond the supervision of adults and in much larger scale spaces than those experienced during their time at school or playing indoors.

Scale

Scale can be defined in numerous ways and is an integral component in the study of any spatial system. Further, scale plays an important role in human interactions in and with space. Along with the multiple definitions of scale there have been numerous attempts to categorize space with respect to various indices of scale (Ittelson, 1973; Lockman & Pick, 1984; Montello, 1993). Changes in scale impact our interactions with space; not only can our direct relationship with the space be changed, but the degree to which we can perceive the entire space from a single vantage point can be altered (Larsen & Abravanel, 1972; Lockman & Pick, 1984; Roskos-Ewoldsen, McNamara, Shelton, & Carr, 1998; Weatherford, 1982).

The standard use of scale by geographers relates to the production of representations of space. Maps, charts, GIS, models, and diagrams all rely on scale transformations in order to accurately represent spaces that are not normally accessible from a single perspective or without special equipment. By setting the scale of a representation, the spatial relationships between objects can be transformed such that their accuracy is not compromised but the viewing of them is facilitated. Cartographic scale is traditionally defined as the ratio between the referent and its representation. Therefore, a large scale cartographic map represents a small area (as in a 1:1000 scale map of the University of California, Santa Barbara campus), while a small scale map can represent a much larger space (as is the case with the 1:500,000 scale geologic map of Colorado). On the other hand, many people refer to scale as the size of a space in which a problem is faced. Thus a large-scale space would have a relatively larger extent than a small-scale space. Montello (1993) argues that it is the relationship between a person (and the possible actions that the person can take) and the size of a space that is most relevant to how humans act and solve problems in those spaces. He describes a classification of space that includes six categories, including miniscule, figural (further subdivided into pictorial and object), vista, environmental, geographical, and gigantic. Each of these spaces is qualitatively distinct from the others in the way it is perceived and subsequently represented internally.

Lockman and Pick (1984) have previously discussed research and theory pertaining to the importance of size in spatial cognition, behavior, and development. They argued that not only are problems faced in spaces of different size, but that children and adults react directly and indirectly to changes in size (Lockman & Pick, 1984). Direct responses to a change in size provide evidence for quantitative differences in perception and cognition of size information, while indirect behavioral responses in different size spaces is evidence for qualitative differences resulting from changes in spatial extent, or size (Lockman & Pick, 1984).

Geographers have traditionally been interested in spaces varying widely in their extent and the functional nature of the activities that take place in them. Garling and Golledge (1987) characterized small, medium, and large-scale spaces. This classification drops the explicit distinction of method of integration (single perspective vs. requiring navigation), although it does imply a need for extended and necessarily piecemeal knowledge integration, particularly with respect to large-scale spaces (Garling & Golledge, 1987). In Mandler's (1983) and Garling and Golledge's (1987) medium-scale spaces, the spatial relations can be viewed from a single perspective, although Mandler (1983) does explicitly indicate that complete viewing is only possible via locomotion through the space.

There are a number of physical and information processing differences between different size spaces. The manner in which knowledge is acquired and integrated is perhaps the most important to geographers and cognitive scientists. The type of direct interaction afforded by a space will vary with the size of the space (Ittelson, 1973). The actual distances between objects in a referent and represented space will be different if only a scale transformation is made between the two spaces, as is the case in this research. Perhaps most obviously, the extent (or size) of the spaces and the viewing perspective afforded by them will be different in spaces of different size. This is the most relevant difference with respect to this research, as all physical relationships between the two experimental spaces are the same, given the scale transformation. For the research presented here, two experimental spaces were selected; one large and potentially navigable, and one small, offering interaction only from beyond the space's boundaries. The only difference is the potential interaction one could have with each space. The large space (playground) affords movement within and through the space, while the smaller space (desktop) only allows one the ability to reach into the space from beyond its physical extent.

Large environments offer the viewer many different perspectives from which to learn about the occurrences present in that space and the relationships among them (Ittelson, 1973). These environments can be viewed from outside or from within, they can be explored actively as in goal-directed navigation or they can be viewed from a stationary perspective. A large space offering this rich array of opportunities for acquiring and integrating spatial knowledge can influence the internal representation that will be developed as a result of interacting with and acting in that space, even if the interaction is static and from a perspective outside the space. This might be considered the experience that an individual is afforded by that space. As an example, take the view of a city from above; perhaps from a plane as you are about to land at the airport. The many possibilities that the real environment holds for you affect the nature of your integration of that information. This is quite different than the experience of viewing your desk cluttered with books, articles, your computer, etc. The latter space will not be explored at any time with the same navigational goals as will the city, although items on the desk might be rearranged in order to find something that is hidden beneath them. If further exploration of a desktop and environmental space is required, two different procedures are followed. In the environmental space, individuals would enter the space and actively explore using locomotion and navigation to maneuver through the space, changing their perspective with respect to the more permanent objects. Smaller desktop spaces can only be viewed from the outside, predetermining the nature of the interaction one will have with that space. In the desktop space, objects are rearranged in order to change the relationships between them, while the perspective from which the space is viewed remains unchanged.

Spatial Cognition

Theoretical and empirical background for the study of children's acquisition of spatial knowledge in different scale spaces comes from a variety of sources. The following section outlines the general nature of child development, as well as presents specific background for the study of children's spatial cognition in different size spaces.

Where possible, I refer to research that deals with either desktop spaces or environmental spaces, or on rare occasions, both.

Piaget and his colleagues (1956, 1960) have done the most extensive work on children's spatial development. Although generally limited to small-scale and representational spaces, Piaget contributed significantly to our understanding of general development in all spaces (Piaget, 1954; Piaget, 1960; Piaget & Inhelder, 1956). Piaget's main belief concerning location coding in children is that it develops from a purely egocentric to an allocentric topological skill. He did not believe that accurate coding of spatial location was possible until a child was at least nine or ten years old and had developed the ability to code metric information. Also of interest to this research is Piaget's work on perspective taking, as measured by the three mountain task, in which children are asked to look at a desktop model of three mountains (occluding each other from various perspectives) and tell an experimenter what someone would see from a perspective other than their own. Researchers have recently argued that Piaget's use of representations of the experimental environment confounded the results, and that perspective taking ability might be present at a much younger age than previous thought (Newcombe & Huttenlocher, 1992). Although Piaget has been criticized on topics central to this research, his contributions to understanding the order of skill development in children cannot be overlooked and has provided a guideline for the bulk of developmental research conducted over the last 40 years.

Contemporary work on children's spatial cognition, as it relates directly to the proposed study, falls into one of two categories: location recall, or the use of different representations and models. The latter will be discussed in the following section. Location recall by children, infants, and toddlers has focused on a number of cognitive and perceptual topics. Newcombe, Huttenlocher and their associates (1998, 1994) have shown surprisingly accurate recall of spatial location of single objects by children as young as sixteen months. In these cases, a single play object is hidden in a small, rectangular sandbox and the child is encouraged to retrieve it (Huttenlocher, Hedges, & Duncan, 1991; Huttenlocher, Newcombe, & Sandberg, 1994; Newcombe, Huttenlocher, Drummey, & Wiley, 1998). Additional research suggests that location within a featureless area will often be placed towards the prototypical center of the space (Huttenlocher, Hedges, & Duncan, 1991). With older children, Acredolo (1977) was able to show that five-year old children could find a previously learned location without the aid of landmarks in environmental space, but that three- and four-year old children were unable to do so. Additionally, the four-year old children improved their performance when instructions were given about the perspective from which they had learned the space, showing a clear development in the ability to locate objects in space with and without landmarks present (Acredolo, 1977). In 1982, Herman and his colleagues examined kindergarten and third grade children's ability to recall spatial locations in a large-scale space (room size space). He compared different viewing perspectives (walking through the space and viewing the space from outside) as well as different layouts (model town vs. an array of toys). He found that while there was no effect of viewing perspective, there was a significant difference between the two layouts. This suggests that for a room sized space (in this case labeled a large-scale space), viewing perspective is not the most important attribute contributing to knowledge acquisition (Herman, Roth, Miranda, & Getz, 1982). Additional research by Herman has shown that the ability to make judgements in unbounded space develops after the ability to make judgements in bounded spaces (Herman & Siegel, 1978). This body of evidence suggests that children are capable of accurately recalling location at a very young age (although with varying non-systematic errors) and that certain environmental characteristics can contribute to improved performance (orientation, boundedness, type of layout, etc.).

Not only does location and perspective taking develop with respect to locating individual and multiple objects in space, but also with the ability to discern location in different fields surrounding the individual. There is evidence that younger children (four years and under) are able to solve perspective problems in the near/far fields but not the left/right fields, while 5-year-old children perform equally well in both fields (Newcombe & Huttenlocher, 1992). These are exactly the frames of reference that would be utilized during the coding of spatial locations in the two experimental spaces used in this study.

Representations and Models

Research in different scale spaces has included the use of representations of space by children: particularly the use of maps, models, and various types of photographs (Blades & Spencer, 1987; Blaut, 1991; Blaut, 1997a; Blaut, 1997b; DeLoache, 1989; DeLoache, 1990; Downs & Liben, 1988; Liben, 1997; Liben & Downs, 1992; Liben & Downs, 1993; Liben & Downs, 1997). DeLoache (1990) has shown that very young children are capable of finding a play object hidden in a referent space (large space) after viewing the object being hidden in a smaller model of the space. Interestingly, at even younger ages, when children are incapable of this task and they are told that the model in which the object is originally hidden is being placed in a machine that is making it larger, they are subsequently able to find the hidden object in the larger space (DeLoache, Miller, & Rosengren, 1997). Keep in mind that these are very young children (29-33 months), but that the evidence suggests that the use of symbolic representations of space is developed quite early in children and can be used to solve goal directed problems. Perhaps more related to geographic education and education in general is work conducted on the use of maps and aerial photography by Blaut (1991, 1997a, 1997b), Blaut and Stea (1971), and Liben and Downs (1993, 1997). Although they disagree as to the nature of mapping in terms of development, both groups have provided some excellent evidence for the early use of maps by children and the potential for incorporating their findings into a geographic curriculum. One of the most important aspects of this work relates to children's use of symbols, a critical element in any representation. It appears that children's ability to use symbols develops slowly and can be impeded by using symbols that themselves have meaning or are real objects (Deloache, Uttal, & Pierroutsakos, 1998; Uttal, et al., 1998).

The preceding relates directly to the choice of spatial scale for this study. It is clear that children develop the ability to recall object location in a variety of spatial situations at a very young age and that the development of this ability relates not only to the characteristics of the space (presence of landmarks, boundedness, perspective, mode of interaction, etc.), but also to the complexity of the arrangement of objects in the space. If the ability to recall location emerges before the end of the second year and proceeds throughout development, this field of research must be extended to consider the development of abilities in less controlled and larger spaces. In a variety of research settings, environmental learning, for both navigation and object recall type tasks, improves meaningfully between 4-6 years of age and 11-12 years of age (Cornell, Heth, & Broda, 1989; Heth, Cornell, & Alberts, 1997). Not only are older children able to select salient and meaningful landmarks (similar to those selected by adults), they are also able to perform complex goal directed activities that require those landmarks and the accurate recall of their locations and relationships with other objects in an environment (Allen, Kirasic, Siegel, & Herman, 1979; Cornell, Heth, & Broda, 1989).

The following experiment examines how 8- to 9-year old children code and recall spatial location in two different spaces; one small space using handheld manipulable objects, and one large and experiential space using shapes that can be carried but not manipulated easily. The experimental age group was selected because it falls in the middle of the age range indicated above as being critical in the development of large-scale navigational abilities. The two spaces have been designed to provide a comparison between one size space that has been commonly used in developmental spatial cognition research and children's daily educational activities (desktop size space) and another space that has received much less attention, but is integral to understanding how children comprehend geographic and spatial concepts (playground). For the purposes of this experiment, these two spaces, and the interactions that participants have with them, have been closely controlled. Only the size is different; viewing perspective, viewing angle, experimental objects, color, and placement in the environment, along with other critical variables, have been kept consistent for both spaces.

METHODS

Participants

Forty students from three third grade classes at La Patera School in the Goleta Union School District, Goleta, CA, participated as volunteers in the study. There were 21 female participants and 19 male participants. All participants were between the ages of eight and nine (average age: 8.4 yrs.), and were randomly assigned to either the large or small experimental space.

Materials

Children were exposed to one of two experimental environments, either a desktop size space or an environmental size space. The desktop space consisted of a student desk similar to desks and tables at which children work during their normal classroom activities. A 60 centimeter square was displayed on the desk's green surface using yellow tape and acted as the experimental space for the study. The large space consisted of a 30 meter square, delineated by high contrast yellow rope, on the school's grassy (green) playground. The scale relationship between the two spaces was 50:1. A set of seven geometric test objects (sphere, long triangle prism, pyramid, box, rectangle prism, tall triangle prism) were used and were always present near each space (along the outside of the bounding box for each experimental space when not being used during testing). The objects used in each space also had the same size/scale relationship as the spaces, 50:1. The environmental or large space objects were between 0.7 meters and 1.3 meters on their longest axis, while the objects for the desktop space were approximately one to two centimeters along their longest axis. All experimental objects were painted blue for consistency, and five of the seven objects were used in each of five trials. Five arbitrary locations were chosen for the objects in each testing trial and were based on ensuring that no perceivable pattern was apparent and that no single object occluded any other object(s) in the space. The same arbitrary locations and objects were used for all participants, and in both spaces. For trials in the small space, children were asked to place their chins at the end of a ruler extending 15 centimeters from the edge of the experimental space (the tabletop was lowered or raised to reduce discomfort from a potentially awkward sitting position). This helped ensure that the vertical perspective was representative of that offered in the large space when standing at the viewing location, approximately 45 meters from the edge of the experimental space. All children (large space or small space) viewed their experimental spaces from the same perspectives in the school playground. This resulted in a similar background for both spaces and placed both spaces with the same surrounding frame of reference. Each day of trials was devoted to one space or the other so children in the small space group could not simultaneously view the large space, or vice versa. Every care was taken to ensure that the differences between the two experimental spaces were minimized to their relative size (scale difference), in order to allow for conclusions related to the different cognitive processes operating in large and small spaces.

Procedures

The experiment consisted of two phases: a learning phase and a testing phase. During the first phase of the experiment, children observed the locations of five geometric shapes in one of the two experimental spaces. In the second phase, they were asked to reconstruct the array of objects by returning each object to the experimental space in the position they remember it being. Between the two phases, research assistants removed the shapes, and placed them with the two distracter shapes at the side of the experimental space.

Children were told by the researcher that they were playing a memory game called "Where are the shapes?" and that they would be playing the game with the researcher while two of the researcher's friends would be helping them. The experiment was conducted on the school's playground and both spaces were laid out in the same orientation with respect to the surrounding environment. Each participant was asked to remember everything he or she could in the square (either on the desk or in the playground). Each participant was told that they had to remember the shapes in the square and where the shapes were in order to play the game. They were given 20 to 30 seconds to view the array of objects in the space. After viewing the objects, the participant was asked to turn away and the objects were removed from the experimental space. After the objects had been removed the participant turned to face the space again. Each participant was first asked to show the researcher where they remember one of the experimental objects (predetermined by the experimenter) being in the space. This represented their recall of landmark-free (absolute) location with no other reference landmarks available within the space. After placing that object in the space, the participant was then instructed to replace the remaining objects in the experimental space. These locations represented their relative or survey level recall of location. After the first two trials, the instruction to replace the remaining objects was no longer needed, as all participants knew what they were to do during the activity. The resultant X, Y coordinates of each object placed in the space were recorded between trials so that Euclidean distance errors could be calculated and location accuracy assessed.

Design

All comparisons in the location memory task were between subjects. This facilitated the identification of a clearer difference between performance in the two spaces, as well as ensured that participants considered neither space a representation of the other space. This experiment is not concerned with the concept of representations as such, although performance in the smaller space will have implications for children's use of representations, as that space is similar in extent to the space of many spatial representations (maps and models).

Anticipated Results

The dominant trend in the developmental literature suggests that children develop an understanding of proximal spaces prior to the development of abilities in larger, more extended spaces (Piaget and Inhelder, 1956). Unfortunately, few studies have attempted to control for all but the size of the space in which a task is completed in order to draw direct comparisons. It must be remembered that the bulk of a child's free time is spent moving through large complex spaces. Sometimes these spaces are open, like their school playground, and sometimes they are bounded, as in their school classroom or home environment. In both types of spaces, movement is afforded and encouraged. This would lead one to speculate that it is distinctly possible that abilities, particularly spatial abilities, might progress and develop more rapidly in these types of spaces, once freedom is allowed. While it is possible that abilities in small proximal spaces emerge earlier than abilities in larger spaces, this is not the only potential model. By a certain age, children explore spaces which they must traverse in order to appreciate. As this freedom increases so might their spatial understanding of relationships in these spaces. With increased experience, I believe children's spatial abilities that operate in large spaces develop more rapidly than those used in small spaces.

I anticipated differences between the two spaces for the third grade participants. As indicated above, there are two potential outcomes and theories of development that might support each. Early school years are essential for the development of spatial abilities associated with acquiring spatial knowledge in both large and small spaces. If recall is better in the larger space, it might be concluded that environmental spaces are very important for the development of spatial and geographic understanding. Although these results may be contrary to Piagetan theory, there is very little empirical evidence comparing large and small spaces that would indicate spatial abilities in large spaces lag behind abilities in small spaces.

RESULTS

Data collected in both spaces were translated to the scale of the small space to allow a quantitative comparison. Error, reported in centimeters, was calculated based on the Euclidean distance between the correct location of each experimental shape and the location chosen by the participant. Two measures of error were computed for each experimental trial. The error in placing the first object was measured to indicate the participant's recall of absolute or landmark free recall. The average error for all five shapes in each trial (including the first object) was measured to indicate relative or survey level location recall. The first shape (used in calculating absolute location recall) was included in the relative measure because participants were allowed to move any of the shapes to new locations as they placed additional shapes in the space. Therefore, the location of the first shapes was elastic after additional shapes were brought into the space. The initial location and final location for the first shape were recorded if it was moved. Absolute location recall (recall of a single object with no other referent objects in the space) and relative, or survey location recall (recall of object location with other experimental objects in the space), were both examined as aspects of children's location recall abilities.

A repeated measures Analysis of Variance (ANOVA) was conducted on both relative and absolute data. This analytical technique

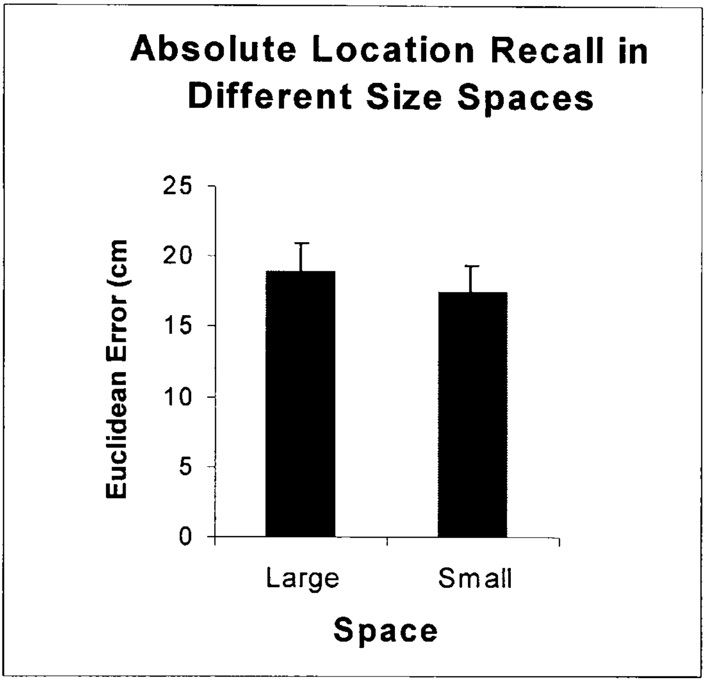

Figure 1. Absolute location recall in different size spaces. Recall is similar for large and small spaces, but overall recall is poor for both spaces in comparison to relative location recall.

made it possible to compare between trials (within subject, within space) and between individuals (between space). It was anticipated that there would be little difference between the individual trials, as all that changed was the location of the 5 experimental objects. This was confirmed; the model indicated that there was negligible difference between the 5 trials for both absolute and relative distance error (absolute: $F(1, 38) = 1.48$, ns, relative: $F(1, 38) = 1.063$, ns)

There was no significant difference between the two spaces when children were recalling absolute spatial location, although error was greater in the larger space than the smaller space ($F(1, 38) = .846$, ns). Average error when recalling the location of the first shape for the large space was 19 centimeters, while error in the small space was 17.5 centimeters (fig. 1). This indicates a certain amount of difficulty determining spatial location in the absence of nearby landmarks or spatial relations in both large and small spaces. This prompted the questions, "How accurately do children recall location

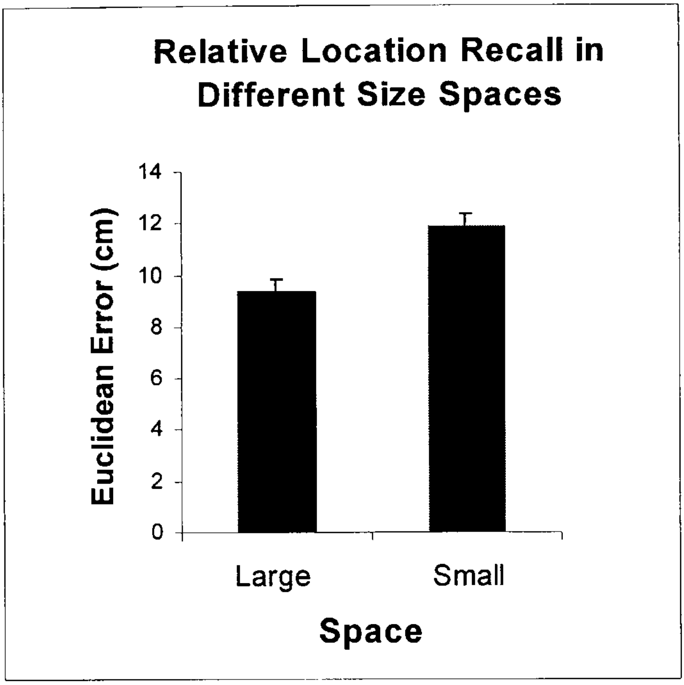

Figure 2. Relative location recall in different spaces. Recall is significantly better in the larger space as well as significantly better for both spaces than absolute location recall.

when they must replace multiple objects in each space? Would the error increase or decrease?"

The accuracy of location recall when other objects or landmarks were present (relative location recall) in the space increased for both spaces. Error for the large space averaged 9.2 centimeters, an improvement of almost 10 centimeters, while error in the small space averaged 11.8 centimeters, an improvement of 5.7 centimeters (fig. 2). This difference was statistically significant in the repeated measures model described above ($F(1, 38) = 7.79, p < .01$). Although there was no difference between the two spaces in absolute location recall, relative location recall was dramatically better in the larger space than in the smaller space. The improvement for both spaces when the children were free to choose and place shapes in the experimental spaces underlines the reliance on relative frames of reference for recalling location at this age. Even more interesting is the significantly more accurate relative location recall in the larger space, as well as a much more dramatic increase in accuracy from absolute to relative location recall in this space. These results would contradict what one might expect if it is assumed that children are more adept and acquire skills in small proximal spaces prior to skills in larger, navigable spaces. These results suggest that the relationship between spatial extent and spatial/geographic abilities in those spaces is more complex than might be concluded from earlier research and theory. Although the results reported here do not indicate that abilities in large spaces emerge prior to abilities in small spaces, they do indicate that abilities in large spaces might be more advanced at one stage in development and that assumptions about spatial size and abilities might need to be re-examined.

CONCLUSION

Many scientists have written about issues dealing with cognition at different scales (Ittelson, 1973; Lockman & Pick, 1984; Montello, 1993; Tversky, Morrison, Franklin, & Bryant, 1999). In addition there has been a variety of research conducted on how children comprehend and make spatial judgements in different spaces (Acredolo, 1977; Herman, Kolker, & Shaw, 1982; Herman, Roth, Miranda, & Getz, 1982; Huttenlocher, Hedges, & Duncan, 1991; Huttenlocher, Newcombe, & Sandberg, 1994; Newcombe, Huttenlocher, Drummey, & Wiley, 1998). Unfortunately, other than Piaget, there has been very little work done that has addressed how children process spatial information and knowledge in different size spaces (Piaget & Inhelder, 1956). Furthermore, work on this issue with mature participants has also been clearly lacking.

Children experience life in many different spaces. They play both inside and outside, in controlled and uncontrolled settings. The same can be said for how they learn and are instructed. Understanding subtle differences in the way children acquire spatial knowledge in different spaces can help us understand much larger issues related to development and education. That children as young as eight years of age can recall spatial location in any size space at the level of accuracy represented by these data indicate that they have a highly accurate basis for making more complex spatial judgements.

The results reported here are only an initial step toward a better understanding of how spatial information in large and small spaces is coded, processed, and recalled. Although there may be few direct applications of these results, they should provide a starting point for further investigation into how location and other spatial concepts are cognized by children. These results also indicate a preference for specific frames of reference when recalling location. The improved recall of spatial location when other objects are present in the experimental space may indicate that children rely on proximal landmarks and, therefore, relative frames of reference for accurately recalling spatial location. Furthermore, it may suggest an inability at this age to use external frames of reference, represented by the bounding box as well as distant landmarks beyond the boundary of both spaces (trees, houses, buildings, etc.). A small amount of spatial complexity in the near environment appears to support a more accurate recall of spatial location, in both large and small spaces, but moreso in large spaces. Recalling a single object in a featureless environment appears to be more difficult which might lead one to believe that this type of task relies on a different type of location coding than recalling the locations of objects within a more complex array of locations.

The significantly more accurate relative location recall in the larger space is additional evidence for the importance of these types of spaces for children. Exploring and experiencing outdoor spaces is an integral component in a child's development (Hart, 1976). Incorporating a variety of spaces into a child's education may allow a teacher to take advantage of optimal learning environments for certain skills, particularly those with a spatial basis. Children may be more at ease learning spatial concepts in spaces in which they are more confident. If accurately solving fundamental spatial tasks is a precursor to comprehending more complex spatial and geographic concepts, the results of this research suggests that activities conducted in larger, experiential spaces may help children develop geographic skills more efficiently and with greater confidence.

Understanding how children code and recall fundamental spatial information is a key piece of knowledge towards a better understanding of how they develop a geographic sense of the world.

Furthermore, it is an important step towards developing curriculum that takes advantage of a child's cognitive strengths rather than constraining them to traditional classroom instruction. Many of the teachers with whom I have discussed this are quite aware of the positive effect of instruction outside the classroom, although in most cases they are on their own when it comes to the development of activities or curriculum that center on outdoor, large environments. That children can think as accurately as they can about spatial concepts and, in some cases, more accurately about large experiential spaces than smaller desktop spaces opens many doors for teacher and researchers alike.

This research was an initial attempt to bring many issues together and offer a "call to arms," so to speak, for developmental scientists, cognitive scientists, and educators. It is hoped that the importance of the issues presented in this paper along with the empirical results of an initial experiment will increase the attention that learning in different size spaces receives by both researchers and educators.

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