Symbol Use and Symbolic Representation:

Developmental and Comparative Perspectives

Emory Symposia in Cognition

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LAWRENCE ERLBAUM ASSOCIATES, PUBLISHERS
2005 Mahwah, New Jersey London

Chapter **1**

Spatial Symbols and Spatial Thought: Cross-Cultural, Developmental, and Historical Perspectives on the Relation Between Map Use and Spatial Cognition

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The following conversation took place on the way to lunch on the first day of the conf'erence that is the basis of this volume:

> LN: I'm taking off guys. I have to do some stuff before the next talk.
> DHU: OK, see you. Oh, wait. We don't know how to get back.
> DM: Don't worry. I'll show you how to get back.
> DHU: Right. I forgot you're from here.
> SW: And it's a good thing she is; otherwise Laura would have to drop bread crumbs.

This everyday conversation illustrates remarkably well the central point of this chapter: Learning about spatial information is often a social and communicative process (Gauvain, 1992, 1993; Uttal, 2000). Without the assistance that other people can provide, we would get lost much more often than we do. Assistance from others may come through direct communication, such as verbal directions (or leaving bread crumbs!), or it may come through less direct media, such as maps.

Given the importance of communicated spatial information, surprisingly little research has been done on this topic. Most research on spatial cognition has focused on how people acquire spatial information on their own, through direct experience navigating in the environment. The emphasis on the (isolated) acquisition of spatial information is probably a legacy of Tolman's (1948) seminal research on how rats and other nonhuman animals (hereafter, animals) acquired information about the layouts of various mazes. Tolman's suggestion that similar processes operated in people and animals sparked an extensive line of research that focused on how organisms acquire spatial information from self-guided navigation (see also O'Keefe & Nadel, 1978).

It is ironic that an aspect of research on spatial cognition in animals actually highlights the importance of communicated spatial information. Researchers must carefully clean the mazes they use after testing each animal. If they do not, the animals can rely on the scent left by prior subjects. Thus, it takes extraordinary efforts to keep animals from relying on information from conspecifics. Moreover, spatial cognition has often been the focus of studies of animal communication. Von Frish's (1993) bees, for example, danced to communicate the location of food, and many other species communicate spatial information (Tomasello & Call, 1997). Put simply, communicated spatial information is critically important for many species, and navigation without assistance from others may be more the exception than the rule.

The main goal of this chapter is to examine the social nature of spatial cognition and the role of culturally embedded symbols (e.g., maps) that people typically use to communicate spatial information. I contend that spatial cognition involves in part the use of culturally constructed mental models of large-scale space that are communicated through maps, verbal descriptions, and other symbol systems. I consider the implications of this theoretical perspective for understanding the development of large-scale spatial cognition, both in individual children and across historical periods.

The chapter is organized into four major sections. In the first section, I discuss the role of scale in spatial cognition. Spatial cognition occurs at many scales, and the cognitive processes that are used to navigate in small-scale space may not work well in large-scale space. In the second section, I argue that knowledge of large-scale space is socially mediated and culturally constructed. Much of this communication is based on culturally embedded mental models of large-scale space. In modem, Western societies, mental models of space are intimately connected to maps. In the third section I consider the implications of this theoretical perspective for research on development, defined both as ontogenetic and historical change. Finally, I present the results of research that demonstrates that maps can influence children's processing of spatial information and their understanding of the layout of spaces.

Spatial Cognition at Multiple Scales

Spatial cognition occurs at multiple scales. In particular, I distinguish often between small-scale and large-scale or geographic-scale space (Montello, 1993; Weatherford, 1982). Small-scale space can. be experienced in a single-glance.

Average-sized rooms thus are prototypical small-scale spaces. In contrast, large-scale space cannot be experienced in a single glance.

Perceptual and cognitive processes that work well in relatively small-scale spaces may not work in larger spaces. Dead reckoning is an example; it involves the integration of rates of speed and the passage of time to obtain distance estimation. Adults (Klatzky, Loomis, Beall, Chance, & Golledge, 1998), children (Newcornbe, Huttenlocher, Drummey, & Wiley, 1998), and many species of animals (Gallistel, 1990) can use dead reckoning in small-scale spaces to return to a goal location, in some cases even when blindfolded.

Dead reckoning is an extremely important cognitive skill, but its use may be limited to relatively small spaces. The reason is that small errors can have catastrophic consequences. An error of .1% might make little difference in a small space, but when multiplied across miles, it could have an enormous effect. The difficulties in using dead reckoning at very large scale are well-known in the history of navigation. Navigators could not reliably determine their longitude at sea; attempts at dead reckoning at this scale often led to dead sailors (Sobel, 1995). A solution took hundreds of years and involved the use of a clock that could keep accurate time at sea.

A more recent example also illustrates why we must be cautious about generalizing the results of research conducted in small-scale spaces to larger-scale spaces. Hermer and Spelke (1996) asked 18- to 24-month-olds to find a toy that was hidden in one comer of a small, rectangular room. The children watched as the experimenter hid the toy. The experimenter then blindfolded the children and spun them around (gently) several times to disorient them. The experimenter then removed the blindfold and asked the children to find the toy. Children searched approximately equally at the correct comer and at the comer that was geometrically equivalent to the correct comer. Moreover, adding a landmark did not affect children's searches. When Hermer and Spelke covered one of the walls with a blue curtain, children continued to search at both the correct and geometrically equivalent comers, even though the landmark (the curtain) would seem to clearly differentiate the two landmarks. In contrast, adults performed almost perfectly when the landmark was present.

Hermer and Spelke concluded that rats and children share a common cognitive module that encodes the shape of the environment. The encoding of shape is presumed to convey an evolutionary advantage. When an organism is disoriented (as the children were in Hermer and Spelke's experiments), then it needs to rely on stable properties of the environment to find its way home. The shape of the environment is perhaps the most stable property and is thus the best candidate for reliable spatial coding. In contrast, landmarks are less reliable or stable. Thus, from an evolutionary perspective, it makes more sense to rely on the stable properties of the environment (shape) than on the less stable properties (e.g., landmarks). Similar arguments have been made from a comparative perspective (see Cheng, 1986; Gouteux & Spelke, 2001; Gallistel, 1990).

A module that encodes only the geometry of a space can work well in a space with a clearly defined shape, such as burrow or cage (Gouteux & Spelke, 2001). Perceiving a rigid shape will, however, become more difficult as the size of the space increases (see Learmonth, Nadel, & Newcombe, 2002). Thus it seems unlikely that this specific cognitive module can work in very large-scale space. This is one, of many, reasons that people often rely on communicated spatial information when navigation in large-scale space.

Navigation in Large-Scale Space

Thus far I have made the case that communicated spatial information is critically important to navigation in large-scale space. In this section I consider in more detail what precisely may be communicated. Often times, spatial communication can be accomplished with simple descriptions, points, or the instruction to "follow me." However, these informal mechanisms will not be sufficient when the distances involved are great, or when there is a need to communicate and share a common view of a large-scale space. Navigating across large-scale space often requires more formal communication and the use of artifacts such as maps. This sort of formalized knowledge of large-scale space is often embedded within a culturally shared (but culturally specific) mental model of the world (Gentner & Stevens, 1983; Hutchins, 1995; Johnson-Laird, 1983).

Mental Models of Large-Scale Space. As used here, the term mental models refers to coherent and systematic representations of systems of knowledge. Examples include mental models of heat flow, the properties of the solar system, and the locations of stars and islands (Gentner & Stevens, 1983; Hutchins, 1995). Mental models help us to understand and communicate information that often times cannot be directly perceived. The notion of mental models fits very well with how people may organize and communicate spatial information. Navigation requires understanding and prediction, often about information, such as distant landmarks, that cannot be readily observed.

Two examples illustrate well that conceptions and communication of large-scale space are often mediated by mental models. Both differ radically from how Westerners think about large-scale space. Nevertheless, both mental models are organized, systematic ways of thinking about large-scale space that support navigation. The first, and perhaps best known, is used by navigators in the Pulawat atoll in the Southwest Pacific. The navigator views his canoe as static, and the stars move across the sky. The positions of out-of-sight islands are located within the framework given by the stars and the relation of the canoe to the stars. The navigators memorize an elaborate system that allows them to predict the appearance of different islands throughout the journey (see Gladwin, 1970; Hutchins, 1995).

The Pulawat model of large-scale space differs dramatically from the modem, Western model. The notion of a stable canoe, for example, with stars moving across the sky is a very foreign concept for most Westerners. Nevertheless, the Pulawat system is clearly a mental model; it provides a systematic way of organizing information about stars, wave patterns, and island locations to support navigation. Moreover, this model serves as the basis for communication of spatial information. It is shared through an apprentice system, which involves both land-based study and navigation experience.

A second example of a mental model of large-scale space that differs radically from the modem, Westem model is found among certain groups of Australian Aborigines (Turnball, 1989). Navigation across open dessert is supported by an extensive, cognitively constructed system of connections between landmarks. These connections (referred to as dreaming or songlines) reflect the cosmology of the navigators. Importantly, the songlines have little perceptible relation to the environment itself. Instead, they are based on folklore and creation myths. A person on "walkabout" can use his or her knowledge of the different songlines to keep track of various landmarks and to plan alternate routes. The locations in the world thus are integrated into a comprehensive mental model that supports prediction and navigation. What makes the information tractable and communicable is the additional organization of these locations into a culturally constructed mental model.

Modern, Western Mental Models of Large-Scale Space. The examples discussed thus far have highlighted mental models that differ dramatically from how people reading this chapter may typically think about large-scale space. This raises the question of precisely what the modem, Western model of large-scale space is. I believe that our conceptions of large-scale spaces are tied intimately to the representation of space on maps.

This discussion requires that I first deal with a common, but incorrect, assumption: that modem maps provide highly accurate representations of the world. This assumption might lead to the view that in modern society we have access to the "correct" information regarding spatial locations in the world. Following this logic, we no longer have a need to construct mental models of the world because we have access to the correct information, through maps. This assumption, however, ignores the fact that maps themselves are models of the world, not copies of it (Downs, 1981). There is no "perfect map"; it is impossible to represent on a two-dimensional sheet of paper three-dimensional spaces in the world. The maps shown in Figure 1.1 are just as "good" or "correct" as any other map of the world. Cartographers must, of necessity, make choices regarding which of the characteristics they will need to distort. They also face the very important question of which features or locations will be represented and which will not be represented. Maps include some information and exclude other information. Put simply, maps are models of the world, not copies of it.

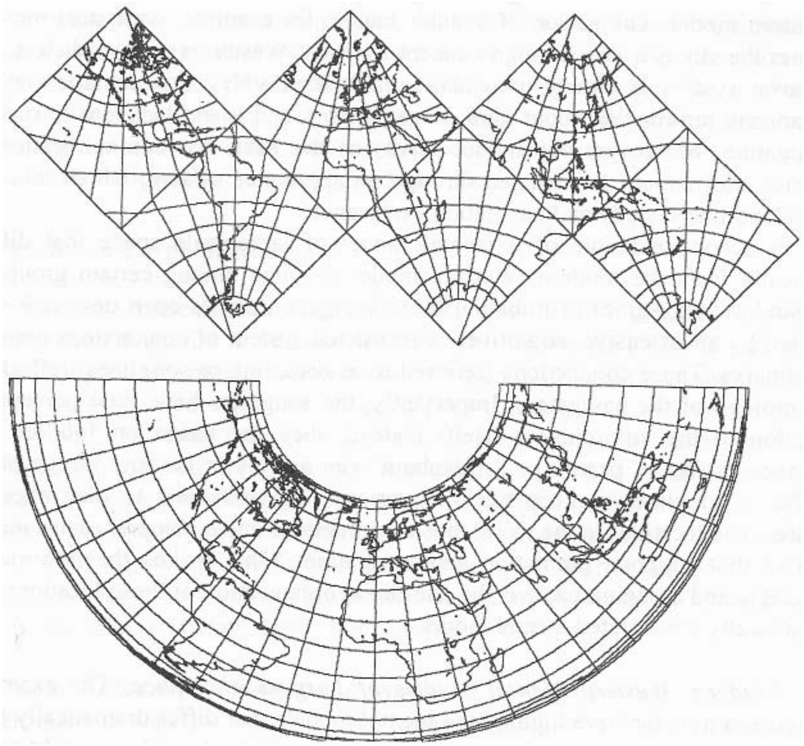

FIG. 1.1. Two examples of map projections. Reproduced from "Gallery of Map Projections": http://www.ilstu.edu/microcam/map_projections/. Permission courtesy of Paul Bryant Anderson.

Wood (1992) put it this way "... all maps, inevitably, unavoidably, necessarily embody their authors' prejudices, biases, and partialities (not to mention the less frequently observed art, curiosity, elegance, focus, care, imagination, attention, intelligence and scholarship their makers' bring to their labor)" (p. 24).

In modem, Western society, the model that maps provide comes to influence how we think about large-scale space (de Certeau, 1984; Uttal, 2000). We begin to think about space in terms of maps because they are nearly ubiquitous; when we think about space, we also often think about maps. As Wood (1992) put it, we live map-immersed in the world, which means "... being so surrounded by and so readily and frequently consulting and producing maps as not to see them as different from the food that is brought to the table or the roof that is overhead or the culture in general that is apparently reproduced, *without effort*" (p. 39).

Other cultures are much less dependent on map use for navigation. For example, in discussing the Micronesian expert navigators, Hutchins (1995) observed that, "The Micronesian navigator holds all the knowledge required for

the voyage in his head. Diagrams are sometimes constructed in the end for pedagogical purposes, but these (of course) are only temporary and are not taken on voyages" (p. 96). Wood (1992) made a similar observation regarding the Zinacantan of the Chiapas highlands in southern Mexico. He wrote, "In the many days I passed there in the home of my friends, I recall seeing but a single map, in the textbook of one of the older boys who was studying Spanish in school. ... Maps do not play the role in their lives that they do in mine. Maps remain special, rare, precious" (p. 39).

The claim that maps have less influence in non-Western mental models of space does not mean that people in non-Western societies do not make or understand some types of maps. They do, but as Hutchins (1995) noted, these maps are used mostly for specific tasks rather than as general artifacts for communicating a model of the world. When it comes to actual navigation, the maps are rarely consulted, as other systems that are not based on maps are seen as more reliable. Maps thus do not necessarily reflect how people think about the world. In contrast, in modem, Western society, we have become so accustomed to thinking about maps that we treat them as ifthey were copies of the world.

A particularly poignant example of cultural differences in map use and mental models of large-scale space comes from the U.S. led military activities in Iraq, which began in 2003. The coalition troops devoted substantial attention and resources to fmding insurgents to prevent attacks. In reviewing why this effort was so difficult, Robert Maass of the ***New York Times*** (2004) wrote of the challenges that one officer, Major John Nagl, faced in attempting to understand and interpret the intelligence information that he receives:

> "There aren't any addresses in this country. The streets don't have names, there are no street signs, there aren't numbers on houses; all the houses look the same." Nagl said he would next offer a map or satellite image to the local and ask him to point out the house. The Iraqi, in most cases, would scratch his head. "These clowns don't know how to read maps," he continued. "So how exactly do I find out which house the bad guy lives in?"

This quote illustrates well that the use of maps is much less ubiquitous in other countries than it is in the United States. It is important to stress that the relative lack of exposure to maps is not a sign of lesser intelligence or spatial ability. Indeed, the Iraqi insurgents were all-too-successful, even though their compatriots seemed to have difficulty understanding maps (or at least American maps). Navigation can be accomplished without maps, and people in non-Western societies may not share with us the immediate association between map use and spatial thinking.

I now turn to a consideration of the specific ways in which using maps may influence spatial information. I discuss the details of the map-based model of large-scale space and point out how it might differ from models that are based on information acquired from direct experience or from verbal communication.

Map-Based Spatial Concepts Are Abstract. First, and most generally, a map-based model of the world allows for the possibility of a separation of spatial thought and travel. Map-mediated concepts of space are *abstract* in the sense that space can be thought of *as space,* independent of how it is experienced, what one might do in that space, etc. (Jammer, 1993).

Maps Depict Space From a Different Perspective. Many (although certainly not all) maps depict spatial relations from above, and thus they allow us to think about the world from a perspective we could not gain easily from direct experience. Hutchins (1995) has written cogently about the effect of this perspective on spatial problem solving, observing that the top-down perspective

> contains some very powerful assumptions about the relation of the problem solver to the space in which the problem is being solved. First, it requires a global representation of the locations of the various pieces of land relative to each other. In addition, it requires a point of view relative to that space which we might call the "bird-eye" view. The problem solver does not (and cannot without an aircraft) actually assume this relation to the world in which the problem is posed. (p. 79)

Maps Highlight Relations Among Locations. When we travel along a route, we may never experience (or even think about) the spatial relations between locations that are not on the route. But when we look at a map, the spatial relation between locations on or off routes is equally available. Thus maps allow us to see, and to think about, spatial relations that are not connected to each other by travel.

Cumulative Effects of Living in a Map-Immersed Culture. A long-term consequence of frequent exposure to maps is the internalization of a map-like view of the world, one that differs fundamentally from the way the world is otherwise perceived. Over time, one becomes used to thinking about space as if it were laid out before one's eyes. The end result is a mental model of the world that is intimately connected to maps. The conceptions of space that we take for granted, that seem so natural, may in fact be partly the result of our long-term interaction with the particular perspective and way-of-knowing that maps provide. "Ultimately, the map presents us with the reality we *know* as differentiated from the reality we see hear and feel" (Wood, 1992, p. 6).

An analogy from another domain of symbolic development, the acquisition of literacy, sheds light on the cognitive consequences of map use. Children enter first grade fluent in at least one language, but they clearly think about language differently than older children and adults do. For example, highly intelligent and fluent first graders struggle to understand something that seems as simple to adults as where to place a period to indicate the end of a sentence. Olson (1994) argued that thinking about language *as language* is in part a consequence of becoming literate. Written language presents a model of language, a model that differs from spoken language. Written language is separated from the communication act in which language typically occurs, and hence additional information, such as punctuation, must be added. Over time, interaction with the written word influences how children think about language, both spoken and written. For example, becoming familiar with punctuation helps children to understand sentence structures, and seeing spaces between words helps to emphasize the divisibility of spoken language into individual words. In summary, metalinguistic awareness is greatly influenced by becoming literate.

A similar process may operate as children learn to think about space through the mediated perspective of maps. Maps provide a ***model*** of space in ways that are analogous to the influences of literacy on metalinguistic awareness. This model could affect substantially how we think about spatial relations. For example, the use of cardinal directions (North, South, East, and West) may be influenced, at least in part, by coming to think about the world in the abstract form that maps afford. Likewise, conceptions of space as geometrically divisible may arise in part as a result of thinking about space from the abstract, top-down, and relational perspective that maps can provide.

The end result of living in a map-immersed culture may be a mental model of space that is tied to maps. Maps, like other symbol systems, amplify aspects of our perception, attention, and cognition (see Bowerman & Choi, 2003; Gentner & Goldin-Meadow, 2003; Hunt & Agnoli, 1991). They become part of the cognitive "tool kit"; they influence thought by focusing attention on a way of seeing the world that differs fundamentally from how it is experienced (Gentner & Goldin-Meadow, 2003; Vygotsky, 1978). Put simply, we learn to think about large-scale space partly through maps, and thus maps, like other symbol systems, come to influence how we think about the information that they represent. Consequently, the acquisition of a model of large-scale space is tied intimately to the way that the information is communicated and represented symbolically. Our mental models of the world cannot be separated from the symbolic representation of the world through maps.

The arguments I have made thus far have obvious developmental implications. We should expect that there would be substantial developmental change in children's large-scale spatial concepts as they acquire and learn to use their culture's spatial mental model. In the next section I consider the developmental implications of the idea that maps influence modem, Western conceptions of large-scale space.

Developmental Implications

Development is not only the acquisition of new forms of representation or of information about specific places, or of the ability to think about more places; it is also in part coming to understand and use the culturally mediated perspective on the world. In modem, Western cultures, development will consist in part of the acquisition of the understanding of a map-based model of the world.

An examination of prior theories of the development of large-scale spatial cognition provides evidence that is consistent with my claims. The end point of development in these theories often is the ability to form mental representations of space that closely resemble modem, Western maps. I interpret this as the consequence of children acquiring the map-based model of the world that I have outlined above. I begin this section by reviewing from this perspective two prior theories of the development of large-scale spatial cognition: those of Siegel and White (1975) and Piaget, Inhelder, and Szeminska (1960). I then consider the developmental origins of map-mediated models by reviewing briefly the developmental course of children's understanding of maps. Finally, I review experimental evidence that is consistent with the claim that maps can influence children's conceptions and use of spatial information.

Siegel and White's Theory. Siegel and White's (1975) theory of the development of large-scale spatial cognition suggests that children pass through three stages that differ primarily in terms of how children mentally represent spatial information. In the first stage, *landmark knowledge,* children's representations of large-scale space are based largely on proximity to landmarks. Preschool children, for example, tend to know locations primarily in terms of their association with well-known features of the environment. A child might represent locations as the "park near the ice cream store," or "the store near the church," etc. What is missing in this representation is any clear association among the various landmarks; the child's representation is an unintegrated series of associations.

In the next stage, *route knowledge,* children encode the sequential ordering of positions along well-known routes. Thus there is now a connection between landmarks, but the representations are connected only in terms of the ordinal position along the route. Route-based representations allow children to make some kinds of judgments but not others. For example, children can estimate, approximately, the relative length of journeys between various points along the route, but they have much more difficulty making judgments about locations that are not on the same route.

In the third and final stage, *survey knowledge,* children can represent large-scale information in a way that differs fundamentally from developmentally earlier forms. Survey representations encode information about the relations among locations, and they allow children (and adults) to make judgments about

spatial relations that are not connected by routes or experienced together on frequent trips. It includes knowledge of multiple relations among multiple locations, or what Levine, Jankovic, and Palij (1982) have termed *equipotentiality*-judgments can be made about any location from any other location. Survey representations thus differ from the other representational formats in that they are abstract and include information about the relations among landmarks, even if those relations have not been experienced directly. Children usually acquire survey representations in middle childhood, at approximately age 8 or later.

The results of studies of children's large-scale spatial cognition are generally consistent with Siegel and White's theory. Young children's knowledge is often tied to the way it has been experienced, often as a series of associations to well-known landmarks or, for slightly older children, as a series of landmarks along a route (e.g., Allen, Kirasic, Siegel, & Herman, 1979).

Piaget, Szeminksa, and Inhelder's Theory. Most of Piaget's research was on small-scale (even table-top tasks), but in chapter 1 of *The Child's Conception of Geometry,* Piaget et al. (1960) reported an investigation of children's knowledge of the layout of particular areas of Geneva. This research was undertaken for a very different reason than Siegel and White's was; Piaget et al. used children's conceptions of large-scale space as a window onto their understanding of geometrical principles, whereas Siegel and White were interested in children's representations of large-scale space per se. Nevertheless, there are many similarities between the two theories and the results obtained in testing these theories.

Piaget et al. asked Genevan children to construct small-scale representations (e.g., models or drawings) of the layout of their neighborhoods. Younger children's constructions were less integrated holistically; the children's representations were piecemeal in general. For example, here is how Piaget et al. (1960) describe the construction of one 6-year-old:

> MIU (6; 10) puts a number of places together in what appears to be a pell-mell arrangement; the building and corridors of the main school, the main school playground, the kindergarten playground and entrance, the gymnasium which is a separate building, and a mound of sand on the bank of the Arve. . . In short, a number of places are bought together by Miu's personal interest, while others show confusion between conceptual similarity and proximity in space. (p. 9)

As this example illustrates, 6-year-olds tended to conflate locations of interest, or those that they experienced frequently, with actual distance. Thus their models were not accurate in an absolute sense. Put simply, the children's constructions did not look like the maps that Piaget et al. were using to assess them. It is also important to note that despite the children's difficulties in Piaget et al.'s tasks, most still seemed to understand the basic requirement to construct some sort of representation of space. That is, the children were not troubled by the representational or symbolic aspects of the task. Instead, their errors are specifically related to their representations of their neighborhoods.

In contrast, older children's constructions were much more accurate and were planned as coordinated wholes from the start. Consequently, their models or drawings looked much more like maps of Geneva than those of the younger children.

Explaining Developmental Changes in Children's Conceptions of Large-Scale Space. Traditionally, developmental changes in children's conceptions of large-scale space have been explained in terms of mental representations of spatial information (Liben, 1999, 2001; Liben, Kastens, & Stevenson, 2002; Piaget et al., 1960) or information processing capacity (Allen et al., 1979; Kail, 1997; Siegel & White, 1975). I argue that the developmental changes could also reflect ontogenetic changes in children's conceptions of maps. Many authors have previously observed relations between survey knowledge and maps (e.g., Tverksy, 1996). I suggest that this similarity is not coincidental. The development of large-scale spatial cognition consists of the acquisition of a map-like (survey) model of the world. Siegel and White and Piaget et al. were picking up on the relevant developmental transitions; their older subjects had acquired a map-like model of large-scale space, while the younger ones had not. Thus the developmental changes that these researchers observed may reflect the transition from encoding of spatial information that is based on how it has been experienced (e.g., as a series of locations along a route) to map-like, abstract, survey representations. The acquisition of survey knowledge may come about partly through learning to view the world through the mediated perspective of maps. Becoming aware of the survey perspective may, in turn, influence how children think about spatial information that they acquire either from maps or from direct experience.

In summary, in most theories of the development of large-scale spatial cognition, the endpoint of development is the ability to think about and represent information in map-like ways. Typically, these developments have been seen as the consequence of underlying changes in representational or information processing capacity. However, the theoretical perspective that I have developed here argues for a different perspective: That the acquisition of survey-like conceptions of maps stems in part from the influences of living in a map-permeated world and coming to understand and use maps.

Development of Children's Understanding of Maps. The discussion thus far suggests that map use may influence children's conception of space. But to be influenced by maps, children must understand how maps work. How do children develop an understanding of maps? What are the developmental milestones in this progression?

As early as age 3, children begin to understand some aspects of the basic, symbolic correspondence between maps and the spaces that they represent. For example, Marzolf and DeLoache (1994) investigated 3-year-olds use of a map in a task analogous to DeLoache's (1987) model task. The child watched as the experimenter indicated on the map where the toy had been hidden in the room. Three-year-olds were able to use the map to find the toy. Other research (Huttenlocher, Newcombe, & Vasilyeva, 1999) has shown that 3-year-olds can use a simple map to find a single hidden toy, an ability that may require scaling or an elementary form of proportional reasoning. By age 4, children can use maps to solve spatial problems involving the relations among two or more locations (Blades & Cooke, 1994; Uttal & Wellman, 1989), and by age ***6***, children can use maps to follow routes through mazes or rooms that require several turns (Bremner & Andreasen 1998; Sandberg & Huttenlocher, 2001).

This research indicates that even young children can understand some aspects of the relation between a map and the space that it represents at an early age. Why then does the map-mediated model of large-scale space not emerge until substantially later, perhaps at around age 8? Several factors come into play. The first concerns an important issue that was mentioned earlier, scale. Almost all studies of children's early understanding of map-space correspondences have been conducted in small-scale spaces (Liben, 1999). It is quite possible that children's early understanding of external spatial representations may be limited to representations of relatively small spaces. A second factor is that the map-mediated view of the world may simply take time to develop. Finally, the acquisition of a map-mediated view of the world may involve exposure to the specific kinds of maps that represent space abstractly and are not tied to travel. Children typically learn about these kinds of maps in the early elementary school years.

More generally, the early development of children's understanding of maps should be construed as the initial insights into map-space correspondences that will provide the foundation for the development of map-mediated conceptions of large-scale space. An analogy to the development of literacy is again useful. Many children begin to know letters and recognize their symbolic properties at an early age, often by 4 and sometimes by 3 (Bialystok, 1996). These accomplishments are precursors to literacy, yet they are far from the end of the developmental story. The influences of literacy on thinking do not become apparent until several years after children make these initial forays into understanding the symbolic properties of letters. I suggest that the same may hold true for the influences of maps on spatial thinking. Young children understand map-space correspondences at an early age, but these understandings are only the beginning of a lengthy developmental process.

Experimental Research on the Influences of Maps. Experimental studies also provide evidence that exposure to maps can influence children's developing conceptions of large-scale space. These studies have for the most part been conducted in small-scale space, but some of their results may be relevant to understanding children's large-scale spatial cognition.

Perhaps the most elegant demonstration of the potential influences of providing map-like information on children's spatial thinking is Rieser, Doxsey, McCarrell, and Brooks' (1982) finding that lifting toddlers above a maze helps them to learn a detour. Children (age 9 to *25* months) were given the task of finding their mothers, who stood behind a barricade in a simple maze. The children watched as their mothers traveled behind the barricade. The experimenter then .brought the children to the front of the maze and let them attempt to find their mothers. Half of the children were held briefly above the maze at the beginning of the experiment, which gave them a perspective that is similar to what they might gain from looking at a map. Children who received this brief exposure to the aerial view performed significantly better than a control group who did not see the maze from above.

Gauvain and Rogoff (1986) conducted a study that parallels Rieser et al.'s in several ways, but with much older children (ages 5 to 8). The critical difference was that children were allowed to *select* on their own the perspective that would give them information that was most relevant to their goal. All children were asked to learn the layout of a series of rooms, in which various activities could be performed. Half of the children were given route instructions; they were told to learn the sequence of rooms in the playhouse. The remaining children were given survey instructions; they were told to learn the relative position of the rooms. The differences in instructions affected children's behavior. The children who were given survey instructions spent significantly more time atop a slide that was placed near the center of the playhouse. From this position, the children gained an aerial (survey-like) view of the maze. Perhaps as a result, they also knew the relations among locations significantly better than children who were given route instructions.

The studies discussed thus far in this section do indicate that exposure to the aerial view can facilitate children's acquisition of survey-like representations of small-scale spaces. However, these studies did not examine the influences of maps per se; in both Rieser et al. (1982) and Gauvain and Rogoff (1986), the children gained the necessary information from direct exposure to the aerial view. Can children also gain a similar advantage from looking at a map? The results of some studies indicate that the answer is yes. For example, Uttal and Wellman (1989) asked 4- to 7-year-olds to learn the layout of a six room playhouse, in which the rooms were arranged in a 2 x 3 matrix. The rooms were identical except for spatial position and the presence of a unique stuffed animal. Half of the children (the *map group)* learned the layout of the playhouse from a simple map before entering the space. The remaining children (the *control group)* did not learn a map, but they did learn what animals could be found in the playhouse. The control group studied simple flash cards with pictures of the toy animals attached. They were given free recall trials until they could recall the animals that they would see in the playhouse twice in a row without error. This design ensured that the unique contribution of seeing the map could be identified. The focus was on how maps might facilitate spatial reasoning, and therefore the researchers wanted both groups to know *what* animals they would find. But only the map group knew *where* the animals could be found.

After learning either the map or the flashcards, the children entered the playhouse and performed several spatial tasks. For example, they were asked to point to rooms that could not be seen from their current position and they were asked to anticipate the locations of animals they would encounter as they traveled through the playhouse. The children who had seen the map before entering performed significantly better on the initial trials, suggesting they had acquired from the map information about the relative positions of the animals.

Toward Investigating the Influences of Maps in Large-Scale Spaces. The studies *I* have reported thus far are consistent with the general claim that looking at a map can enhance children's spatial thinking. However, most have been conducted only in small-scale spaces, and the manipulations have been limited to one-time exposure to maps. There have not been, to my knowledge, follow-up studies with the same children. This is a serious limitation because the theoretical perspective I have advanced suggests that the acquisition of a map-mediated mental model is a rather lengthy one involving true conceptual change. Although it is interesting and important to show that a one-time exposure to a map can facilitate children's spatial thinking in a particular task, longitudinal data will be required to investigate fully the kinds of changes that I believe occur as children become increasingly familiar with map-based representations of large-scale space.

With the help of Clare Davies (Davies & Uttal, 2003), I have begun to provide some of the necessary information regarding how maps may influence children's spatial thinking in large-scale space. Much like Piaget et al. and Siege1 and White, we are assessing children's knowledge of the layout of a familiar space, their neighborhood. However, unlike these earlier researchers, we are exposing half of the children to maps of their neighborhood and are assessing whether, and how, this exposure affects children's representations of their neighborhood. Our specific focus is on whether studying the map helps children to think about spatial information in a manner that transcends how the information has been experienced. Put simply, does looking at a map help children to acquire survey-like knowledge of their neighborhoods? We studied children's knowledge of their neighborhoods because this provides a strong test of the idea that maps can influence children's thinking. We expected that children (ages 7 to 10) would already be familiar with their neighborhood. The important question was this: Would the maps change *how* the children thought about or mentally represented the spatial relations among familiar landmarks.

We began in pilot testing by assessing children's familiarity with a set of Potential landmarks within their neighborhood. We winnowed the number of landmarks to a set that were reasonably well known to the children in our study. We began the main study with a baseline assessment of children's familiarity with the landmarks and of their knowledge of the relations among them. For example, we took children on a walk of the neighborhood and asked them to point to out-of-sight landmarks. After the baseline assessments, the children were assigned to either the *map* or verbal group. The map group studied maps of the neighborhood at the next two sessions. The verbal group provided a control for the effects of learning from the map. These children received extensive training about the locations, but they did not study a map. For example, we described the landmarks in detail, showed pictures, and asked the children about routes they might take between the landmarks. Throughout the session we assessed children's knowledge of the spatial relations among landmarks, in several ways. We used tasks, such as pointing to out-of-sight landmarks, that have been assumed in prior research to require survey-like representations.

The results do show a substantial effect of exposure to the map on children's cognition of the large-scale neighborhood. The children who saw the map were better able, for example, to construct map-like representations, even for landmarks that were not included on the maps. In other situations, however, the results interacted with the sex of the subjects. Boys and girls performed differently when asked to point to unseen locations. Although boys benefited substantially from the map view, girls actually benefited more from the verbal descriptions. Clearly, additional research is needed to outline and detail the consequences of map use in the real world. The benefits of additional training may greatly facilitate children's knowledge. But the evidence available to date strongly suggests that maps can facilitate children's thinking about spatial relations, both in small-scale and large-scale space.

Historical Evidence. The perspective I have outlined also predicts historical change in the development of maps and the influences of maps on this process. Although maps have existed for millennia, they became common only relatively recently. Maps were not available to the general public until well after efficient printing became possible, and even then, printed maps were expensive and rare (Harvey, 1994; Wood, 1992). Maps became a nearly ubiquitous part of American society less than 100 years ago (Wood, 1992).

Historical changes in the existence of maps provide a window for studying the cognitive changes that are associated with map use. "Only when we look at the history can we see just how many problems had to be solved and how many could have been solved differently in the course of the development of the modem practices" (Hutchins, 1995, p. 115). In this section I consider two examples of the historical transition from a relative absence of maps to frequent reliance on maps. The first is the well-documented emergence of maps in Tudor England (Harvey, 1994; Sullivan, 1999), and the second is changes in the representations (maps and charts) that were used at sea.

Changes in Map Use in Tudor England. Harvey (1994) documented a "cartographic revolution" in the uses of maps in Tudor England. In roughly 100 years (from approximately 1500 to 1600), the use of maps increased dramatically in England. The change is well-documented; approximately 25 maps survive from England before 1500, but more than 800 survive from the second half of the next century. Harvey observed,

> By the 1590s not only were maps consulted for a host of purposes by men of affairs, but they were printed on playing-cards, woven into tapestries, engraved on medals and included in illustrations in Bibles. Queen Elizabeth I was painted standing, symbolically, on a map of England. . . . All this would be unthinkable a hundred years earlier, in the reign of Henry VII. . . . It hardly ever occurred to anyone to draw even the simplest sketch-map. (p. 7)

Why was there such a dramatic increase in the use and availability of maps? It seems unlikely that technological changes per se were a primary cause. Certainly the availability of technologies for map-making increased dramatically, but the absence of printing in itself cannot explain the dramatic increase in maps. Texts had been printed and survive in substantial numbers from the same historical period. Likewise, changes in the quality of paper cannot explain the changes, as many texts survive from well before 1500.

Instead, the changes in the number of surviving maps seem to reflect fundamental changes in how people thought about large-scale space. The few maps that survive from before 1500 were drawn for very specific purposes, such as representing a particular route between two towns, planning divisions within an estate, etc. Likewise, navigators sometimes relied on charts, but these were drawn for particular voyages. There were few, if any, maps that represented large areas and that were not tied to specific purposes. During the 1500s, people became accustomed to looking at maps that were designed primarily to represent space *as* space, independent of travel. For example, surveys and plots became associated with real estate transactions (Sullivan, 1999). Thus there was a dramatic increase both in the availability of maps and in their appeal as representations and models of space. Map use and spatial thinking became intertwined.

It appears, then, that the historical changes in map use stem largely from cognitive, rather than technological, development. As people learned more about the world beyond their experience, they needed to archive and communicate this information. Maps, plots, and diagrams served the necessary functions. The greater availability and use of maps then influenced how people thought about space, which in tum led to more demand for maps. From the theoretical perspective advanced here, the most important change was in terms of what people thought about the world beyond their direct experience. The British acquired a top-down, abstract notion of space, one that was not tied to direct experience and that was informed by looking at maps. These changes directly parallel those discussed earlier regarding the development of children's understanding of maps and their conceptions of large-scale space. In both cases, maps are an important contributor to a mental model of the world that is not tied to how spatial information has been experienced.

Navigation at Sea, and the Use of Charts and Maps. Navigation at sea has always been risky business, and the need for better ways to navigate was one of the most important forces that shaped the development of modem maps and other technologies. The historical development of nautical charts parallels the changes that took place in Tudor England. Standard nautical charts, which assume a top-down perspective, developed gradually. Ancient navigators relied on legends, descriptions, and detailed descriptions of the positions of stars. Although these were effective in many situations, they were at times difficult to remember or use. Navigators eventually developed log books, which provided information about ports, landmarks, or other features that a sailor could expect to find along a particular course. These logs were essentially serial listings of features, reflecting the ordering of the locations that a sailor might expect to find. They were written from the same perspective as the referred locations would be experienced on the journey.

The transition to chart-based navigation, which took a perspective from above the ship, was a gradual one. Initially the navigator's perspective was from that at the end of the bow, reflecting how the seaman might see the information as he or she traveled across the water. Eventually, ship navigators, like their land-based counterparts, began to rely on the top-down perspective that maps can provide. This change occurred over several hundred years, reflecting again the conceptual change that is needed to understand a different model of the world (and of looking at the world). (See Vosniadou & Brewer, 1992).

In summary, although maps have existed for thousands of years, maps have become common only in the last 500 years. The dramatic increase in the use of maps has had important effects on people's conception of their world and how they think about spatial information. Walter Ong (1982) has summed up well the influences of maps on large-scale spatial thinking, "Only after print and the extensive experience with maps that print implemented would human beings, when they think about the cosmos or universe or 'world,' think primarily of something laid out before their eyes, as in a modem printed atlas" (p. 73).

Conclusions

Navigating in large-scale space is a fundamentally important problem for people in all cultures. To assist in this task, people often rely on mental models of the world, which are shared through folklore and creation myths. These mental models served as the basis for communication of information that could facilitate

travel, and it is not an exaggeration to say that survival often depended on leaming them.

Perhaps the most important contribution of this chapter is to suggest that modern, Western conceptions of large-scale space are also based on culturally shared mental models. In this case, our models are tied closely to the way we represent large-scale spaces, through maps. This means that development will consist at least in part of the acquisition of a culturally mediated model of large-scale space, one that is intimately connected to the abstract representation of space through maps. Prior theories of the development of large-scale spatial cognition can be reinterpreted from a perspective that emphasizes the role of maps on spatial thinking. The end point of development in classic theories of large-scale spatial cognition, such as those of Siege1 and White (1975) and Piaget et al. (1960) may well be the acquisition of a map-based model of the world. Maps, like other symbols, influence thinking by focusing attention and by giving us new ways to think about the information that they represent.

Finally, the theoretical perspective I have outlined here also has implications for understanding the future development of large-scale spatial cognition and the influences of symbol systems on these developments. **As** we become more reliant on new technologies for representing the world, it is possible that our conceptions of large-scale space may also change. In other words, it is possible now to convey large-scale spatial knowledge as a series of procedural steps. Navigation systems based on global positioning systems can make it possible for people to navigate across the country without reference to maps. How will the widespread availability of GPS-based navigation systems affect our conceptions of large-scale space? Currently, many people who own GPS systems are also very interested in maps and in geography more generally. But as GPS systems and in-car navigation systems become increasingly common, the need to think in map-like ways may start to decline. Most GPS-based navigation systems display maps, but there is no need for them to do so; navigation instructions could be totally route-based, without references to maps. In this case, the information would simply augment direct experience; it would not require or benefit from the alternative perspective on space that leaming about maps can provide. Such a decline in the use of maps would be very consistent with the theoretical perspective I have outlined. Because our models of the world are socially constructed and symbolically mediated, they are likely to change as the technologies for representing space change. If the symbolic representations of large-scale space change, we should expect that our understanding of space will change too.

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