MAP USE AND THE DEVELOPMENT OF SPATIAL COGNITION

Clare Davies & David H. Uttal

This is what maps give us, reality, a reality that exceeds our vision, our reach, the span of our days, a reality we achieve no other way.

As the chapters in this volume indicate, interest and research in spatial cognition and its development have increased substantially in the past decade or two. However, it is fair to say that the vast majority has been conducted in relatively small spaces. For example, perhaps the most influential study of the development of spatial cognition that has been conducted in the past 20 years (Hermer & Spelke, 1994) was conducted in a space that was the size of a small closet (for an excellent critique of this study and evidence that room size matters, see chapter 3 this volume). Studies in small-scale space convey many advantages. In particular, they allow researchers to tightly control factors that may influence performance and hence to identify and isolate causal mechanisms. At the same time, studies that are limited to small spaces cannot investigate all that is interesting and important in the development of spatial cognition. Children in modern, Western society need to know about spaces at a variety of scales, from local scales right up to global scales.

For many years, researchers have argued that the perceptual and cognitive processes that are used in small-scale space may differ fundamentally from those used in large-scale space (Acredolo, 1977; Herman & Siegel, 1978; Montello, 1993). For example, small spaces can be experienced in a single glance, but larger spaces can be experienced directly only in “snapshots”
or sequential routes. Consequently, when we learn about a large-scale space from direct experience, we must integrate the various views into a coherent layout if we are asked to make judgments that require knowledge of relations among locations in the space, such as a route detour (Uttal, Fisher, & Taylor, 2006). Such judgments are often difficult for adults and are particularly difficult for young children (e.g., Siegel & White, 1975; Uttal et al., 2006). The need to learn about large-scale space and the challenges that such learning presents have led to the development of tools that facilitate the communication of spatial information. Maps are perhaps the best example.

A map is a unique form of symbolic representation. It forms a spatial one-to-one relationship with some, but not all, objects in the geographic landscape. By scaling them down to miniature size, it allows the viewer to see far more at one glance than could ever be possible from ground level. Maps are seen from a spatially realistic (but rarely viewed) aerial perspective, but not necessarily with any pictorial realism. Symbols replace and distinguish what is otherwise, say, in a suburban landscape, a mass of tiny rooftops and blobs. The result adds extra information as well as enhancing clarity, as shown in figure 10.1.

In this chapter, we argue that these features of maps may also play a role in the development of spatial cognition. We suggest that the use of maps may influence how children come to think about space beyond their immediate experience. This means, in part, that the development of cognition of large-scale space is symbolically mediated. Uttal (2000) has described the relationship between children and maps as a two-way street. Maps are tools that can be used by children to solve spatial problems but are also a potential accelerator for development, if their portrayal of spatial relations can help the child to think about space, and the correspondence between their own and external knowledge, in new ways.

Figure 10.1 An (edited and labeled) aerial photograph, and corresponding street map, of part of the Evanston neighborhood used in our research. (Reproduced with kind permission of the City of Evanston, IL.)

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Our perspective on the role of spatial cognition is aligned with those who have stressed the influences of symbolic and representational experiences. Our perspective on spatial cognition therefore stresses the symbolic nature of spatial cognition and that spatial cognition is increasingly symbolically mediated. Symbolic mediation of spatial cognition here is to bring the symbolic and representational aspects of spatial cognition under this general rubric. Being drawn without necessarily considering the nature of the representations, such as maps, we refer to such symbolic information then influence the development of spatial cognition.

This chapter describes some of the research we have conducted, tied to developmental and other disciplines such as cognitive psychology, and many contributions from those fields. Based partly on these findings, we will explore the different ways in which spatial information can be represented, the cognitive benefits of these representations, and the implications for the development of spatial cognition as it is distributed across the environment.

Before discussing the development of spatial cognition, it is useful to be clear on how the terms imply that children develop spatial representations in the environment. Figure 10.1 shows a simplified "bird's-eye" view of a part of a city, indicating landmarks, some of which may be difficult to find in the environment. As children develop spatial representations, they will use these landmarks to help them navigate the environment. For example, they may use the landmarks to help them navigate between different parts of the environment, such as the school and the library. These landmarks may also be used to help them remember important information, such as the location of their friends' houses. Furthermore, spatial representations may be used to help children plan their daily activities, such as organizing their study schedule, or planning their routes to school. These representations may also be used to help children make decisions, such as deciding where to go for a walk or where to have lunch. Spatial representations may also be used to help children solve problems, such as finding a lost item or determining the best route to a destination. These representations may also be used to help children develop their creativity, such as planning a new route or coming up with new ideas for a project. Furthermore, spatial representations may be used to help children develop their critical thinking skills, such as evaluating the effectiveness of different routes or determining the best way to get to a destination. Finally, spatial representations may be used to help children develop their emotional intelligence, such as understanding the feelings of others or determining the best way to cope with stress.
Our perspective on the relation between maps and the development of spatial cognition is aligned with that of other researchers who have stressed the influences of symbols. In particular, space beyond immediate experience is communicated and hence symbolically mediated by maps or language. Our perspective on the development of large-scale spatial cognition therefore stresses the role of symbols as tools for thought, following the tradition of Vygotsky (1978) and more recent researchers (e.g., Loewenstein & Gentner, 2005) who have stressed the influence of symbolically mediated information on cognitive development in general. Our contribution here is to bring the domain of large-scale spatial cognition under this general rubric. Because such space cannot be experienced directly without exerting great effort, people have traditionally relied on the information that others can provide through maps, directions, and other forms of communication. We hypothesize that these experiences with symbolic information then influence the development of large-scale spatial cognition.

This chapter describes some of the ideas and evidence from a research program that has investigated these possibilities. Such work is intimately tied to developmental and cognitive psychology, but also interfaces with other disciplines such as cartography, geography, and environmental psychology, and many contributions to our thinking come from researchers in those fields. Based partly on this body of knowledge and partly on our own research program, we will explore the apparent antecedents, challenges, task dependencies, and cognitive processes that impact children's effective use of maps, and the implications of these for our understanding of spatial cognitive development as it relates to large-scale space.

10.1 WHAT MAPS DO

Before discussing the development of map use, we focus on exactly what a map implies for cognition. It is clear from the modern urban street map shown in figure 10.1 that maps offer far more than a simple way to match locations on the map with locations in the world. In particular, maps offer the following:

1. A simplified "bird's-eye" visual image that integrates multiple locations, many of which can be experienced only separately on the ground, into a single structure.
2. Accurate (or at least, consistently distorted), easily perceptible information about the relative distances and directions between any two landmarks.
3. The opportunity to view whole routes between two distant points and to compare their relative lengths and complexity.
4. Representation of some invisible, nonphysical elements such as town boundaries, functions of land and buildings, and one-way traffic restrictions.
5. Depiction of the constrained topology of the street network, in effect highlighting where it is possible to walk or drive or cycle. Here, as we discuss further below, geometric shape and size are often less crucial than relative position and connection.

6. Pictorial or iconic symbolization of categories of real-life elements. Crosses may stand for churches, single lines for streets, squares or flags for schools, and so on.

7. Identification labels (using language) for many individual elements (e.g., street names and local landmarks).

Without a map or other representation, most of the items in this list would have to be abstracted from the experience of navigating the real space itself. For some items, particularly the first four, this is quite difficult and requires multiple experiences. These items are also hard to communicate efficiently through media other than a small-scale map, diagram, or model. In fact, item 1, drawing on the precise geometry of a consistent map projection, can generally only be shown by these means. Although maps of this kind may thus seem unavoidable, this is certainly not the case since city maps have tended to have this consistent geometry only since the Enlightenment. During the eighteenth century, the now-common overhead “planimetric” maps became gradually more common than the more aesthetic and easily understood (but geometrically distorted) oblique views used in older city maps (Elliot, 1987). Because the need for accurate configurational knowledge developed relatively late in civilization, we might expect its spontaneous appreciation by children to come relatively late in development. However, this may not be the case.

In contrast to the first four items in the list above, one could convey the later items through linguistic (e.g., a descriptive list) or pictorial means, perhaps without any integrated plan. Symbolic representation of anything carries with it the potential for alternative symbol systems, such as language, to do the job equally well. Therefore, only the earlier items in the list may necessitate some specifically spatial cognitive processes when used in problem solving. At the same time, one of the primary advantages of maps is that they facilitate and promote this spatial reasoning. When looking at a map, it is often possible to see, and hence to think about, the relations among many locations simultaneously. We believe that depicting relational information in this single visual array is a key feature of maps. Much of our research has focused on the developing use of relational information to strategically solve problems in situations where such information may usefully improve accuracy, speed, or cognitive efficiency.

It is important to note that not all map-reading tasks necessarily tap into this specific function of maps, just as the maps themselves do not “only” show an aerial view of space. For example, consider one commonly used task: using a map or model to find a hidden toy. As Blades and Cooke (1994) demonstrated, this task can be solved without thinking about the spatial relations among multiple locations. Often it is possible for children to find the hidden toy on the basis of the pictorial object and the corresponding model.

In some situations, using a map is more difficult, especially where mental alignment to one’s direction of vision, in addition to the rotation of the map’s overhead view to children, and also many adults, although they are still often able to (Bal, & Presson, 2004). A map may have features that a particular map does not. The most salient to the user’s interpretation is the harder time extracting task-relevant information (Bentin, 1967/1987) until the desired information is given. Map symbols are iconic rather than meaningful, and can be interpreted via a less intuitive map, perhaps. Misinterpretations or, at best, to some extent, clear, however, which aspect of the performance on a spatial task: sometimes by enabling a more accurate spatial effort.

Indeed, some tasks demand the advantages that a map can provide, such as judging the spatial relations among them independent of any experience of them. Knowledge of a specific, changing place may not be relevant if a person does not know how it is used. These tasks may require knowledge, a mental representation of spatial relations among locations within a context. Thinking about space in situ can be hard at a map, because a map would otherwise have to be accurately oriented. Reading a map is a different matter (Thorns&yke & Tversky, 1993). We should be careful, however, not to confuse this with knowledge. The past two decades of research have suggested that every cognitive-geographic space, it is important to have a “cognitive map,” if a map is a cognitive map because a map is a cognitive map.

It follows us to mentally or physically. It is clear that this overview is itself stored. In particular, much evi-
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to find the hidden toy on the basis of a single correspondence between a depicted object and the corresponding real object in space.

In some situations, using a map may even hinder or limit cognitive flexibility, especially where mental rotation is required. Use of a map that is not aligned to one’s direction of view or travel requires a second mental rotation, in addition to the rotation and translation already required to match the map’s overhead view to one’s ground-based, real-world viewpoint. Children, and also many adults, apparently find this extra rotation difficult, although they are still often able to do it in a simple environment (Vosniak & Presson, 2004). A map may also place other demands on cognition: the features that a particular map design emphasizes may not be those that are most salient to the user’s interests or tasks; thus, the user might have a harder time extracting task-relevant features in the face of salient distracting information (Bertin, 1967/1983). Another potential source of cognitive load is what Gombrich (1977) called the “pathology” of symbols. Where map symbols are iconic rather than pictorial, people may be forced to interpret them via a less intuitive matching process, which can lead, at worst, to misconstruals or, at best, to some slower cognitive processing. It is not always clear, however, which aspects of a map may impair or enhance performance on a spatial task: sometimes the same aspect of a map may do both by enabling a more accurate solution but at the cost of greater mental effort.

Indeed, some tasks demand that children (or adults) exploit the special advantages that a map can provide. For example, one might expect tasks such as judging the spatial relation between two out-of-sight locations to be facilitated by looking at a map, because it allows a person to compare them independent of any experience of travel between them. Even when it exists, knowledge of a specific, navigable route between the two locations may not be relevant if a person needs to consider the true direction “as the crow flies.” These tasks may require what is commonly referred to as survey knowledge, a mental representation that allows one to think about multiple relations among locations without calling on one’s experience of navigation. Thinking about space in survey-like terms is greatly facilitated by looking at a map, because a map provides directly much of the information that would otherwise have to be acquired through exploration and mental integration of routes (Thorndyke & Hayes-Roth, 1982; Uttal, 2000).

We should be careful, however, not to simplify this notion of survey knowledge. The past two decades of research on human environmental cognition have suggested that even when we possess such knowledge about a geographic-scale space, it would be misleading to call that knowledge a “cognitive map,” if a map implies a direct analog to the fixed two-dimensional paper artifacts designed by cartographers (e.g., Hirtle & Heidorn, 1993; Tversky, 1993). It is clear that high familiarity with an area allows us to mentally or physically visualize an overview of it, but it is not so clear that this overview is itself the form in which all of the information is stored. In particular, much evidence has demonstrated that such survey
knowledge tends not to include metrically accurate representations of distance or direction. For example, even adults’ judgments of distance are influenced by the semantic salience of landmarks (e.g., Tversky, 1992). Perhaps this is not surprising when we consider that even in smaller scale spaces such as rooms or tabletops, groups of objects tend to be encoded hierarchically to some extent, which biases our judgments of their relative locations (e.g., McNamara, 1986). Thus, another important potential use of a map is to correct or supplant these frequently incorrect estimates of spatial relations.

Arguably, to use a map or any other tool in problem solving, one must realize its potential value and relevance to the task, as well as be able to interpret it and incorporate it into the strategy one will follow. The task of judging the distance from one’s current location to a distant location, for instance, may be solvable by mentally visualizing the route to the distant location and then making allowances for the difference between route and direct straight-line distances (e.g., in a regular urban street grid, by calculating the difference between the diagonal and the sum of two sides of a typical street block). It may also be solved—albeit not very accurately—by recalling how much effort or time it seemed to take the last time one traveled to the distant location. If one has not directly traveled there, then one may try to integrate separate portions of other routes, and so on. In other words, the strategic choice of operators in solving this type of problem will determine the accuracy of its outcome, and different strategies may “trade off” differently in terms of speed and mental effort. Therefore, in addition to realizing the relevance of a map to distance judgments, a child or adult must also judge that use of a map will be worthwhile, resulting in (usually) increased accuracy. To some extent, then, map use demands an appreciation that one’s internal representation of a space may be poorer than an externally produced one, even though the former may seem more “real” and salient to us than the latter.

Even when a map is not physically present, it is logical to assume that one’s memory for the spatial relations it depicts is likely to involve fewer distortions and biases than one’s memory for the corresponding real-world space, if only because those relations could be taken in with just a few saccades over a single visual array. Therefore, if a child even subconsciously adopts a task strategy that exploits her/his memory of a map, rather than relying solely on her/his (probably) incomplete and highly distorted experience of the space, then this indicates an understanding that metric space is not the same as those experience-based internal representations. It suggests that children are willing to recognize that the correspondence from the map to some kind of objective reality is at least as strong as that from their own internal “reality” to that outside world. Once such notions of the utility of symbolic representations become established, many other types of problems may be more readily solved. The child is learning to truly value external spatial, symbolic information. When and how do children become

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Imagine entertaining some very young children in a map-using culture who have never used a map before. They will be unfamiliar with the symbols, conventions, and very large spaces. Yet they will not be unfamiliar with the perspective—seeing an array of objects in the distance from the outside landscape from a viewpoint that is later transformed if necessary into comic strips and games. Their initial recognition of the comic strips, seems to vary between some (e.g., Blades, & Spencer, 2002) but not others (e.g., blades & Spencer, 2002). Once preschool children have an aerial photograph, they are generally able to correctly identify geographic features.

Children can also cope with maps at preschool age. Symbolic play before school age (Göncü & Kılıçaslan, 1982) is reduced and simplified to states or dimensions that the symbolic representations of objects that are meaningful to a child, but not to a child and are the first few years of life. A long time period passes (e.g., Blades & Spencer, Presson, 1982): preschool children can interpret maps in a room-sized space if they have seen photographs does not necessarily have potential problem-solving benefits. Children can also cope with these maps in a room-sized space if they have seen photographs does not necessarily have potential problem-solving benefits. Children can also cope with these maps in a room-sized space if they have seen photographs does not necessarily have potential problem-solving benefits. Children can also cope with these maps in a room-sized space if they have seen photographs does not necessarily have potential problem-solving benefits. Children can also cope with these maps in a room-sized space if they have seen photographs does not necessarily have potential problem-solving benefits. Children can also cope with these maps in a room-sized space if they have seen photographs does not necessarily have potential problem-solving benefits. Children can also cope with these maps in a room-sized space if they have seen photographs does not necessarily have potential problem-solving benefits. Children can also cope with these maps in a room-sized space if they have seen photographs does not necessarily have potential problem-solving benefits.
ready to do this? As we describe in the next section, we have only indirect answers to this question at present.

10.2 CHILDREN'S RESPONSES TO MAPS

Imagine entertaining some visitors from a long-past century or a non-map-using culture who have never previously viewed a conventional map. They will be unfamiliar with its symbols and with its use for representing very large spaces. Yet they will not be entirely unfamiliar with its survey perspective—seeing an array of objects from above. As soon as children can view a backyard from an upstairs window or stand on a hilltop, they experience the outside landscape from an aerial view. Thus we should not be surprised that even 2- to 4-year-old children quickly grasp the nature and contents of an aerial photograph of both familiar and unfamiliar landscapes. Their initial recognition of the nature of the photograph, without being told, seems to vary between studies (Blades et al., 1998; Plester, Richards, Blades, & Spencer, 2002) but is successful around the age of 4–5 years. Once preschool children have identified or been told about the nature of an aerial photograph, they are generally able to run toy cars along its roads, correctly identify geographic features, and make route-planning decisions.

Children can also cope with some of the symbolic aspects of maps even at preschool age. Symbolic play is a regular feature of children's lives well before school age (Göncü & Klein, 2001), as is dealing with objects (toys) reduced and simplified to small-scale caricature. There is no reason to assume that the symbolic representation of a map, if it clearly indicates objects that are meaningful to a child, would not be understood as such within the first few years of life. A long line of studies has shown that this is indeed the case (e.g., Blades & Spencer, 1990; Blaut, McCleary, & Blaut, 1970; Presson, 1982): preschool children can correctly identify depicted landmarks in a room-sized space from their representations on a map. Nevertheless, children's willingness and ability to engage with maps and aerial photographs does not necessarily mean that they appreciate all of the potential problem-solving benefits of such representations (Uttal, 2000), nor that they can or want to apply the mental rotation and other transformations required to take advantage of them in many situations.

One potential impediment to early reliance on maps is the primacy of direct experience with spaces. Children's (and adults') internal representations of a known landscape, such as their home neighborhood, are built up mainly through the experience of wayfinding and being taken on journeys through it. However, people often do not extract multiple interroute relations (going from B to C having previously only been from A to B and from A to C) nor exact metric distances and directions from such spatial experiences (e.g., Hirtle & Jonides, 1985; Millar, 1994; Yeap & Jefferyes, 2000). Instead, we make inconsistent and semantically biased judgments of distance and direction, based on such issues as salience, familiarity, and
similarity. Lack of experience coupled with the relatively slow development of metacognitive skills could cause children to be unaware of this tendency in themselves, which could lead them to choose less effective and internally resourced strategies for spatial problem solving. In other words, even when a map is available to offer accurate multiple-object relations and even when a child understands the map, it may not appear better than his or her experience-based solutions when solving a problem that requires (geo)metric accuracy or a “survey” perspective.

In addition to a lack of metacognition, there are real challenges that children face when trying to apply maps to some tasks in a real space. In particular, the application of a map to a real space necessitates both a scale change and a mental rotation. The latter is trivial if the map is aligned with the child’s viewpoint, involving only the change of view from overhead to ground level, but it can be quite complicated if not. At such times, the mental effort involved in these transformations is unlikely to encourage map use unless the gains are clearly apparent. Yet as children’s spatial experience at the geographic scale grows, and as geometric representations become more familiar and offer a corrected view of the overall space, children may spontaneously realize the value of this. We might then see a greater tendency, as children grow older, to draw on less topological and more geometric solutions to spatial problems such as wayfinding and locating distant objects (Liben & Downs, 2001).

There is some evidence that even young children can use, learn, and remember quite precise spatial relations among multiple stimuli, when they are clearly aware that a task requires it (e.g., Sluzenski, Newcombe, & Sallow, 2004) and when no major scale transformations are involved (e.g., Uttal, 1996; Vasilyeva & Huttenlocher, 2004). Yet it might be expected that children may only gradually learn the value of external representations such as maps in enabling more accurate spatial judgments (e.g., of distance and direction), especially when such judgments can be approximated from experience.

Indeed, in most everyday real-world spaces and for many tasks including wayfinding, such accuracy is arguably not required, especially for sighted people. Within a room, playground, or street scene, it is relatively easy to judge distance and direction using direct visual cues. Physical constraints—doorways, hallways, stairs, a street network—strongly affect our experiences in space, and finding locations within such constrained spaces is greatly simplified by street addressing systems and other conventions, so accurate geometric knowledge is not always necessary. Even in rural areas, footpaths and fences may constrain movement to some extent, at least in most developed countries. Where such constraints allow a reliance on the topology rather than on the metrically scaled topography of the local landscape, it may be even more likely that map-based spatial solutions might be spontaneously appreciated relatively late in child development, since approximations are both possible and often “close enough.” There is some evidence for this: children from rural areas who live in less spatially constrained environments, and also tend to have more formal learning experiences, did not benefit as much as their suburban counterparts (Norris, 1980).

To summarize, then, despite the importance of developing an understanding of spatial relations, especially in urban environments, many early experiences are unaided by maps and do not necessarily require competence in map use. Yet the potential for this kind of competence remains, and can be taught and developed when maps are introduced (Liben & Downs, 2001). In this sense, there is a potential for developing an understanding of maps and their use even before they are taught explicitly. However, the development of this potential is not automatic, and needs to be supported by appropriate educational interventions.

In the remainder of this chapter, we will look at how children develop an understanding of spatial relations and how they use maps to represent and navigate their environment. We will consider how children develop an understanding of spatial relations, how they use maps to represent and navigate their environment, and how these processes are influenced by the context in which they occur. We will also consider how the development of spatial understanding can be supported by educational interventions.
and also tend to have more freedom to explore them, outperform urban and suburban children on various spatial tasks, including map drawing (Norman, 1980).

To summarize, then, despite clearly being able to understand basic map concepts by the age of five, and being able to use maps to locate items in simple room-sized spaces, it is less clear when or how well this "scales up" both to other tasks and other sizes of space. Map use is a choice when solving problems in large-scale spaces. It requires that children appreciate both the disparity between their internal and the map's external representation and the value of the latter. Map use also requires that children be proficient at relevant cognitive spatial skills (e.g., mental rotation, relative scaling of distances) so that the amount of effort required to derive a map-based solution to a spatial problem will not be too great. Otherwise, children are likely to select other strategies even if they know that the map holds more accurate information. For all of these reasons, it is helpful to examine what children choose to do with a map once they are at an age of being active navigators of geographic-scale environments, and hence potentially able to learn what maps can do.

In the remainder of this chapter, we will describe two lines of research that have helped us explore this question of the relations between children's developing understanding of maps and their internal, mental representations of space. The first concerns laboratory studies of children's map use, and the second is a new line of research that focuses on the use and influence of maps on children's thinking in a much larger and more naturalistic space, their neighborhood. Although these studies do not directly enable us to tease out the relationships among awareness, motivation, and cognitive skills, they take a step in this direction by examining when and how grade-school-age children take advantage of maps across various situations and tasks.

We have also attempted to take into account some of the dimensions on which situations and tasks vary. We focus on two dimensions in particular—environmental scale (the size of the space under consideration) and familiarity (of the child with the space). These factors are not always explicitly considered when making generalizations about children's "spatial abilities," but they may be critically important. For instance, laboratory studies of children reproducing object locations from simple maps (e.g., Vasilyeva & Huttenlocher, 2004) may involve different cognitive requirements from outdoor wayfinding and orientation (e.g., Aroishin & Young, 1981), which may be different again from tasks that probe knowledge of wider geographic regions such as across a whole city, country, or the world (e.g., Axia, Brenner, Deluca, & Andreasen, 1998). As an example, a room-sized space is at a scale that a child has, many times, appreciated within one single turn of the head (a "vista" space; see Montello, 1993) and may well have been seen from above (e.g., being held above an adult's head, or looking down from a balcony). It is therefore likely to be considerably easier to conceive of and apply a map of that space than a larger scale space such as a neighborhood (an "environmental" space) or country (a "geographical" space).
The level of familiarity has been varied in past research, particularly among outdoor-scale studies; however, it is not clear exactly how familiarity influences spatial performance across situations and tasks. Some studies have looked at children's knowledge of familiar environments such as their school grounds or home neighborhood (e.g., Anooshian & Young, 1981), while others have asked children to learn new environments (e.g., Cornwell, Heth, & Skoczyk, 1999; Ambrose, 2000). Arguably, these studies could tap into different cognitive processes. For instance, the explicit learning of novel information for the sake of problem solving likely relies on processes that differ from those at work in incidental learning situations. Moreover, familiarity may interact with age in terms of children's spatial strategies and responses, even within one environment (e.g., Cousins, Siegel, & Maxwell, 1983; Lehnung, Leplow, Haaland, Mehdorn, & Ferstl, 2003).

10.3 CHILDREN, MAPS, AND ROOM-SIZED SPACES

In this section, we summarize results of three studies of the development of children's use of maps as spatial representations, that is, as visualizations that facilitate solving spatial problems and acquiring survey-like representations. In contrast to other studies of children's spatial reasoning, our focus was specifically on the relational, survey-like quality of maps and their relevance to spatial problems that may be harder to solve without them.

Our first study of children's acquisition of survey-like representations from maps (Uttal & Wellman, 1989) was conducted in an 18' x 12' playhouse. Even though this is a relatively small-scale space, our goal was to design a task that required children to think about spatial relations in survey-like ways. The space consisted of a 3 x 2 arrangement of small square rooms. Each room was identical except for the presence of a different animal. Thus, the individual rooms could be referred to as the dog's room, the cat's room, and so on. Children learned the layout of the space and then were asked to perform various spatial tasks to assess how they had mentally represented the information.

In the initial study, children 4–7 years of age were assigned randomly to learn the animals either from a map or from flashcards, so that they all learned "what" but only the map group learned "where" the animals were. The learning procedures and criteria were as similar as possible for the two conditions; in both cases, the children had to recall all the animals' names. In the map condition, the children also had to recall the animals' locations, by naming the correct animal when the experimenter pointed to its room. Once the children could recall all the animals twice in succession without error, the testing phase of the experiment began. The procedures were thus designed to ensure that children thoroughly knew the relevant information (the cards or the map) before we assessed their transfer of knowledge to the real environment.

At test, children were taken (without the map or cards) on a specific route through the actual playhouse and asked each time to state which animal lived in the next room before they could anticipate each animal. Perhaps surprisingly, even though the map group were able to recall better than those in the card group, they did not rely on the map for the route.

In interpreting this finding, we required the children to recall, test, and think about the spatial relations. The route that we followed in the test was different, and hence the children had no way to enter or not get the information from the survey-like representation. Children could remember the locations in a manner that was not dependent on whether or not they remembered it well on any given spatial relation.

Further evidence to support this comes from the experiments in which we asked children to anticipate on and off the route they followed during the learning phase (see Uttal & Wellman, 1989). They were required to identify animals that were relative to the direction in which they moved, as well as left right judgments, and maps showed better performance on the two measurements. This reveals that the map-group children knew the route and that they could exploit this knowledge.

For these reasons, we conclude that children's performance on the route task was due to the spatial knowledge they acquired, and could reconstruct an accurate mental map of the space. The map helped the children to learn the locations, thus conferring an advantage on the children even to 4-year-old children. Although even the 4-year-old took advantage of the map, one of the first studies to show that maps have a unique advantage.

We can therefore conclude that children's performance on a immersed, ground-based navigation in a random, ad hoc order, even to 4-year-old children. However, it was still relatively small, but the map itself that children used to solve the specific kinds of problems that require unique advantage.

We can therefore conclude this chapter with an overview of the map itself that children used to solve the specific kinds of problems that require unique advantage. However, it was still relatively small, but the map itself that children used to solve the specific kinds of problems that require unique advantage.
mal lived in the next room before entering it. Children navigated this route until they could anticipate each animal twice in succession, without error. Perhaps surprisingly, even the younger children's responses demonstrated a substantial advantage of having learned the map. Overall, children in the map group were able to recall locations well and hence perform much better than those in the card group, particularly in the earlier rooms along the route.

In interpreting this finding, it is important to note that our tasks required the children to recall, translate (from the map, in that condition), and think about the spatial relations among locations within the playhouse. The route that we followed in the playhouse was never shown on the map, and hence the children had no basis for knowing which rooms we would enter or how we could get from room to room. Thus, the task required the sort of random access or equiavailability that is characteristic of a survey-like representation. Children could think about multiple relations among locations in a manner that was not tied to navigation of a specific route. Although the children did not perform perfectly, they performed about as well on any given spatial relation as on another.

Further evidence to support this claim came from a follow-up study in which we asked children to anticipate the identity of animals that were both on and off the route they followed through the playhouse after the initial learning phase (see Uttal & Wellman, 1989). That is, children were required to identify animals that were both ahead and to their left and right, relative to the direction in which they were traveling. The children did just as well on the left-right judgments as they did on the straight-ahead, and performance on the two measures was highly correlated. This result again reveals that the map-group children knew the relations among the locations and that they could exploit this knowledge in a navigation task.

For these reasons, we concluded that the best and most parsimonious explanation for the results was that the children viewing the map had acquired, and could reconstruct and manipulate, a survey-like representation of the space. The map helped them to think about multiple relations among locations, thus conferring one of the important advantages of using maps, even to 4-year-old children. Although performance did improve with age, even the 4-year-olds took advantage of the spatial relations on the map and used them to solve the spatial problem of identifying locations. Thus, this was one of the first studies to show that young children can use maps to solve the specific kinds of problems for which maps convey a special or even unique advantage.

We can therefore conclude that the basic skills of matching an overhead view to an immersed, ground-based one and accessing this spatial representation in a random, ad hoc order are already present in a typical American 4-year-old. However, it was still unclear whether it was the configural overview of the map itself that children were recalling, or only the individual items (pairwise spatial relations) conveyed within it. In the next section, we describe some more recent work that helps to clarify this point.
10.4 MAPS, WORDS, AND SPATIAL KNOWLEDGE IN ROOM-SIZED SPACES

Uttal et al. (2006) recently investigated how children form mental representations from maps and from verbal directions. We began this research with the observation that in a verbal description, spatial information can be described only serially. That is, each spatial relation must be described individually; it is not possible to describe multiple relations simultaneously. In this regard, acquiring spatial information from a verbal description shares an important similarity with how we acquire spatial information while navigating in the world. In both cases, we encounter most of the relevant spatial relations (what follows from what) sequentially, while listening, reading, or traversing a route. To form a survey-like representation similar to that given by a map, a person would need to do more than simply remember the spatial information as it was encountered: the information must be integrated into a single structure. The person would need to hold each new relation in short-term memory, linking it to others to build a cohesive mental representation on the basis of either verbal descriptions or direct experience. It is likely that this would take place when first hearing the description, so that a mental image of the overall layout could be constructed and serve as a reference frame for information about individual locations within it. This is more cognitively economical than storing individual relations.

In general, such integration is easier with a map because it draws on basic integrative visual processes while actually viewing it. Multiple relations can be taken in with a single saccade, and the whole already exists as an integrated layout, so no “guesses” or estimates are required. One scans the map in the same way as any other tabletop array or picture; no physical turning or traveling is required. In the geographic-scale environment itself, however, this is rarely possible except when viewing from a highly elevated vantage point.

Nevertheless, research has suggested that adults do seem to form and use integrated surveys regardless of the form of the input. In one well-known study (Taylor & Tversky, 1992), adults either read or looked at a map of hypothetical places, such as a zoo. They were then asked to make judgments about spatial relations, some of which had not been included in the descriptions, and thus subjects had to infer them. This type of inference is clearly easier to solve if participants can recall or recreate a survey-like representation of the multiple locations. Therefore, one could have expected participants who learned from a map to do better regardless of the specific relations involved, as maps convey equiavailability of all spatial relations.

Surprisingly, Taylor and Tversky (1992) found that the form of the input did not affect adults’ judgments. Those participants who learned from descriptions did about as well as those who learned from a map, even for those spatial relations that were not explicitly described. Moreover, this finding held up even when the subjects were not informed beforehand that they would be asked to make judgments about spatial relations, regardless of the form of the instruction. The complexity of the map and effects of related constraints likely not the case in most real-life situations, since adults have the ability to effortlessly invert verbal descriptions.

When do these abilities develop? Spatial information regardless of the form of the input might be acquired in the same way to which the answer might be affirmative. Young children have not been suggested that young children can learn about spatial relations. They do so by a process that serves the sequential ordering of instructions, such as “Go to the corner by the door.” Skelton & White, 1975; but see also Blades, & Morsley, 1989; Yap & Sweller, and Spear (1995) have shown that only one spatial relation at a time appears in the sequential order of the information presented to children. For these reason, models of spatial information developing their use of those models in probabilistic order of the information presented to children.

To test this hypothesis, we set up a situation akin to the original Uttal and Wellman’s task. In this case, however, half of the children were asked to learn the layout from a description, and the other half were asked to repeat the description out loud. The children were asked to repeat the description out loud, and then the entire set of relations were given to each participant. The children were then asked to memorize a map, and the participants were asked to tell what the child might be asked to remember about the layout. The pointing task, in which the participant was asked to point to the correct location in the map, the participant was then asked to point to the correct location in the map. The pointing task, in which the participant was asked to point to the correct location in the map, the participant was then asked to point to the correct location in the map. The pointing task, in which the participant was asked to point to the correct location in the map, the participant was then asked to point to the correct location in the map.
they would be asked to make judgments about spatial relations. These results suggest that adults can integrate spatial information into survey-like representations, regardless of the form of the input. Of course, in that study the complexities of the map and description were closely matched, which is likely not the case in most real-life situations. Nevertheless, it demonstrated that adults have the ability to effectively integrate spatial knowledge using verbal descriptions.

When do these abilities develop? Do children also integrate spatial information regardless of the form of the input? There is reason to believe that the answer might be no—that is, that the flexibility that adults demonstrate might have important developmental antecedents. For example, it has often been suggested that young children’s recall of the locations of landmarks tends to be based on route knowledge, a representation that preserves the sequential ordering of landmarks but does not encode relations among locations that were not included on the same route (Allen, 1981; Siegel & White, 1975; but see also Anooshian & Young, 1981; Spencer, Blades, & Morsley, 1989; Yeap & Jefferyes, 2000). Likewise, Plunnett, Ewert, and Spear (1995) have shown that 3-year-old children sometimes focus on only one spatial relation at a time, even in situations where two simultaneous relations must be processed or described to avoid ambiguity (e.g., noting “It’s in the bag by the chair” to disambiguate cases where there are two identical bags). For these reasons, we predicted that children’s mental models of spatial information derived from verbal descriptions, or at least their use of those models in problem solving, might be more tied to the serial order of the information presented than are those of older children and adults.

To test this hypothesis, we set up an experiment that was in some ways akin to the original Uttal and Wellman (1989) work. As before, there were six rooms in a 2 × 3 layout, with a different toy animal in each room. In this case, however, half of the children (8 and 10 years of age) and adults learned the layout from a description. They were told, for example, that the bear was to the left of the frog and that the cat was to the left of the pig. We asked the children to repeat the descriptions from memory until they could say the entire set of relations two times in a row without error. The remaining participants memorized a map, following procedures similar to those used by Uttal and Wellman (1989).

After the participants had learned the layout, they completed two spatial tasks that were designed to assess how they had mentally represented the spatial information in the descriptions or on the maps. In the model construction task, the experimenter gave the children six cards (in random order), each with a photograph of an animal from the playhouse. The child was asked to arrange the cards to make a model of the layout of the playhouse. In the pointing task, the experimenter and participant entered a room into which a toy animal was placed. The experimenter then asked the participant to point to other animals’ rooms. For example, the participant might be taken into “the pig’s room” and asked to point to the
bear's room and the car's room. The pointing task thus demanded that children think about pairwise relations between locations, whereas the model task required the children to integrate those pairs into a coherent configuration.

The results revealed a distinct developmental transition in the integration of spatial information from descriptions. In general, the 8-year-olds did not appear to integrate the descriptions into survey-like representations. Their representations instead were based on the serial information in the descriptions and thus were akin to route-based representations. This was revealed particularly in their model constructions. Whereas most of the adults and many of the 10-year-olds placed the cards in the correct positions, the 8-year-olds did not. However, it was not the case that the 8-year-olds were simply bad at the task. Further examination revealed that almost all of the constructions preserved the contiguity relations between adjacent pairs of animals. In fact, on average, the children's constructions preserved at least five of the six contiguity relations that were described (but not their specific directions). Thus, the performance of 8-year-olds in the description condition was far from random, even though the constructions were inaccurate when assessed according to an absolute criterion. Their constructions (and their pointing) reflected the serial nature of the descriptions of spatial information in language.

In contrast to these findings from the description condition, all subjects performed very well when they learned from the maps, indicating, again, that maps can facilitate children's learning of spatial relations. The map allowed children to see and to think about the relations among all the locations.

In a follow-up experiment, we demonstrated that the advantage of using a map was not limited to having seen the exact location of each individual animal (avoiding the need to interpret left and right correctly from the descriptions), but was also related to the opportunity to learn the outline of the overall configuration. We tested whether providing this configuration in isolation would be sufficient to help young children perform better in the description condition. In particular, we created an outline map that showed only the overall layout, without the specific animals in the locations, and showed it to the children. We then had the participants (8-year-olds and adults) learn the descriptions, as in the first study. We hypothesized that seeing the outline map might give them the structure needed to integrate the descriptions into a cohesive, survey-like cognitive map, even though they would still need to learn the specific locations for each animal by correctly interpreting the relations they heard. This hypothesis was confirmed: 8-year-olds who saw the outline map and then heard the descriptions performed almost as well as those who learned from a complete map. This result demonstrates how maps can facilitate children's thinking about space: in addition to showing the individual relations between adjacent locations, the overall spatial structure is made clear and provides a reference frame for encoding those relations.

Map Use and the Development of Spatial Knowledge

Taken together, these two studies suggest that facilitating children's thinking about space with maps—"tools for thought" (Carey, 1985)—can help them encode spatial relations in an efficient and sometimes impossible, to gather coextraordinary descriptions. In this way, maps can aid the relations among multiple spatial elements.

10.5 MAPS, WORDS, AND ENVIRONMENT

As stated above, there is a relationship between children's spatial behavior and their use of maps. Thus, in this section, we discuss the laboratory studies described in the previous section in the context of children's early spatial development in the home environment. In particular, we examine how children's spatial knowledge can be assessed and how it relates to their use of maps.

This chapter focuses on children's use of maps to navigate their environment. It describes how children can learn to use maps to find their way around a new place, and how they can use maps to remember where they have been and where they are going. It also describes how children can use maps to plan their day-to-day activities, and how they can use maps to explore their environment.

To investigate how exposure to maps facilitates children's performance in a microgenetic study of around 60 children, data on each child's prior knowledge of landmarks across their neighborhood was gathered via a structured interview. Immediately following this, we asked which she or he was exposed to each geographic feature. Children were then asked to assess learning from map use.

The design allowed us to get in touch with a local map, this time through a new and more complex task than rote learning. Exposure to maps in the environment that we called an "informational place" allowed children to learn about local landmarks and to use this information to navigate their environment. Children in this study had a variety of information in an "informational place," as they could see the drawing activity, was performed both with and without the map. There were two tasks:

1. Solve a "Mystery Places" puzzle: match six cards giving verb phrases to local landmarks.
Taken together, these two studies demonstrate the role of maps in facilitating children's thinking about spatial relations. Maps can become "tools for thought" (Carey, 1990; Vygotsky, 1978), allowing children to encode spatial relations in an efficient, integrated manner that is difficult, and sometimes impossible, to gain from direct experience or from linguistic descriptions. In this way, maps make it relatively easy to see and judge the relations among multiple spatial locations.

10.5 MAPS, WORDS, AND SPATIAL KNOWLEDGE IN ENVIRONMENT-SIZED SPACES

As stated above, there is a relatively unexplored gap between findings from studies of children's spatial behavior in room-sized versus larger spaces. Thus, in this section, we discuss research that attempts to "scale up" from the laboratory studies described in the previous section to a larger and more familiar space—children's home neighborhoods. In particular, we used the central manipulation from Uttal et al. (2006) with an extended age range (7–10 years), to probe whether and when exposure to the configural information in maps would again facilitate spatial performance, in contrast to verbally presented information; however, there were two key differences. First, the space was outdoors, several hundred times bigger than the playhouse and much more complex (see figure 10.1). Second, the landmarks/objects probed in the study were already known to the children.

To investigate how exposure to maps versus verbal descriptions influences children's performance in a large-scale space, we conducted a partial microgenetic study of around one hundred children. First, we gathered data on each child's prior knowledge of (and emotional responses to) 18 landmarks across their neighborhood, coupled with a wealth of background data gathered via a structured interview with a parent or guardian. Immediately following this, we ran three weekly sessions with the child in which she or he was exposed to either a map or verbal descriptions of local geographic features. Children were also tested on spatial tasks at each session to assess learning from maps versus verbal descriptions.

This design allowed us to gradually expose children in the map condition to a local map, this time through a set of interactive activities rather than rote learning. Exposure to the map occurred through a set of activities that we called an indoor "information game." This centered around the locations of local landmarks and routes and also encouraged the use of symbolic representation. Children in the verbal condition received a similar set of information in an "information game" that, apart from one symbolic drawing activity, was performed using spoken and written descriptions rather than the map. There were five main tasks in this information game:

1. Solve a "Mystery Places" problem: match six dots on the map (or match six cards giving verbal descriptions) to six photographs of local landmarks.
2. Create a “Mystery Place” by marking a dot on the map (or providing a description) for their school in one session, and for their home in the other session.

3. Draw on the map (or on blank paper symbols for a local post office, a church, the local canal and the railroad.

4. Draw on the map (or verbally describe) their usual route from home to school.

5. Report the names of three local friends and mark (or describe the location of) their homes, and say which lived closest and which farthest away from the children’s own homes.

The study took place over two summers in Evanston and Wilmette, two suburbs in Illinois directly to the north of Chicago. Most of the children had lived most of their lives in the same neighborhood; we avoided testing children who were recent arrivals. We visited each child at his or her home on three weekly spaced occasions. During (usually) the first of these sessions, one experimenter interviewed the child’s parent or guardian to gather background data, while in a separate room another experimenter asked the child to rate her or his familiarity with each of 18 local landmarks, to rate how much she or he liked the landmark (via a set of “smiley faces”), and to state whether each landmark was in what they thought of as “my neighborhood.”

Then the child went outside and completed an outdoor spatial performance test. In this test, the child stood within sight of the street (usually on the sidewalk). The experimenter named a distant landmark and showed the child a picture of the landmark. Then, the child had to point straight toward the landmark. We told children to imagine they could travel straight through buildings and fences in order to go straight to the landmark (e.g., Cousins et al., 1983). Besides doing this for each of four landmarks, the child had to rank how far each of the same four landmarks was from the current location, by studying the photographs and successively eliminating the one closest to home. Given that there are alternative strategies children might use when judging distances and directions (especially from a familiar starting point such as home), we also included a “pretend” or “imagined” version of the pointing and distance-ranking tasks. Here the child had to imagine standing at one of the landmarks and to point to (and rank) the others in the set. Figure 10.2A shows a child performing the pointing task.

The second session started inside the home with the map or verbal “information game” activities. Then we took a walk through part of the neighborhood (navigated by the child as far as possible) to the landmark that the child had imagined standing at during the “pretend” spatial task in session 1. We then ran the outdoor spatial performance test again, at that location. This enabled us to see whether the children’s (immediately previous) exposure to the map would help when they could less easily count on the familiarity of home as a potential spatial “anchor point.”

In the third session, we again went indoors in the child’s home, and the performance test. There was this the “circles task” because the foamboard cutouts, each showing the child had seen earlier in the real in real life” (see figure 10, left panel). Producing the earlier maps was more shaped and much larger, and only on the earlier maps (the remaining both conditions, children had never been mentioned in the critical task.

Below we briefly outline the.

First, we discuss how children’s neighborhood influenced their performance test. This is of interest about how children’s experience in the ability to make judgments real or imagined viewpoints. The how particular experiences with
Figure 10.2 Children performing the pointing task (left) and the circles task (right) in the neighborhood study.

In the third session, we again conducted the map or verbal activities indoors in the child’s home, and then tested the child on the outdoor spatial performance test. There was then a final task where the child had to construct a layout from memory of all 18 of the tested landmarks. We called this the “circles task” because the child was instructed to place circular foamboard cutouts, each showing the same photograph of a landmark that the child had seen earlier in the study, onto a large square sheet “as they are in real life” (see figure 10, left panel). It should be noted here that simply reproducing the earlier maps was not possible: the map layout was differently shaped and much larger, and only six of the landmarks had ever been shown on the earlier maps (the remaining six had never appeared at all). Thus, in both conditions, children had to integrate a configuration of landmarks that they had learned about (though at different times) with landmarks that had never been mentioned in the “information game.” Because children in the map condition were effectively given a configuration in the information game that could act as a reference frame for placing the circles, we expected that children in the map condition would show a particular advantage on this critical task.

Below we briefly outline the findings of the two phases of this study. First, we discuss how children’s prior experiences and knowledge of their neighborhood influenced their initial performance on the outdoor spatial performance test. This is of interest because, at present, very little is known about how children’s experiences with real-world spaces lead to differences in the ability to make judgments about distance and direction, from either real or imagined viewpoints. This investigation provides an initial look at how particular experiences with a large-scale space are related to these spatial
skills. Second, we focus on the central manipulation in this study and ask whether exposure to maps versus verbally presented information affected children’s performance on the outdoor spatial tests and the final circle task.

10.5.1 The Influence of Prior Experience on Initial Spatial Performance

Besides our questions to the children about the familiarity and salience of the landmarks we used in the study, our interview with their parent included a range of other factors covering aspects of the child’s local activities within the neighborhood, frequency of taking trips by car or bicycle or on foot, experience (as far as the parent knew) of viewing various kinds of maps and learning other relevant information and skills, and the parent’s assessment of the child’s landmark familiarity (on the same rating scale as we used for the child). The latter was averaged with the child’s ratings, to minimize the effect of situations where either the parent or the child confused one landmark for another, failed to recognize it, or forgot the extent to which the child would actually have visited or passed it. The parent was also asked to use a map-annotating task to indicate what area she or he thought the child would know well, the area where the child was free to go without adult accompaniment, and the places that the parent felt were potentially dangerous for the child (again, an aspect of salience, but this time via the parent’s response to the place such as a verbal warning or ban). Some aspects of the parent’s own knowledge were also examined: her or his own familiarity ratings of the 18 landmarks, the extent of what she or he would define as “my neighborhood,” and the extent of her or his own activities around that neighborhood.

Given a sample size of approximately 100 children, it was possible to perform an exploratory multivariate analysis of these predictors to see which ones appeared related to the children’s initial performance on the outdoor spatial test. In particular, we used canonical correlation analysis (following the methods of Thompson, 1984). This analysis technique is useful in that it allowed us to examine which of the above independent (predictor) variables contributed to which particular dependent (performance) measures—that is, how prior experiences are linked to specific aspects of spatial test performance. Canonical correlation analysis is thus one step beyond multiple regression: the latter relates the variance in a collection of predictor variables to the variance of a single dependent measure, while the former relates the predictors to a set of dependent measures. Canonical analysis results in a set of orthogonal (i.e., uncorrelated with one another) canonical variates (underlying dimensions or factors); each pair of these represents a specific relationship between the original sets of dependent and independent variables, in each case drawing on some of those variables more than others. As with related multivariate techniques (e.g., multiple regression or factor analysis), the correlations within successively extracted canonical variate pairs tend to decrease, representing successively less of the original variance. The overall size of the canoni cal factor loadings, in terms of the proportion of variance explained on each variable in contributing to the canonical variates, followed the convention of ignoring loadings representing less than 10% of the overall variance.

The canonical correlation analyses included factors that related background measures (e.g., the child’s age, gender, nonverbal intelligence, and parents’ education) to their session 1 performance on the outdoor spatial tests. Below, we discuss each factor in turn.

The first and strongest factor was child’s age. Perhaps not surprisingly, this factor came from a composite variable based on the child’s age, birth rank, and gender. The second strongest factor was the child’s age, followed by the number of days between the child’s age and the date of the test. The third strongest factor was the child’s age, followed by the number of days between the child’s age and the date of the test. The fourth strongest factor was the child’s age, followed by the number of days between the child’s age and the date of the test. The fifth strongest factor was the child’s age, followed by the number of days between the child’s age and the date of the test. The sixth strongest factor was the child’s age, followed by the number of days between the child’s age and the date of the test. The seventh strongest factor was the child’s age, followed by the number of days between the child’s age and the date of the test. The eighth strongest factor was the child’s age, followed by the number of days between the child’s age and the date of the test. The ninth strongest factor was the child’s age, followed by the number of days between the child’s age and the date of the test. The tenth strongest factor was the child’s age, followed by the number of days between the child’s age and the date of the test.
original variance. The overall significance of the analysis was tested and found to be high. The variates can be interpreted by examining the simple correlations of the original variables with the canonical variates (often called canonical factor loadings), in tandem with the statistical weights placed on each variable in contributing to each variate. Like most analysts, we also followed the convention of ignoring all correlations below 0.3 (i.e., representing less than 10% of the overall variance in the children's behavior).

The canonical correlation analysis of our data showed three significant factors that related background measures of children's everyday life (predictor variables) to their session 1 performance on the pointing and distance comparison tasks from a real and imagined starting location (dependent measures). Below, we discuss each factor in turn.

The first and strongest factor was linked to the child's pointing performance. Perhaps not surprisingly, the strongest predictor contribution to this factor came from a composite measure of the child's overall familiarity with the 18 landmarks and the space that encompassed them, based on the child and parent ratings and some related measures. The next strongest contribution came from what we labeled children's "problem-solving experience"—parents were asked to rate how often their children had ever personally navigated a route and given verbal route directions to someone else. Clearly, their having done this, and their knowing the overall space, allowed the children to develop what could loosely be termed a "sense of local orientation" that would be required for the pointing tasks. After this, the next strongest contribution was a composite measure of the child's previous exposure to various types of map (from fictional maps in adventure story books, up through various scales of real-world map). Children who had been exposed to maps either at home or at school (even though most parents and a schoolteacher felt that this had been minimal for most of them) were already performing better than their peers in local direction judgments. After that, the child's specific familiarity and "liking" of the specific set of four landmarks that they were pointing to were the next factors, followed by age, and then by their average "liking" of all the landmarks across the neighborhood.

Although these findings do not allow us to make a strong claim that map exposure and route-planning experience were more important than age in determining children's pointing performance, we can hypothesize that the common link here is most likely to be children's awareness and development of a spatial representation that is sufficiently "metric" (as opposed to loosely topological) to allow quite accurate estimates of relative direction even from a location where the child is not currently standing. It also suggests that children of grade-school age can utilize map-derived knowledge and strategies for making judgments in large real-world spaces (each of the two neighborhoods was 1–2 km across).

The second factor identified in the analysis was strongly linked to children's performance on the distance ranking task. The predictors that influenced children's performance on this task appeared related to experiences,
both direct and indirect, that could provide information about relative local distances. These included (in descending order of strength of contribution) the extent of the child's own participation in local activities (from shopping to sports), the various questions we asked the parents about their own local knowledge and activity, and then the child's age. Again, the child's experience of route planning tasks (navigating and giving directions) was also a factor. Interestingly, the specific salience (smiley-face "liking") of the specific landmarks in the session 1 set correlated negatively with the child's distance-ranking performance. As suggested previously, this may indicate that highly salient landmarks are judged to be nearer than they really are—a bias similar to that found in adults (e.g., Hirtle & Heidorn, 1993).

The third factor showing reasonably strong canonical coefficients was most strongly and positively linked to children's distance rankings from home and their "imagined" pointings, but was negatively linked to their "imagined" distance rankings. The strongest predictor of this factor was the extent of the child's freedom to roam unaccompanied by an adult (corrected for their age, with which it was strongly correlated), followed by their familiarity with the four specific landmarks. Problem-solving experience appeared to load negatively onto this factor.

At first sight, this is a counterintuitive result: we might not expect children's roaming experience to impact negatively on their ability to estimate distance in the "imagined" scenario. However, we interpret this as demonstrating a key point discussed earlier in this chapter—that it is possible for children (and adults) to try to solve large-scale spatial problems by relying solely on their personal navigational experience. Imagine a child who, having experience with roaming around the neighborhood, can recall or construct a vague and perhaps near-topological representation of the local neighborhood structure, but with little knowledge of the more accurate metric topography. Such a child may be able to use that personal wayfinding experience to estimate and compare distances from home to other places. This child would also perform much better at the imagined pointings if, from having traveled there, she or he knew exactly where the imagined starting location was. The pointing responses themselves would then draw on the child's semiotopological awareness of the local layout, as would the direct pointings from home. However, for the imagined distance comparisons, he or she has no knowledge of metric distance to draw on unless through direct travel between the landmarks (which appeared to be unlikely in most cases: the landmarks tended to be single destinations in their own right).

These results underscore the mixed effects of reliance on personal wayfinding experience in children who probably possessed only vague topological knowledge of the neighborhood's spatial configuration. Reliance upon personal wayfinding knowledge helped with direct distance estimates and with indirect direction estimates, but it hurt indirect distance estimates where personal knowledge was simply unavailable. Yet, children who had greater experience with imagining locations and the spatial relations between them, as shown by our measure of prior roaming experience, were presumably more likely to adopt a strategic approach to solving problems on physical navigation. Those children showed a consistent pattern of results.

From a developmental perspective, a significant contributor to both outcomes in neither case was it the most simplistic, ageless, on average, 7-year-old children's median error of 48°, whereas 10-year-olds had an improvement over the age range reported by Herman, Heim, and the 10-year olds' accuracy is still impressive (E.g., Davies & Pederson, 2001). Although it is important to approach these results with caution, the above results suggest that the canonical correlation, the reasoning behind these findings are consistent with our own results with children and adults. The strong visual nature of local familiarity, and of past experience, and the strategic and tool-using nature of young children's maps are integrated, relatively unbiased, surveys.

10.5.2 Children's Interaction with Maps on Subsequent Exposure

Before turning to the central empirical findings of exposure to maps versus verbal declarative knowledge in the outdoor and indoor setting—we first evaluated children's performance. This was important to consider because children may show only gradual development over a series of approximate stages (Timko & Trahan, 1987) to cope with interpreting more maps. This is why we could not expect the performance to improve over time. Therefore, we were interested in children's performance on maps. Children found the matching, drawing, and mapping tasks fun, although their accuracy was lower than expected. One of the landmarks that might have placed the children in a lower stage of development was the "stall" stage theory, by critiquing children's strategies, if recognizing that alternatives were available.

In general, children coped very well with very few made more than a handful of errors.
as shown by our measure of prior spatial problem-solving experience, were presumably more likely to adopt an alternative strategy that was less based on physical navigation. Those children therefore showed the opposite pattern of results.

From a developmental perspective, it is worth noting that age was a significant contributor to both of the first two factors identified above, but in neither case was it the most significant factor in its own right. Nevertheless, on average, 7-year-old children pointed to each landmark with a median error of 48°, whereas 10-year-olds’ error averaged only 25°. This improvement over the age range roughly matches previous studies (Anooshian & Young, 1981; Herman, Heins, & Cohen, 1987; Lehnung et al., 2003), and the 10-year-olds’ accuracy is similar to that quite often found for adults (e.g., Davies & Pederson, 2001).

Although it is important to treat the results of multivariate analyses with caution, the above results are interesting given the relative rigor of canonical correlation, the reasonably sized sample, and the fact that these findings are consistent with our existing knowledge of spatial cognition in children and adults. The strong roles of previous spatial task performance, of local familiarity, and of past exposure to maps all suggest a link to the theoretical interpretations suggested above. These place an emphasis on the strategic and tool-using nature of children’s spatial problem solving, and on the possible advantages conferred by appreciating and developing an integrated, relatively unbiased, survey-like representation of the space.

10.5.2 Children’s Interactions with Maps and Their Impact on Subsequent Spatial Performance

Before turning to the central empirical question of this study—whether exposure to maps versus verbal information influenced children’s performance in the outdoor and circles tests as it had in the previous laboratory setting—we first evaluated children’s performance in the information game. This was important to check, given previous predictions that children will show only gradual development in map interpretation skills via a series of approximate stages (Liben, 1999). If children were indeed unable to cope with interpreting more “real-world” maps in the information game, then we could not expect the maps to influence their spatial test performance. However, there were no significant age differences or apparent “stages” in children’s performance in the information game. Rather, children found the matching, drawing, tracing, and interpreting tasks easy and fun, although their accuracy was not always perfect and they were not always familiar with all of the landmarks. A few children even made comments that might have placed them near the highest level in Liben’s proposed stage theory, by critiquing the content and design of the map itself as if recognizing that alternatives were also possible.

In general, children coped very well with the “Mystery Places” game—very few made more than a handful of errors over the two sessions. Children’s
drawings and map annotations also demonstrated that they had no trouble understanding either the symbolic or spatial aspects of the map. Examples are shown in figure 10.3. When spatial errors occurred in placing landmarks such as the child’s home or a local church, these tended to be within a block of the correct location. Moreover, children’s symbols (in both conditions) ranged imaginatively from a simple cross or envelope up to quite detailed buildings, but there was no apparent systematic increase or decrease in symbolism with age. For the railroad or canal, although the children were often able to draw only a small portion of the line due to ignorance of its route, they had no trouble drawing a simplified railroad track or wave patterns to signify them. Age also had no discernable effect on the correctness of the children’s placement of these symbols in the map condition or on their placement of their own home and school.

Overall, then, all symbolic and basic spatial aspects of the information game seemed quite easy. This was the case even for 7-year-olds and even though most of the children had never previously seen any spatial representations of their local area (and few maps in general). This matches other research suggesting that children’s approach to the symbolic aspects of maps is largely mature by the age of 6 (Lee & Karmiloff-Smith, 1996). It also helps to explain why some children’s previous exposure to maps had apparently benefited their initial spatial test performance (at least on the pointing tasks), as described above. As far as we could ascertain, none of the children had received any actual formal training in map interpretation. It makes sense to assume that if prior map reading skills are related to spatial performance even before training, they already had sufficient spatial knowledge to use our (relatively simplified) maps, just as comfortably as with the accurate metric and compass.

At the same time, it is important to remember that the two groups of children were equally able to perceive and locate landmarks to their photographs, just as comfortable with using approximate as well as with the accurate metric and compass.

With this background, we turn to the improvement gained from the information session. Children in the outdoor spatial performance tests showed no improvement on outdoor tests, there was some improvement in the “imagined” pointing tasks, and especially when performing these pointing tasks, it appears to suggest that the value of the spatial tasks lies where they are designed to be—that is, as personal experience can be recorded and directions. As with the laboratory studies, children’s performance on the comparison tasks was also aided by the simulation. As sessions continued, they were again able to learn pairwise, and if one group was insufficient without the other, the rate configuration was required for these tasks.

Again, as with the model of the study, success on the “circle” tasks is being available; simple pairwise tasks were clearly adequate for constructing the maps, and all the children tackled the circle task quite easily. The maps were drawn quite confidently in the layout to be held in memory, and the maps were widely used for geometric reality. A significant accuracy in this task gave the two groups, with the map generally, that there was a gradual increase in the map condition, before appropriate verbal condition, by contrast, proving the 7- to 9-year-olds before maps 10. In terms of difference between the performance of 7- and 9-year-olds showed the strongest change in the information game producing the greatest task, while those who played the maps (in terms of mean error of place...
sense to assume that if prior map exposure was able to influence children’s spatial performance even before we showed them our map stimuli, then they already had sufficient spatial cognitive skills to be able to understand our (relatively simplified) maps, too.

At the same time, it is important to note that children in the verbal condition were equally able to perform the tasks in the information game: the two groups of children were equally successful at matching the landmark locations to their photographs. This suggests that the children were just as comfortable with using approximate, verbally described information as with the accurate metric and configurational representation of the map.

With this background, we turn to the question of whether the knowledge gained from the information game would and could be used by children in the outdoor spatial performance and circles tests. With regard to the outdoor tests, there was some evidence that the map benefited children more in the “imagined” pointing and distance tasks than in the “real” ones, especially when performing them both at home in session 3. This again appears to suggest that the value of such “survey-based strategies” in solving spatial tasks lies where they are clearly the best way of solving the problem with any degree of accuracy—their influence appears less critical when direct personal experience can be recalled to help calculate direct distances and directions. As with the laboratory study described above (Uttal et al., 2006), children’s performance on the more basic pointing and distance comparison tasks was also aided by the verbal condition (as shown by a similar improvement between sessions 1 and 3). We can conclude that children were again able to learn pairwise spatial relations from verbal stimuli, but these were (again) insufficient when an integrated and geometrically accurate configuration was required—which was the case in the “imagined” tasks.

Again, as with the model construction task in the Uttal et al. (2006) study, success on the “circles” task depends heavily on such a configuration being available; simple pairwise knowledge of distances and directions is clearly inadequate for constructing an integrated model of a space. Almost all the children tackled the circles task with enthusiasm, and most seemed quite confident in the layouts they produced, even though some differed wildly from geometric reality. As might be expected, children’s mean placement accuracy in this task gave the strongest statistical difference between the two groups, with the map group clearly performing better. Additionally, there was a gradual increase in performance on the circles task with age in the map condition, before apparently leveling off around age 9. In the verbal condition, by contrast, performance actually worsened with age for the 7- to 9-year-olds before making a dramatic improvement around age 10. In terms of difference between the two conditions, this meant that 9-year-olds showed the strongest effect, with those who had played the verbal information game producing the worst overall performance on the circles task, while those who played the map information game produced the best (in terms of mean error of placement when compared to an “ideal” layout).
There was no difference among 10-year-olds in the two conditions, perhaps because their local knowledge had matured to the point of being able to recall or reconstruct a fully integrated "survey" representation of their own (which is supported by our earlier observation that their pointing and distance accuracies were close to those of adults).

It is important to note that, as in earlier experiments, the children were never explicitly encouraged to learn or transfer knowledge from one task to another; it was up to them to decide which of our "games" with them were helpful to other tasks. In this study, the only task for which the children were given feedback on their performance was the information game, to ensure that they always had a chance to learn the correct matchings and locations. However, there was no explicit suggestion that we wanted them to learn the correct solutions for later use in other tasks. Unlike the earlier experiments, there was no repetitive rote learning of the spatial representations: the children learned through interaction with them, and any committal to memory was up to them. Nevertheless, playing the "game" did affect children's spatial responses in other tasks. Despite the complexity and multiple sources of bias that are present in cognitive models of real-world spaces, both phases of the above analysis demonstrate that the chance to view a consistent Euclidean representation of the space does facilitate more accurate spatial problem solving where such geometric factors are important, particularly for tasks where other strategies cannot easily be applied.

10.6 CHILDREN AND MAPS: CONCLUSIONS AND RECOMMENDATIONS

At the start of this chapter, we outlined the types of information that a map gives to its user, placing special significance on the spatial configuration as the main feature of maps that cannot be easily supplied in any other form. That configuration, we pointed out, is also likely to be a more accurate spatial representation in terms of Euclidean geometry than the mental representations we generate as a result of real-world spatial experience. However, we also cautioned that a child must be able to appreciate the value of such a representation and its superiority (in geometric terms, at least) over his or her own imperfect spatial knowledge, before he or she is likely to choose to use a map in a task where alternative strategies are possible. This may be particularly true in circumstances where maps are harder to use or apply, and also where accurate metrics are less important in solving common spatial problems such as locating landmarks or planning routes.

Our laboratory studies avoided these issues by constraining the task such that no alternative was possible that would allow successful problem solving within the artificial space; the child had no other prior experience of it. In this way, we were able to demonstrate that children from 4 years of age are at least capable of utilizing a map within a large-scale environment, for encoding and recalling spatial relations (and that 8-year-olds can do this even when those spatial relations are scaled up the task to study the neighborhood, where past direct experience was not made a difference primarily for any alternative strategy, such as rankings, and the circles task.

We also found that past experience, even when they used it, had apparently contributed only to make direction judgments spontaneously appreciating the representations. That same analysis of problem solving spatial problems, such as the tendency to children's initial spatial skills are more likely to play. At the same time, familiarity with pointing and distance estimation of the child. Yet specifically salient estimates, possibly due to may have been depending on the landmarks, which improved the accuracy of pointing estimates of distance or direction.

Age tends to be a significant factor, suggesting that it may be applied in terms of children's opportunities to do anything dependent on an invention could still, theoretically, underlie their ability to respond to the task. Rather, a more parsimonious test of whether and much of the work on children's (1978) notion of "proximal devices" take advantage of the tools which often include experiences of locations that can help them to infer a framework for spatial reasoning.

Since these studies demonstrate that greater exposure to them are
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even when those spatial relations are not explicitly shown on the map). We also saw that the spatial knowledge children gained from descriptions was insufficient for a configurational task such as model construction. When we scaled up the task to study children’s map use within their familiar local neighborhood, where past direct and indirect experience offered even more alternative strategies for spatial problem solving, we again found that maps made a difference primarily for tasks where it was difficult for a child to use any alternative strategy, such as in the “imagined” pointings and distance rankings, and the circles task.

We also found that past exposure to maps, with no formal training in their use, had apparently contributed meaningfully to children’s initial ability to make direction judgments, which suggested that they might in fact be spontaneously appreciating the value of these integrated “survey-like” representations. That same analysis also showed that having already tried to solve spatial problems, such as route planning, appeared to be strongly linked to children’s initial spatial performance, although, of course, we cannot be sure of the direction of causality: perhaps children with better spatial skills are more likely to solve problems, or back seat drivers and explorers.

At the same time, familiarity with the landmarks was crucial to general pointing and distance estimation ability, as was their personal salience to the child. Yet specifically salient landmarks appeared to negatively affect distance estimates, possibly due to bias. It also appeared that some children may have been depending on their physical experience of traveling to the landmarks, which improved their distance estimates to them from home but worsened their ability to make such estimates among them. This demonstrates the importance of an integrated “survey” reference frame in solving some, but not all, spatial tasks. Where this frame is absent or incomplete, performance worsens on tasks that demand it, but not on simple spatial estimates of distance or direction.

Age tended to be a significant but non-dominating factor in these analyses, suggesting that it may be appropriate to consider this type of task more in terms of children’s opportunities to learn from experiences than as something dependent on an invariant developmental “stage” (although this could still, theoretically, underlie the differences among children by affecting their ability to respond to those experiences with optimal effectiveness). Rather, a more parsimonious theoretical framework, for interpreting our and much other work on children’s responses to maps, is Vygotsky’s (1978) notion of “proximal development.” Under this interpretation, children take advantage of the tools to which they are exposed, where the tools often include experiences of local spatial relations as well as map representations that can help them to integrate those experiences together into a usable framework for spatial reasoning.

Since these studies demonstrate clearly that first-grade children are capable of understanding and using the symbolic aspects of maps, we suggest that greater exposure to them at this age, along with some encouragement
to improve mental rotation skills and to interpret the less pictorial and more iconic symbolism that many maps rely on, could help children of this age group toward maximal effectiveness and confidence in the use of maps and other spatial representations. This is a useful skill in several subjects later on in the school curriculum, and indeed across the life span.

To summarize, our research suggests that exposure to survey representations such as maps induces spontaneous use in some types of spatial problem-solving by the age of 7–10 years, at least for children living in a midwestern U.S. suburban area. This implies that making maps available to children by this age can encourage their use and appreciation of such external representations.

NOTE

1. We had used a relative rather than an absolute task here, owing to concerns about the artificial nature of most large-scale distance estimate tools used with children in previous studies. If the child has to scale down the distance artificially to a straight-line rule or row of lights, this adds a level of artifice and transformation to the task that may confound the results. Children’s ranking scores were then weighted by difficulty (i.e., according to the size of the actual difference in distances to the two landmarks).

REFERENCES


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