Seeing Space in More Than One Way:
Children's Use of Higher Order Patterns in Spatial Memory and Cognition

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The movie *James and the Giant Peach* (Selic, Burton, & DiNovi, 1996) opens with James and his parents relaxing at the shoreline. Lying on their backs, they look at the sky and begin to see patterns in the clouds. With a little effort, James begins to see various shapes, including a camel, a train, and a rotated version of the world's tallest building (at that time, the Empire State Building). James is delighted because he has found a new joy in something as simple as looking at clouds. He has realized that he can use information about familiar shapes to reinterpret other, more amorphous forms such as the shapes of clouds.

Our focus in this chapter is on the development of children's ability to see spatial patterns in the way that James saw the shapes of clouds. We are interested in the consequences and the development of the ability to think about spatial locations in more than one way—to find structures and patterns in distributions of locations that are not given by the properties of the locations themselves. We suggest that thinking about spatial locations or configurations in this way can facilitate spatial cognition and its development substantially. We demonstrate that finding structure in otherwise unstructured forms or locations can facilitate spatial memory, mapping, and communication.
As an example of how these structures might facilitate spatial cognition and its development, consider a child who is learning about U.S. geography. The child will hear, for example, about the panhandle of Texas or Florida, about the thumb of Michigan, or that Italy is a boot. Learning these names and what they mean will facilitate the student’s knowledge substantially. For example, if the student is told that Tallahassee is in the panhandle of Florida, then the range of the state of Florida that he or she must search on a map is constrained substantially; most of the state is eliminated from the search. Moreover, the information will now be much easier to communicate to another person, as the range of locations that must be described will be reduced substantially.

People’s tendency to think about spatial location in terms of familiar patterns or structures has an important history in psychological research. Indeed, since the time of the Gestaltists, psychologists and geographers have stressed that the perception and cognition of spatial locations involves more than remembering individual locations. Instead, people attempt to structure locations either in terms of contiguous or patterns within the locations. For example, ancient navigators imposed constellations on patterns of stars; doing so made the locations of specific stars easier to remember and easier to communicate to others. However, this tendency to impose structure on otherwise amorphous or random structures is not limited solely to constellations. It shows up also when a person labels geographic structures in terms of well-known objects or figures as well as when a person uses the constellations to locate or communicate information about stars.

Despite the historical importance of this work, relatively little research has focused on the development of children’s ability to think about spatial information in terms of well-known figures or pattern. In addition, the majority of the work that has been conducted has focused primarily on perceptual development; relatively little research has examined how these issues may apply to tasks that are typically considered to be within the realm of spatial cognition, such as searching for hidden objects or communicating location. In this chapter, we make the case that learning to think about space in terms of familiar patterns may contribute substantially to the development of spatial cognition.

This chapter is organized as follows. First, we consider the advantages of thinking about spatial locations in terms of higher order patterns. Next, we consider the potential role of higher order spatial patterns in the development of spatial cognition. We argue that the ability to think about spatial relations in this way is an important but relatively unexplored aspect of the development of spatial cognition. Coming to think of locations in terms of patterns is an important accomplishment in the development of spatial cognition. We then present research that has addressed this capability, the results of which highlight the challenges and advantages that children can gain by thinking in this manner.

Before beginning this discussion, it is important to define what we mean by the term higher order pattern. We are referring to relatively knowledge-driven, or “top-down,” processes that involve an active construal of locations. The defining feature is an application of prior knowledge of a structure to a new set of locations or bits of information. Perceiving or thinking about spatial locations in terms of higher order patterns requires that an individual go substantially beyond the characteristics of the information that is presented; it requires instead that the person recruit knowledge of a pattern and apply (or map) this pattern onto a set of locations or individual elements within a distribution of locations. For example, a constellation is not defined solely by the properties of the objects in which it is embedded; therefore, it is not a dipper or a pair of twins in the sky. Our knowledge of these figures must be transferred, at least in part, to the pattern of the relevant stars to perceive the relevant structure (constellation) in the sky.

Because our interest is in cognitive-mediated patterns, we focus less on the role of other mechanisms of perceptual organization. For example, we do not discuss children’s use of gestalt principles in spatial organization, in part because these issues have been discussed at length elsewhere (e.g., Stiles & Tada, 1996; Vurpillot, 1976). Our principle focus here is on what could not be given by gestalt principles per se, which is a construal of a set of locations based on properties of those locations that are not given by the locations themselves. For example, gestalt principles could explain why we perceive a set of locations as forming a line, but they could not explain why we see these locations as a camel or a skyscraper. Obviously, gestalt principles are not unimportant in that they contribute to the higher order organization of spatial patterns. For example, a precondition of construing a location in terms of a camel or a dipper might be that a certain number of locations must be arranged closely enough so that gestalt principles would dictate that these locations would be seen as forming a line. This line then could become part of the higher order pattern, perhaps as a leg of a camel or a handle of the dipper.

**SPATIAL ADVANTAGES OF HIGHER ORDER CONSTRUALS**

Although it may be entertaining to see camels in the patterns of clouds, does doing so actually facilitate spatial thinking or communication? If seeing locations in terms of higher order patterns does facilitate communication, how does the facilitative effect occur? To address these questions, we consider in this section three characteristics or effects of higher order patterns that can facilitate performance in spatial tasks.

**Redundancy of Form**

The first and most general facilitative effect of higher order patterns is that they give a person more than one way to think about a location or set of locations. Consequently, the structured pattern provides redundancy that can be useful at both encoding and retrieval. For example, one could en-
code the location of a city in Italy both in terms of cardinal directions as well as in terms of a particular part of a boot. Likewise, one can remember the location of a star both in terms of its position relative to other stars as well as in terms of its position within a constellation. These multiple forms of encoding provide redundancies that increase the probability that relevant cues can be generated or used at recall. If a person forgets, for example, a specific location, then he or she can think of the general part of the figure in which the target was located. This information then could help to refresh the memory of the specific location.

The redundancy of form also can contribute substantially to spatial communication. One of the most important challenges of spatial communication is establishing a common perspective or reference frame. Communicators must search for “common ground,” and it is well known that young children have difficulty establishing a common perspective or taking the perspective of another in a spatial communication task (Shantz, 1993). More recent evidence suggests that even adults are at least initially “egocentric” (referring to reliance on their own perspective) and that they work on finding common ground only when it becomes clear that the interlocutor does not understand the descriptions or instructions (Keysar, Barr, Balin, & Brauner, 2000; Keysar, Barr, Balin, & Paek, 1998; see also Schwartz, 1965).

The problems of egocentrism and finding common ground can be reduced somewhat if the locations are constituted in terms of a higher order pattern. For example, once both interlocutors agree that a set of locations can be construed as a pattern, then the parts of the pattern provide a clear common ground. For example, if people perceive that a set of stars forms the outline of a crab, then both interlocutors will often agree on what constitutes a part of the tail or a part of a claw. Put another way, well-known figures typically have a canonical orientation and a clear set of parts (Olson & Bialystok, 1983). Both of these characteristics can serve the function of orienting and establishing common ground.

Limiting the Search Space

As we mentioned earlier, higher order patterns can also limit substantially the potential search space that must be considered when searching for a location. People can eliminate many possible locations if they know the general region of the pattern in which a hidden object is located. This reduction in search space in turn can increase dramatically the probability of identifying the target location. A person may not know, for example, the precise location of an east African nation, but if they can remember that it is in the horn of Africa, then they can eliminate most of the continent as a possible location. A similar advantage accrues when one is attempting to communicate a location. For example, when a person hears that a star is located on one side of Orion’s belt, then the number of possible stars that must be considered in finding the target is greatly reduced.

Limiting the possible search space can also have important advantages when a person is attempting to use a chart or map. One of the central challenges of using maps or other spatial representations is to establish correspondences (mappings) between information on the map or chart and the corresponding locations in the represented space. This is not always a trivial task; even adults can find it difficult to establish correspondences, particularly when the amount of detail is high, and young children often have great difficulty establishing correspondences between spatial relations on maps and in the world (Liben, 1999, 2000; Uttal, Gregg, Tan, Chamberlin, & Sines, 2001).

Systematicity

Redundancy and limits on search space are important characteristics, but they do not capture all of the advantages of thinking about spatial locations in terms of higher order patterns. An important and unique advantage is that construing locations in terms of the higher order pattern helps to convey a degree of systematicity to what might otherwise be random relations (Clement & Centner, 1991; Centner & Markman, 1997; Uttal et al., 2001). As used here, the term systematicity means a predictable, hierarchically organized set of relations among locations. Systematicity implies that knowing about one part of the figure also gives a person knowledge about other parts. For example, if people know that a to-be-remembered location is in the tail of a constellation figure, then they know something about the relation of the locations that constitute the tail to the locations that constitute the remainder of the body. Thus, higher order patterns allow us as humans to borrow from our knowledge of real-world figures, knowledge not only of the parts of the figure but also the relation among the parts of the figure. Having established the whole, one can then use relations between the whole and its constituent parts to describe relations.

The role of systematicity in higher order patterns helps to explain why so many of the constellations are based on animal figures, including both variations of the human form (sisters, hunters, etc.) as well as various animals. Animal figures are both well known and well organized in terms of part-whole relations (Tversky & Hemenway, 1984). Animal figures thus are often inherently systematic, and mapping these to a set of locations can convey to the locations some of the same organizational advantages that are given in the original figure.

The effects of systematicity can be particularly helpful in tasks that involve spatial communication. Spatial relations are often very difficult to describe verbally because each relation must be described in a serial fashion (Linde & Labov, 1975; Ondracek & Allen, 2000; Taylor & Tversky, 1992a, 1992b, 1996). For example, people have to say, “It’s one over from the left, two up from bottom, and three over from the far right.” Each of these spatial relations must be stored in short-term memory, and processing lim-
its may constrain the amount of information that can be recalled or integrated into a survey-like representation (Ondracek & Allen, 2000). However, the systematicity of a higher order pattern makes it possible to describe these locations on the basis of relations between parts and wholes.

**DEVELOPMENT OF CHILDREN'S USE OF HIGHER ORDER PATTERNS**

Up to this point, we have described several ways in which thinking about a set of locations in terms of a higher order pattern can facilitate spatial memory, mapping, and communication. Do these advantages also apply to young children? Children might gain a substantial advantage from thinking about locations in terms of higher order patterns. For example, as noted previously, children often have difficulty using maps when the correspondence between the map and the represented locations must be established on the basis of spatial relations rather than on the correspondences between individual locations (Blades & Cooke, 1994; Bluestein & Acredolo, 1979; Liben, 1999, 2001; Liben & Downs, 1992; Loewenstein & Gentner, 2001; Uttal et al., 2001). Construing locations in terms of a higher order pattern could be of considerable assistance on these kinds of tasks. Higher order patterns make spatial relations more systematic and hence more tractable; it is easier to think about how a set of locations relates to a well-known figure than it is to think about (and map) them in terms of complex and perhaps arbitrary spatial relations.

Likewise, it is well known that children under 5 or 6 years of age often have difficulty describing a single location among many alternatives (Flavell, 1968; Glucksberg & Krauss, 1967; Plumer, Ewert, & Spear, 1995). In particular, children have difficulty communicating spatial information when they must take into account the relations among multiple locations. When adults are faced with such a task, they often impose a well-known structure on a set of locations. Descriptions then can be based on the structure of and relations within the pattern rather than on an arbitrary set of spatial relations (Gentner & Rattermann, 1991; Uttal et al., 2001). Learning to think about and use patterns may, therefore, contribute to the development of spatial communication.

The possible advantages for young children in constructing a set of locations in terms of higher order patterns motivates a research program that we have pursued for the past few years. Uttal et al. (2001) studied the development of young children's ability to impose a higher order pattern on a set of locations. The research examined specifically (a) the development of the ability to think of a set of locations in two different ways and (b) to exploit these higher order construals to facilitate memory, mapping, and search.

We have studied both the way a higher order pattern could facilitate mapping and search and how it could facilitate spatial communication. In the next sections, we present summaries of these lines of research. The results reveal that a higher order pattern can indeed facilitate children's spatial behavior. However, there are important developmental prerequisites that children must achieve before they can take advantage of what higher order patterns can offer.

**Using a Higher Order Pattern to Facilitate Mapping and Search: Conceptual Issues**

This research focused on whether young children could benefit from constructing a set of locations in terms of a higher order pattern and whether they could use this construal to facilitate mapping and search. Uttal et al. (2001) asked young children to use a map to find objects that were hidden in a room. In this regard, our studies resembled those of classic studies of the development of map-reading skills; the children were asked to use a simple map to find a hidden object (Blades & Spencer, 1987; Bluestein & Acredolo, 1979; Marzolf & DeLoache, 1994; Presson, 1982). Whether they succeeded provides an index of their ability to understand and to exploit a correspondence between a map and a space that it represents (see Blades, Spencer, Teeter, & Desmond, chap. 12, this volume).

However, in a different sense, our studies are quite different from previous research on the development of map-reading skills. Our (Uttal, Chiong, & Wilson, 2002; Uttal et al., 2001) research asked whether children could interpret a set of locations in a new way—whether they could impose a structured pattern on a set of locations. Specifically, the set of locations that served as hiding locations (and that were represented on the map) could be interpreted as forming the outline of a familiar figure, a dog. We investigated when the children could interpret the locations as a dog and the cognitive consequences of doing so. We hypothesized that if children could think of the locations in this higher order way, then they might gain a substantial advantage, both in terms of memory and in terms of the process of establishing a mapping between the map and the space.

**Facilitating Mapping and Search (Uttal et al., 2001)**

The participants for this study were 3-year-olds, 4-year-olds, and 5-year-olds, approximately equally divided between the two sexes. The children were recruited through direct mail to their parents. The majority of the children were White and middle class to upper middle class. Approximately 25% were minorities. All of the children came from the north side of Chicago and the northern suburbs. The children were randomly assigned to one of two groups. The non-lines group saw a simple map that represented the locations that were shown on the map. The lines group saw the same circles but with one addition; these locations were connected with lines to indicate the overall shape of the dog pattern. Figure 6.1 shows the two maps.
The search space was a 10 ft × 10 ft yellow piece of felt. The felt was placed within a larger room. There were windows at one end of the room. However, although these windows were not shown on the map and because successful searches could only be accomplished by using the map (or by very lucky guessing), it seems unlikely that the windows could have served as landmarks or otherwise influenced children’s performance. The hiding locations were paper coasters that were distributed across the felt.

The experiment began with a brief introduction to the task. The experimenter showed the children the felt carpet with the coasters scattered across it. He or she told the child that a second experimenter would hide a sticker under one of the coasters and that the child would be asked to find the sticker. The experimenter then showed the child the map for the condition to which the child was assigned. To help children understand the map, the experimenter pointed out correspondences between two circles on the map and the corresponding circles in the space. The experimenter did not tell the child that the locations formed the pattern of a dog, regardless of the condition to which the child was assigned.

The experimenter then took the child behind a room divider so that he or she could not see the search space. The second experimenter then hid a sticker under one of the 27 coasters in the search space. The second experimenter then walked across the entire length of the felt carpet on each trial to reduce the possibility that sound cues could communicate the location at which the sticker was hidden. While the second experimenter hid the sticker, the first experimenter indicated the corresponding location on the map. The child was asked to point to the location three times to ensure that he or she could remember the location. The experimenter then said, “Now it’s time to go look for the sticker.” The child was not allowed to take the map with him or her during the search. The child was allowed to turn over up to three coasters while searching for the toy. If the child still had not found the sticker after three attempts, the experimenter pointed out the correct location.

This basic procedure was repeated across the 10 trials. On each trial, the sticker was hidden under a different coaster. Figure 6.1 (top panel) shows the locations under which the sticker was hidden. There were four different hiding orders; children were assigned randomly to one of the orders.

The results were clear: Seeing the lines maps (and hence becoming aware of the dog pattern) improved the performance of the 5-year-olds substantially. The 5-year-olds in the lines group averaged 71% correct searches (SD = 16%), whereas those in the no-lines condition averaged 54% correct searches (SD = 13%). The performance of the 3- and 4-year-olds were not affected by seeing the lines map. However, different factors accounted for the lack of an effect in the two younger age groups. The 3-year-olds overall had substantial difficulty with the task, averaging less than 25% correct searches. These children may simply not have understood that the map was relevant to finding the sticker. The 4-year-olds performed better, averaging approximately 36% correct searches, but the lines and no-lines 4-year-olds performed nearly identically. Thus, the 4-year-olds clearly could use the map to guide their searches in the room, but they did not benefit from seeing the dog pattern.

These results raise two important questions: How did seeing the dog pattern facilitate children’s performance, and why was the effect limited to the 5-year-olds? We consider several possible answers in the next section.

**Is the Effect Due Solely to Facilitating Memory?** One possible explanation for the results is that seeing the dog pattern facilitated children’s memory for the correct location. As mentioned previously, one of the primary reasons that people interpret locations in terms of higher order patterns is that doing so facilitates memory for individual locations. Could this explanation account for the results in this case?

It is certainly true that seeing the dog pattern on the map could have facilitated children’s memory for the locations. However, this alone would not be enough to help the children find the sticker in the room. Recall that the lines that defined the dog pattern were not present in the room. All children saw the same space when they were asked to find the hidden sticker; this space consisted of a room within which we distributed the 27 coasters.
The lines that one-half of the children saw on the map were never present in the space. Therefore, to realize the advantage that they gained from seeing the dog pattern on the map, the children had to reinterpret the locations in the room in terms of this pattern. The better memory for the locations on the map could only help if the children mapped the structure of the dog pattern in the space to the unlined locations in the room. This mapping process is not one only of memory. It requires that the children construe locations in the room in terms of the pattern that they had seen on the map; they had to carry over the higher order pattern from the map and then reapply it to the locations in the room. Put simply, the memory advantages of using the dog pattern derived from children’s ability to first map the dog pattern to the locations in the room.

Could the Results Have Stemmed Solely From Lower Order Effects of Adding Lines to the Map? One potential limitation of Experiment 1 in Uttal et al. (2001) concerns how the higher order pattern was instantiated; the locations were connected with lines. Pilot testing had revealed that this method was the most effective way of communicating the higher order construal of the locations. In addition, adding lines to the location was most consistent with the way that higher order patterns are communicated in the real world; astronomical charts often show constellations by connecting stars with lines. However, that the locations were connected with lines does raise the possibility that the effect was due more to the lines per se rather than to what the lines formed. The sheer presence of the lines themselves may have affected children’s performance, regardless of the pattern that the lines formed. For example, the lines might have helped to parse the locations into sets of unrelated parts on the basis of perceptual characteristics such as local minima of lines. Parts can be defined on the basis not only of relations to a whole figure but also on the geometrical properties of the region themselves (Hoffman & Richards, 1984; Hoffman & Singh, 1997). Because their claim is that children imposed a higher order pattern on the locations in the room, Uttal et al. felt it was important to pursue in greater detail whether the sheer presence of lines per se on the map could facilitate children’s performance on these tasks.

To address this question, Uttal et al. (2001) used a second figure, shown in Fig. 6.2, which we called the “scrambled dog.” This figure has the same number of parts as the original dog figure, but they are arranged in a different ordering. This created a pattern, but it was not, by our definition, a higher order pattern; there was no clear mapping between a well-known figure and the new, scrambled dog. Uttal et al. predicted that adding lines to the scrambled dog would convey no advantage specifically because the lines do not convey a higher order pattern.

The study was similar in all other aspects to the original study; the children saw the map (either with lines or without lines), pointed to the location, and then were asked to find the hidden sticker in the room. The lines and no-lines groups performed almost identically, averaging 42% (SD = 21%) and 45% (SD = 21%) correct searches, respectively. Of importance, the average level of performance in this study did not differ significantly from that of the no-lines group in the original study. Across the two studies, all groups of 5-year-olds performed comparably except those who saw the dog pattern highlighted with lines.

However, Tan and Uttal (2001) demonstrated in another follow-up study that 5-year-olds could gain advantages from seeing the lines on the scrambled dog pattern but only if they had first used the dog pattern. In this study, Tan and Uttal gave 5-year-olds experience with the dog pattern; the children completed 5 searches using the map with lines that showed the regular dog pattern. Then the children were shown the scrambled dog pattern and completed 10 searches in this space. Thus, the children completed a total of 15 searches. Their performance was compared to a control group that used the scrambled dog pattern for all 15 trials. The performance of the prior experience group was substantially and significantly greater than that of the control group.

Tan and Uttal’s (2001) results suggest that children transferred their knowledge of the higher order dog pattern to the scrambled dog. In essence, when they saw the scrambled dog pattern, they saw only a discon-
nected set of parts, and this did not convey an advantage in the search task. In contrast, when they first saw the dog pattern, the children may have gained insight into the idea that these locations formed a familiar pattern. They then gained the advantage of mapping and relational thinking that the dog pattern conveyed initially.

Taken together, the results of these follow-up studies strongly suggest that the effect of adding the lines in the original study was to convey a higher order pattern. Children only benefited from seeing the lines if those lines formed a meaningful pattern or if the relation to a meaningful pattern was instantiated through prior experience.

We suggest that seeing the dog pattern facilitated performance because the pattern makes it easier for the children to think about and use spatial relations. The dog pattern not only facilitated memory; it also helped children to establish connections between spatial relations on the map and corresponding relations in the room. The task required that children map spatial relation because very few of the locations could be thought of as distinct or unique; the locations could only be mapped and discriminated from one another on the basis of spatial relations. This is a task that young children often find difficult. The dog pattern facilitated performance because its systematicity made the spatial relations more tractable and more memorable. In essence, the dog pattern provided a scaffold for thinking about and mapping spatial relations, and hence, it allowed the children to succeed at a task that is normally quite difficult for them.

Using Higher Order Patterns to Facilitate Spatial Communication: Conceptual Issues

We turn now to a brief summary of an ongoing series of studies on the use of higher order patterns to facilitate spatial communication. Although the task is different, the results converge with those of the mapping and search task presented earlier. Thus far, our focus has been on the ability to use structured patterns to facilitate memory and search. However, as we pointed earlier, the advantages of using higher order patterns are not limited to these tasks. Indeed, one of the most common uses of higher order patterns is to facilitate spatial communication. We now consider an ongoing series of studies that is investigating the development of children's use of a higher order pattern to aid spatial communication.

Chiong, Wilson, and Uttal (2001) investigated whether, and when, children can benefit from using a higher order pattern in a referential communication task. The task was in some ways similar to the previously described search task; the children saw the same configuration that we used in the prior studies (see Fig. 6.1). However, rather than search for a hidden object, the children instead communicated locations to a listener. The results revealed important developmental differences in the ability to recruit the higher order construal and to use this to facilitate referential communication.

Facilitating Communication: An Illustrative Study

The children for the Uttal et al. (2002) study were ages 4 through 6. We also included a group of university students to provide a standard to compare with the children's performance. The participants were recruited from the same sources as in the prior studies.

As in the earlier experiments, the participants were assigned randomly to see either the lines or the no-lines configuration. The participant sat on one side of an opaque screen, and another person (the listener) sat on the other side. We told the participants that we would place a small piece of clay on one of the to-be-described locations and that their job was to tell the listener where the clay was located. We had children describe 10 locations, 1 at a time. On each trial, we placed the clay on a new location and asked the children to describe it. If the child's description of a given circle did not provide enough information to specify the precise location, then the experimenter requested additional information. These requests were tailored to the children's first description. For example, if a child said, "It's in the tail," the listener would say, "Can you tell me where in the tail?"

One challenge in this research involves coding and scoring children's descriptions. In contrast to the prior search studies, we could not simply score performance in terms of correct searches. Instead, we had to code children's descriptions in two different ways to capture different aspects of their performance. One coding addressed what characteristics of the configuration the children mentioned in their descriptions. Some of the most common strategies for descriptions included references to parts of the dog, counting (e.g., "it's one over from the top"), and use of spatial references and prepositions (left, over, above, etc.). The second coding addressed the accuracy or specificity of the descriptions. We based this coding on the approximate number of locations that a given description eliminated. A perfect description would eliminate all locations except the target. A poor description would eliminate no possible descriptions. For example, saying, "It's on the dog," tells the listener no useful information, because every location was part of the dog. We also coded intermediate descriptions such as "It's in the dog's head," or "It's near the top." These descriptions eliminate some, but not all, of the locations.

The results in terms of the specificity of the descriptions were for the most part straightforward. In general, children who saw the dog pattern (as instantiated with the lines) performed better than those who did not see the dog pattern. This effect diminished with age, as the older participants (particularly the adults) performed well regardless of whether they saw the lines. However, seeing the dog pattern did not benefit the 4-year-olds and many of the 5-year-olds.
The codings of the content of children's descriptions revealed two major findings. First, the younger children (most of the 4-year-olds and many of the 5-year-olds) rarely mentioned the dog pattern unless the locations were connected with lines. Second, the younger children in the lines group tended to describe the locations only in terms of the dog; they would mention a part of the dog and little else. Thus, the children tended to describe the locations either in terms of the dog (and only the dog) or in terms of spatial characteristics of the locations but not both. In the minds of many of the younger children, they thought about (and communicated) either a dog or a set of locations but not both. The two construals of the locations (as a set of a circle and as a dog) seemed not to coexist in the minds of the younger children. Consequently, the younger children's descriptions were less specific than the older children's were, even when they used the dog figure to describe the locations.

CONCLUSIONS CONCERNING SEEING SPACE IN MORE THAN ONE WAY

Taken together, the results of the research discussed converge on the same conclusions. First, they provide evidence that higher order patterns can indeed facilitate children's performance in spatial tasks. In both studies, it was the relational nature of the dog pattern that facilitated children's performance. Seeing the dog pattern helped children to remember, map, and communicate locations. Many of the challenges that young children typically face in thinking about and remembering spatial locations were alleviated when the children could rely on the relations inherent in a familiar pattern rather than on arbitrary and complex relations among unrelated spatial locations.

Second, the studies indicate that age 5 may represent an important developmental transition in children's ability to exploit higher order patterns. In both series of studies, children less than 5 did not benefit from seeing the dog pattern. Moreover, the results (particularly) with 4-year-olds cannot be attributed to children failing to pay attention to the task or to the task being too difficult for them. For example, in the mapping and search tasks, the 4-year-olds performed much better than would have been expected by chance, which indicates that they understood and paid attention to the task. Nevertheless, they did not benefit from seeing the dog pattern.

In this final section, we consider a possible source of the developmental difference that we observed. Why did the 5-year-olds benefit from the pattern, and why did the 4-year-olds not benefit? The answer may lie in the development of the ability to perceive one stimulus in two different ways. A critical prerequisite for benefiting from a higher order pattern is being able to perceive the locations in two different ways: as a set of possible hiding places and as parts of a structured pattern. The 3- and 4-year-olds in these studies did not benefit from the dog pattern because they could not see the locations in both of these ways.

Before explaining in detail how this could account for the developmental results that we observed, we first review a series of studies that may be highly relevant to understanding the challenges of using a higher order pattern. For example, Elkind and colleagues (Elkind, 1964; Elkind, Koelger, & Go, 1964; Elkind & Scott, 1962) have demonstrated that young children seem incapable of thinking simultaneously about a whole figure and its constituent parts. In these studies, Elkind and colleagues created figures in which the whole and its parts could be interpreted in different ways. For example, one of the figures was a face that was composed of drawings of individual pieces of fruit. Young children tended to see either the fruit or the face; very few children simultaneously mentioned both the fruit and the face. Despite several attempts, Elkind and colleagues could not convince the children that the figure could represent both individual pieces of fruit and in composite an entire face.

More recently, Gopnik and Rossant (2001) have reached similar conclusions using a somewhat different task. They investigated whether children could conceive of both interpretations of an ambiguous figure such as the "Rabbit Duck" or the "Rat Man" figures that appear in many introductory psychology textbooks (see Fig. 6.3). The results were clear: Children less than 5 did not appear capable of seeing (or entertaining the possibility of) two interpretations of the same figure. For example, children saw the figure as either a Rabbit or Duck, and the experimenter could not convince them that the figure could be seen in alternate ways. Even after the experimenter showed how the figure could be disambiguated (by moving the eye in the case of the rabbit duck figure), the children still insisted that their initial in-

FIG. 6.3. Examples of ambiguous figures. The figure in the top panel can be seen as either a duck or a rabbit. The figure in the bottom panel can be seen as either a rat or a man. Note. From "Duck or Rabbit? Reversing Ambiguous Figures and Understanding Ambiguous Representations," by A. Gopnik and A. Rossant, 2001, Developmental Science, 4, pp. 175-183. Copyright ©2001 by Blackwell Publishing. Reprinted with permission.
terpretation was the only one possible. Despite several attempts, the children did not conceive of the figure as reversible.

These and similar results (e.g., Vurpillot, 1976) suggest that children younger than about 5 years of age cannot perceive spatial figures in more than one way. How might these results relate to children’s use of higher order patterns and to the developmental results that we observed? We suggest that successfully using a higher order pattern in a spatial task requires that people think simultaneously about the pattern and about the locations that are embedded within the pattern. It would do little good, for example, to think of the locations as forming a dog if one did not also keep in mind precisely how the locations related to the dog pattern. Both of our tasks (search and communication) required that children think about not only the pattern but also about the relation between the individual locations and that pattern. We suggest that the 3- and 4-year-olds in our task did not do this; they thought either about a set of locations or about a dog but not both.

This limitation could have affected the younger children in the work reviewed here. In the mapping and search task (Uttal et al., 2001), the younger children would have had difficulty relating the lined pattern on the map to the unlabeled pattern of the coasters in the room. They knew about the dog when they saw it on the map, but when they entered the room, all they saw was the coasters.

The results of the spatial communication task strongly support our interpretation of the developmental differences. The 4-year-olds did sometimes use the dog pattern in their descriptions, but when they did so, this was only what the information they provided. When the dog pattern was obvious (because we connected the locations with lines), the younger children lost sight of the more local information about the circles that formed the dog. (Navon, 1977). Consequently, they provided descriptions almost solely in terms of the dog. Their descriptions either mentioned the dog or spatial properties of the individual circles but not both characteristics.

In summary, we conclude that what the younger children lacked was the ability to think simultaneously about the dog pattern and about the locations that constituted the dog pattern. The research presented here therefore demonstrates that children can benefit from higher order patterns in ways that are analogous to how adults can benefit. Much like ancient navigators, the children in our studies benefited substantially by reinterpreting a set of locations in terms of what is essentially a constellation. Once the children could think of the locations as a dog, many of the problems that they typically encounter in remembering or communicating spatial information were ameliorated. At the same time, our results highlight the importance of what is perhaps a fundamental transition in cognitive development: acquiring the ability to see, and to think about, one thing in two different ways. Spatial cognition can be facilitated greatly by being able to think about locations in more than one way.

6. SEEING SPACE IN MORE THAN ONE WAY

ACKNOWLEDGMENTS

 Portions of the work that is reviewed in this chapter were presented at the April 2001 meetings of the Society for Research in Child Development, Albuquerque, New Mexico. The work was supported by National Science Foundation Grant 0087516 and National Institute of Health Grant R29HD34929. We thank Mavee Hennety, Carolyn Freedman, Catherine Fried, and Catherine Learned for their help.

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The Neuropsychology of Object-Location Memory

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Spatial memory involves information about location, orientation, and direction. It supports a multitude of cognitive and behavioral activities ranging from basic “spatiomotor” actions and locomotion to navigation and recognizing complex figures. In this chapter, we focus on the neuropsychology of memory for object locations. Object-location memory includes several specific functional characteristics, some of which may set it apart from other types of spatial memory. First, and most important, unlike navigation, remembering object locations typically does not involve storing a sequence of spatial decisions or temporally ordered spatial information (cf. Schummann-Hengsteler, Stroßl, & Zoellch, chap. 5, this volume). Instead, it is a representation or description of where things are in space, independent from how and in which order the observer wants to attend to these locations. Second, object-location memory can apply to small-scale space (e.g., “Where is your manuscript on your desktop or computer screen?”) as well as space in a larger scale (e.g., “Where are your running shoes within your house?”). In both cases, the essential coding processes are supposed to be viewer independent. Small-scale displays, however, usually include an alignment of test and presentation displays (see also Goldstein, Canavan, & Polkey, 1989). Thus, items are perceived from the same perspective, and performance might essentially rely on viewer-centered coding. Third, object-location memory primarily represents abstract knowledge about a person’s environment without directly prescribing motor actions. In other words, people may know where an object is, but it is another question how they should act on this object. The latter requires navigational knowledge (how to reach the object) and memory-guided spatiomotor actions.