Thinking With Spatial Analogies

Bloomfield is to Detroit as Shaumburg is to Chicago – upstream, upwind, and upscale.

(Drafted 2009, revised 2012, update 2014 and 2015)

This chapter is about organizing and representing geographic information by noting places that have *analogous locations* (and therefore may have similar conditions and connections). An analogous location is one that is spatially similar in some way – a similar latitude, for example, or elevation above sea level, distance from city center, position within a river system, proximity to an airport, etc.

Reasoning by analogy is a highly structured form of thinking. A person notes a relationship of some kind between two known objects or parts of an object (conventionally called the *base*) and posits that the same relationship exists for a less-well-known object (the *target* - see Sternberg 1977; Helman 1988; Gentner and Markman 1997; Holyoak and Thagard 1997; Doumas and Hummel 2013).

Analogies almost inevitably involve a mix of logical and perceptual similarities and differences. In exploring the topic, the psychologist Dedre Gentner described an analogy between a battery and a reservoir. In this rather abstract analogy, the similarities include only the storage function and its limited capacity, whereas the list of differences is long and includes shape, position, enclosure, use, and the thing that is being stored – electricity or water (Gentner 1983). Her conclusion has great relevance for a discussion of spatial analogies: "the contrast between analogy and literal similarity is a continuum, not a dichotomy" (Gentner 1983, p 161; see also Bender and Beller, 2014).

Geographers use many different kinds of spatial analogies, which range from relatively simple to quite complex. A simple spatial analogy has its main focus on distance and/or direction between places: "Muskegon is to Lake Michigan as Buffalo is to Lake Erie." In this simple analogy, the first-named place is a city that is located on the eastern shore of a Great Lake.

In a more abstract spatial analogy, the spatial similarity may have several constraints. For example, a southwest-facing mid-elevation slope on volcanic rock in Nevada is likely to have plant cover that closely resembles the vegetation growing in a similar position on another volcanic rock in Nevada (but probably not on a sandstone mountain in Nevada, or on any slope in Maine). Once we have established an analogical relationship, we can make other inferences – for example, the "same" slopes on each Nevada mountain might also have similar soil type, animal inhabitants, fire regime, groundwater characteristics, and potential human use (see, e.g., Bede-Fazekas 2011).

Spatial analogies can be a powerful tool for geographical analysis and communication. This form of reasoning can be used in describing the patterns of climates on different continents, plant communities on different mountains, neighborhoods in different cities, land uses around different freeway exits, conditions near strategic straits or international border crossings, and so forth.

Communicating by analogy places great demands on the working memory and background knowledge of the hearer (Walz et al. 2000). Consider this simple "test question:"

JD is to green as AC is to a) violet b) blue c) yellow d) orange e) red

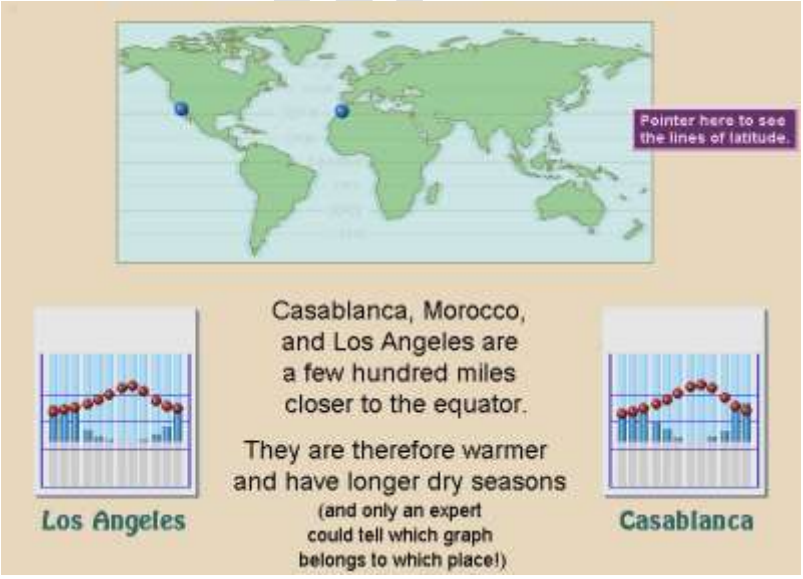
To answer this question, you need to know that JD is an acronym for John Deere, a farm-machinery manufacturer whose tractors and harvesters were painted green as a form of brand identity. The question, therefore, basically asks what color was used by the Allis Chalmers company. If "orange" did not pop into your head, please note that this question comes from a "culturally rebiased aptitude test" developed by people raised on farms. Its questions draw on prior knowledge that nearly every rural schoolchild in the 1970s would probably have, but most urban or suburban Americans would not.

We chose this example to highlight the crucial role of prior knowledge in analogy. This is an important issue in education, and it should be a warning flag in front of any attempt to link school support to outcomes on standardized tests. Bluntly speaking, simply having one or two rural or inner-city teachers as "representatives" on a 20-person team constructing questions for a standardized test does not ensure that a "consensus" package of questions will be free of prior-knowledge biases that favor suburban students. This is a BIG issue – I hope the JD/AC example makes it more memorable!

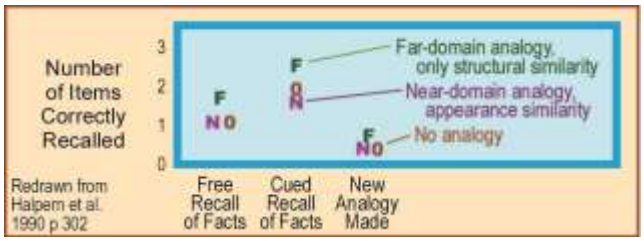
Quick Review of Research about Spatial Analogies

Spatial analogies are basically a subset of analogies-in-general – they are analogies in which either the relationship between the components or a key attribute of one of the components is explicitly spatial. One common spatial analogy is a distant place with a geographic location that is similar to that of a familiar local place. Given that similarity, the distant place is presumed to have other conditions that are like what we see in the familiar place. For example, Hong Kong's location is analogous to Miami's on a world map. Both cities are about the same distance north of the equator, and both have a similar position near the southeastern coast of their continent. As a result, someone familiar with the hot, humid summers, autumn hurricanes, and mild winters of Miami would be justified in assuming that the climate of Hong Kong might be similar.

Reasoning by analogy gets its power because it is easy to extend (Gavetti and Rivkin 2005). For example, to gain a fairly good mental map of climate around the world, a person may choose to learn the seasonal patterns of temperature and precipitation at a dozen distinct places. Other places can then be described as analogs of those places, with varying degrees of fidelity. For instance, Casablanca (in Africa) is a nearly perfect climatic analog of Los Angeles (in North America) – both cities are situated between the ocean and some mountains, near the western edge of their continents, about 34 degrees of latitude away from the equator. Not surprisingly, average temperature and precipitation at the two places are nearly identical in every month of the year – as clearly shown by this "electronic quiz" from the ARGWorld CD.



A city in Tunisia might also be described as analogous to Los Angeles, but because it is a little farther from the Equator, the temperature might be a bit lower and the winter rainy season somewhat longer than at Los Angeles. Ironically, research seems to suggest that the more "distant" analogy can actually help teach the concept better, as long as students are still able to make the connection. A distant analogy like Tunisia demands looking more closely at structural relationships as well as surface similarities, and that in turn seems to promote more durable learning (Halpern et al. 1990).



There is a danger with citing a climatic analogy as an example – we do <u>not</u> want to imply that all spatial analogies are climatic, or global, when in fact they can involve virtually any geographic topic at virtually any scale. For example, suppose you are trying to describe a city neighborhood to a group of urban planners. If you call it a "gentrifying area near the old railroad warehouse district," you can be fairly confident that the phrase will elicit memories of analogously-located areas in different cities across the country. In a similar way, you can mention a floodplain near the junction of two third-order streams, and different hydrologists are likely to draw similar conclusions about flood hazard, pollution potential, and land use. In short, analog reasoning is a powerful way to organize impressions about many aspects of the world, as well as hypotheses for geographical inquiry.

As noted earlier, there are different kinds of spatial analogy. In one kind, the spatial aspect of the analogy is the relationship between parts (Gentner 1977). For example, a roof has a consistent spatial relationship to a house – it is physically above the occupied part of the house, and topologically between the occupants and the atmosphere. It is the latter sense, *between-ness*, that led Russians to use the word krysha (roof) to describe the protection that could be "purchased" by start-up businesses in Mafiya-controlled parts of Moscow after the fall of the Soviet Union.

This concept occurs in many cultures. The left diagram shows the Chinese character for "tong," a kind of business-protection organization among immigrant Chinese (and whose members occasionally strayed close to the boundary between "protection" and "protection racket"!) The other character translates as "association," which is what some former tongs prefer to be known as today. Note that both symbols have "roof-like" traits that are quite obvious even to people who cannot read Chinese.

Other analogies that imply protection-by-spatial-interposition include *mother hen*, *insurance umbrella*, or *angel's win*g. A *glass ceiling* is a more distant structural analogy about protection, in this case turned 180 degrees and protecting the "higher powers" from "invasion" by those below.

Analogic reasoning has another important implication: a powerful analogy has a way of inserting itself into long-term memory even over the "objections" of a person, something that skilled propagandists have known for a long time (Perrott et al. 2005).

At geographic scales, one could say that Berwyn, a suburb southwest of downtown Chicago, is analogous to Dearborn, southwest of downtown Detroit. Someone familiar with either area is likely to "get" more than a simple geographic relationship when someone else mentions the analogy. In a more abstract way, London is to the Thames as Paris is to the Seine. Likewise, Delhi is upstream of Dhaka, like Islamabad is upstream of Karachi (practical knowledge if one is studying water quality and the geopolitics of cross-border water pollution!)

A still more abstract kind of spatial analogy occurs when a spatial characteristic is just one of the components of the analogy. For example, a second-ring suburb is a familiar shorthand name for a kind of settlement that developed at a particular place and time, shortly after the technological shift from public railroads and streetcars to private automobiles. Noting that a community is a second-ring suburb can therefore trigger a host of analogic inferences – ideas about distance, accessibility, street layout, lot size, house architecture, and, importantly, some even more distant and variable but potentially revealing hints about the age, occupation, income, and political leanings of the residents.

In short, the power of a spatial analogy resides in the fact that many geographic forces operate in somewhat predictable ways, creating similar consequences in similar locations. Learning that one place has a location that is similar to another, therefore, can give us some insights about the conditions we are likely to encounter in that place (or at least what questions we might ask in formulating a geographical inquiry about the place – this is an especially important consideration in an era when educators are being asked to develop plausible scenarios for "capstone inquiry projects").

If teachers consciously use a variety of spatial analogies, their students' range of plausible analogic relationships continues to expand (Alexander et al. 1987). Like any scaffolded form of knowledge, this can pose a problem in a classroom, because some students may be reasoning with sophisticated, abstract analogies, while others are still able to comprehend only concrete comparisons (Ratterman and Gentner 1998). For example, some students may define "island" abstractly, as a remote piece of land surrounded by water, while others can conjure up only a concrete image of a warm, sandy place (example from Keil 1989). Describing a community as a "religious island" can therefore convey an important message to the first student, whereas it might only confuse the second. This issue of uneven conceptual development becomes even more serious when we are unable to monitor facial expressions and other clues, as (for example) when designing assessments or educational software (Kolodner 1997). That brings us back to the point that opened this chapter – reasoning by using spatial analogies is a powerful form of spatial thinking, but it depends heavily on prior knowledge.

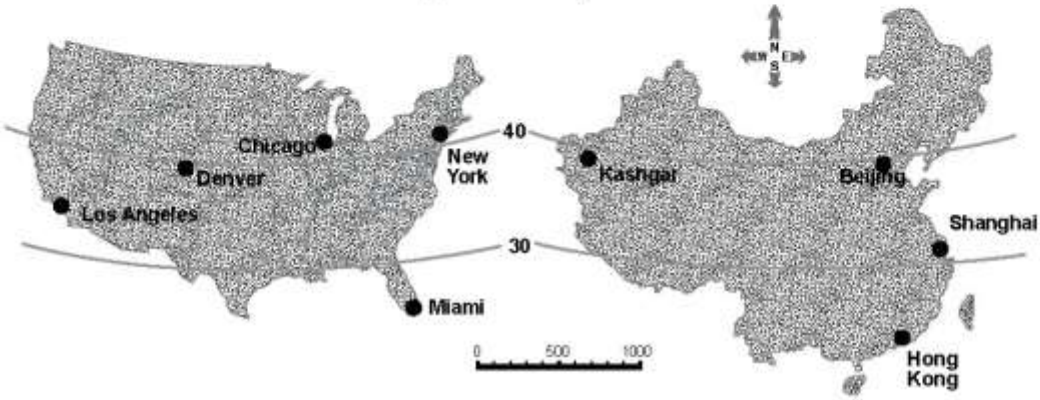
Of all the modes of spatial reasoning, analogy has by far the most complicated neurologic base. As might be inferred from my earlier description of the process, reasoning by analogy involves a wide range of different brain areas, from the grammar structures around the left ear (in most people) to the relative-position structures in the parahippocampal region below and behind the frontal lobe (Boroojerdi et al. 2001; Bunge et al. 2005; Krawczyk et al. 2011; Watson and Chatterjee 2012). At this stage in the research, we are probably justified only in saying that reasoning by analogy is complex and likely to involve at least one other mode of spatial reasoning – sequence, hierarchy, proximity (aura), pattern, association, or region.

Similar (Analogous) Locations in Two Large Countries

When we want to learn more about a place, one good strategy is to look for a familiar place that has a similar position in the world. For example, to learn more about a city in China, we might look for a city in the United States that has a similar position.

What do we mean by "a similar position?" The answer to that question depends on the topic we are investigating. To find out about the weather, for example, we should look for a city that has a similar latitude, elevation, and distance from a large lake or ocean. Why? Because the weather in a place depends on its latitude, elevation, and distance from water!

To illustrate how to use this kind of spatial thinking, let's look at two countries that are about the same size and distance away from the Equator.



Suppose you wanted to know more about the weather in Beijing, the capital of China.

The map tells you that Beijing is located near the eastern coast of Asia. and close to the 40th line of latitude. What city in the United States is located near its East Coast and the 40th parallel?

Circle one: Los Angeles Denver Miami New York

Kashgar was a major city on the Silk Road that went from ancient China to Rome. What U.S. city has a similar location far from water but close to the 40th parallel?

Circle one: Los Angeles Denver Chicago Miami New York

Miami is located about 25 degrees of latitude on the east coast of the United States. Hurricanes are a big problem in this location, because the nearby ocean gets very warm. What city in China has a similar location and therefore may also have hurricanes?

Circle one: Kashgar Hong Kong Beijing

Shanghai is another city on China's east coast, about halfway between Beijing and Hong Kong. The U.S. map shows no large city in a similar location. What state map would you want to see in order to find a smaller city with a location similar to Shanghai?

Circle one: Arkansas Georgia Oregon Texas Wyoming

Thought question: is China likely to have a city in a location that is similar to Los Angeles? Why or why not?

Sample dialogs, from two teachers trying to teach the meanings of "CBD" and "suburb"

T: Here is a picture I took in a big city. What do you see in it?

S: a stoplight, cars on the street

T: What's behind the cars? (gesture) S: big buildings with lots of windows

T: Yes, the core area of a big city usually has tall buildings with many windows. We call that area the *central business district*. Now here's a picture of a suburb. That is what we call an area that is located near the edge of a city. What do you see in it?

S: houses, cars, trees

T: What else? [silence] T: what's the green in front of the houses? S: looks like grass

T: Right. Big cities have big buildings. Suburbs usually have houses with green lawns and trees around them.

120

T: This picture shows the middle of Dallas. That's a big city in Texas. And here is a picture of the middle of Minneapolis – a big city in Minnesota. What do these pictures have in common?

S: Cars on the street.

T: Good. What else? (gesture) S: big buildings with lots of windows

T: Right. The core areas of big cities usually have tall buildings with many windows. We call that area the *central business district*. Now, here is a suburb close to Dallas. And a suburb close to Mnneapolis. What do you see in these photos?

S: Houses and cars. T: What else? S: trees, grassy areas around the houses

T: So, what's our generalization? [elicit] CBDs have big buildings, suburbs are places with houses, trees, and grass.

120

These dialogs illustrate something we have been saying throughout this book – the difference between a lesson that reinforces a specific mode of spatial thinking and one that does not is often quite subtle, but it also is usually quite pervasive – in short, "the devil is in the details," and the details are cumulative

The two dialogs are the same length (120 words). The second one, however, has set up a situation where students are likely to engage the analogical thinking areas of their brains. It has also provided the names of two important cities for students to associate with pictures of them. Many students are likely to forget these details, of course, but the association of images with placenames is a cumulative process. The second dialog just might be what it takes to reinforce the association for a few students, so that the memory sticks. What is certain is that the first dialog, with its abstract portrayal of "a big city," has <u>no</u> chance of doing that!

The second dialog is also preferable because it allows students to focus on the essential features of each neighborhood – it provides several examples and asks students to extract the common feature, rather than trying to memorize all of the details of one "perfect" example. In short, the second dialog provides three different potential hooks to facilitate learning – analogic reasoning, placename association, and feature extraction.

Additional student activities that involve thinking about spatial analogies

A. Describe analogous locations in restaurant table settings. A typical restaurant table setting is a great illustration of analogous location of cups and other utensils with respect to the central plate.

1. Students individually draw a place setting from memory. (Or, if you suspect that their collective memories may not contain enough information, provide individual photos, preferably taken in local restaurants, to different students. Taking the photos could be a class project for an upper-grade graphic-design class – once done, they will last for years.)
2. Small groups compare drawings and suggest corrections.
3. Write (or reveal) a list of analogic terms – left of, right of, close to, far from, toward the middle of the table, etc. Students discuss which terms apply to forks, spoons, glasses, salad plates, etc.

B. Describe/illustrate the rings and sectors of urban models.

1. Present the characteristics of one of the historical urban models – Burgess, Hoyt, etc.
2. Students gather photographs or screen captures of satellite images to illustrate the landscape at different distances in different directions from the CBD.
3. Discuss the appropriateness of various images and construct a model with yarn stretching from places on the model to photos that illustrate those rings/sectors.
4. Extension: test the model in other cities, first in the United States and then elsewhere. Explore variations of the models that have been developed for cities in other continents.

C. Investigate fjords. Many physical phenomena, such as fjords, autumn fires, cold ocean currents with rich fishing resources, etc. tend to occur in analogous locations with respect to continents.

1. Show students some photos of fjords. Students brainstorm advantages or disadvantages of living on a coastline that has steep slopes plunging almost directly into deep water.
2. Note the location of the place in Norway (and also mentioning that *fjord* is a Norwegian word).
3. Elicit a hypothesis about location – fjords form on the west sides of continents, about 45-65 degrees of latitude (i.e., more than halfway from the equator to the pole).
4. Students test the hypothesis by opening a satellite viewing program such as Google Earth and zooming in on other places with analogous locations in Canada, Chile, New Zealand.
5. Continue with a geomorphology lesson about how fjords were formed (and/or a history lesson about why Norwegians chose to become fishers or the traders/raiders known as Vikings!)
6. Extension: apply the principles to other features – hurricanes, wheat regions, fires, etc.

D. Map sources and destinations of major flows of immigrants.

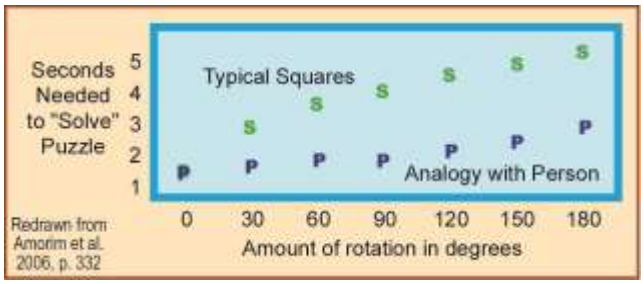
1. State the hypothesis that trans-oceanic migrants often chose to move to world regions with climates and other conditions that were similar to what they knew in the "home country."
2. Illustrate by showing pictures of Catholic missions in Spain and California, or lake-studded forests in Sweden and Minnesota (the CD folder has some examples).
3. Have each group of students do research on a major historical migration (perhaps limiting their scope by providing a list of migrations that fit your school curriculum or state assessment) in order to test whether that hypothesis is true for that group.

E. Identify places that are in analogous locations in different watersheds, and explore the steps that people in those places might use to resolve issues of water quality, diversion, pollution, etc.

1. Describe the location of a city or region of interest (e.g., Washington DC, Cincinnati, the Mississippi Delta, Sacramento, Timbuktu, Wuhan, Dhaka, Baghdad).
2. Students try to identify places that are analogously located upstream, downstream, on another branch of the same river, upstream AND in another country, etc.
3. Describe the places that can influence other places' water quality, quantity, or seasonality.

Detailed review of research about thinking with spatial analogies

Like the skill of qualitative spatial comparison outlined in Chapter 5, the skill of reasoning by analogy is basically a linkage between some spatial-processing structures and the verbal areas of the brain. A spatial analogy is basically a generic analogy that has an explicit spatial dimension. As such, it begins with something that could also be described as a simple comparison. In time, however, "the process of comparison can act as a bridge between similarity-based and rule-based processing" (Gentner and Medina 1998; Gronau et al. 2008). For example, adding a shape that can be interpreted as a "head" or "foot" of an otherwise abstract shape appears to trigger analogical reasoning that in turn facilitates performance on a mental rotation task (Amorim et al. 2006).



Unlike quantitative comparison, which can be localized to a very specific part of the brain, the process of analogical reasoning appears to be defined less by a specific locus than by a network of activity that includes a specific group of brain structures (Wharton et al. 2000; Boroojerdi et al. 2001; Luo et al. 2003; Bunge et al. 2005; Green et al. 2006; Cho et al. 2007, 2010; Volle et al. 2010; Krawczyk et al. 2010, 2011; Cardillo et al. 2012; Knowlton et al. 2012; Watson and Chatterjee 2012; see the table of prior localization studies in Hampshire et al. 2011 or the general review in Krawczyk 2012). Some have suggested that body analogies play an important role as a structural foundation for many other kinds of analogic reasoning, and therefore the neural network of analogic reasoning usually includes the areas call "mirror neurons" (Aziz-Zadeh 2006). Others add that both comparison and categorization are involved in the development of an idea of relational similarity (Kotovsky and Gentner 1996; see also Gentner and Medina 1998, Möhring et al. 2014).

The logical progression from comparison to analogy is not a one-way street, however. Analogical reasoning may also help children learn how to form categories (and therefore, by extension, to develop more abstract and powerful concepts about regions, in which the extent and shape of a region is based on causal connections as well as perceptual similarities (Kemler-Nelson 1995). More recent research extends that idea to suggest that the brain continually makes analogies as a way of generating predictions about relationships, and those often subconscious predictions in turn guide perceptions (Bar 2007). The importance of this predictive process may be one of the primary ways in which human reasoning differs from other primates (Haun et al. 2009, 2010).

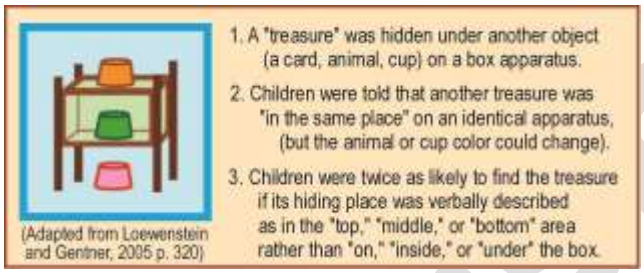
A progressively more elaborate concept of analogy is intimately connected with the growth of a person's content knowledge. Indeed, some have suggested that the power of analogical reasoning is precisely that it provides a mechanism for the extension of ideas into new domains, with the caveat that the speed of extension depends in part on the availability of factual knowledge in the new domain. In short, the extension of analogical inference is constrained by the need to acquire domain-specific knowledge at roughly the same time. Analogies can serve as one way to help students acquire that knowledge, but the success of the analogy always depends at least in part on prior knowledge (Keil 1986). In a later paper, as noted above, the same author explored the shift in logic that occurs when children come to define "island" as a piece of land surrounded by water (a category based on functional spatial relationships), rather than as a warm and sandy place (a category based on perceptual similarity; see Keil 1989). Obviously, children must have made that conceptual shift before

they can meaningfully enter a discussion of the strategic importance of islands in the Age of Exploration!

To help students make these inferences about islands, a teacher must either:

- have some kind of classroom activity that explicitly addresses the difference between abstract island-concept and concrete beach-image, or
- find some other way to assess and diagnose the perceptions that students link with the word "island" ("formative evaluation of prior knowledge!")

A spatial analogy is by definition a form of comparison between two places that have been identified as having similar situations in a frame of reference, such as a map with latitude and longitude lines. An observer, however, might personally be situated within one of the places shown on the map. That person, therefore, can also view the surrounding conditions through a more personal (egocentric) frame of reference, using terms like *left*, *right*, and *near*. This mismatch of reference frames has neurological implications that may, in turn, affect the ability of students to store the information in long-term memory (Postle and d'Esposito 2003). A related study found that the terms *top*, *middle*, and *bottom* were easier to apply in a find-the-treasure game than *on*, *inside*, and *under*. In this case, the researchers suggested that the difference occurs because the first set of terms involve three positions in a single sequence, whereas the terms in the second set are basically independent ideas with separate frames of reference (Loewenstein and Gentner 2001).



The available evidence from developmental psychologists seems to suggest that analogical reasoning is definitely within the competence of pre-school children, but they do not respond well to explicit prompting at that age, perhaps because young children simply find that analogies are difficult to access intentionally (Singer-Freeman 2005). That seems reasonable, especially in view of the need for prior knowledge in several domains for a successful analogy. In that way, the available research underscores the need for explicit inclusion of factual spatial knowledge as a means of building the prior knowledge base that is needed for future analogical reasoning, which in turn can allow more efficient acquisition of additional spatial knowledge (Holyoak et al 1984; Markman 1997; Richland and McDonough 2010; for an attempt to model this process in order to "train" a computer to reason analogically, see Hummel and Holyoak 1997).

By kindergarten age, however, the spontaneous use of analogy is more frequent, and "explicit training of the less proficient reasoners had a significant, positive effect on performance" (Alexander et al 1989; for an interesting comment on the importance of language, see Gentner and Christie 2008). Other studies underscore the fact that great individual differences may occur at that age (Gardner et al. 1975; Brown et al. 1986; Tunteler and Resing 2002). What is not known, unfortunately, is whether individual differences are due primarily to a paucity of prior knowledge, a delayed development of working-memory skills, lack of appropriate language, or simply a tendency to privilege other forms of reasoning. In any case, the evidence shows that teacher training can significantly improve student performance (Alexander 1987). That training should include explicit consideration of the role of spatial analogies, both as a path toward future geographic understanding and as a means of expanding the range of reasoning strategies available to the learner.

Did we hear someone say "math link" here? It certainly seems plausible that a well-developed concept of spatial analogy would be mathematically useful, even for acquiring and refining basic concepts such as addition (Farrington-Flint et al. 2007). Obvious ways include identifying and working with geometric shapes, comparing lengths, or reading graphs (see Gattis 2002). More subtle ways include interpreting the structural relationships implied in various kinds of word problems (see Anooshian et al. 1984; Henson 1999; Salvucci and Anderson 2001; Richland et al 2007; Lovett et al. 2009; for an extension into the domain of fine arts, see Forbus et al. 2003). Moreover, there is also a body of research that suggests a complex set of links between analogic reasoning and language arts. One study, for example, concluded that

> "'balanced bilinguals,' individuals who show high and relatively equal levels of competence in two languages [tend to have] greater cognitive flexibility, improved analogical reasoning and classification skills, and a greater understanding of syntactic, symbolic, and arbitrary features of language" (Winsler et al. 1999; see also Haun et al. 2011).

Working more-or-less independently of the behavioral and developmental psychologists cited above, vision scientists have looked at the possibility that analogous spatial position in a visual field may serve as an organizing schema that influences our perception in a subconscious way. One recent review, for example, noted that

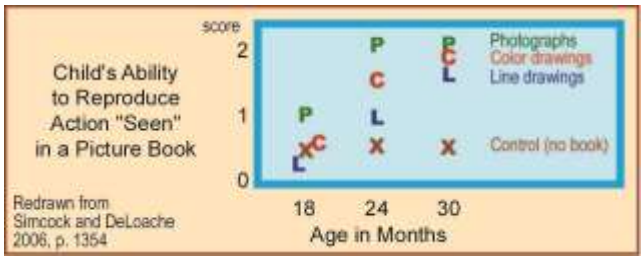
> "Objects have a tendency to occur in particular positions and in particular spatial relationships with other objects. If the visual object recognition system maintains position frequency information, it can be used as a constraint to aid in the recognition of ambiguous or occluded figures" (Kravitz et al 2008, p 120; see also Ryan and Villate 2009).

An early test of that hypothesis found that reaction times are much shorter if a hat appears *above* a foot in a composite picture than if it is *below* the leg (Bar and Ullman 1996; for additional examples and a review of more recent empirical studies, see Umemura et al. 2007; Kravitz and Baker 2008; for a look at how this applies to artificial intelligence, see McGreggor et al. 2010).

More recently, psychologists have extended this idea to include objects in the space surrounding a person (Endo and Takeda 2005; Holmes and Sholl 2005). In doing so, they note that objects are easier to remember if they are aligned in a way that can be described, e.g. parallel to a boundary in the environment (Schmidt and Lee 2006; Sturz and Bodily 2011). In this way of organizing knowledge about the world, however, the distinction between the concepts of spatial analogy and spatial pattern become somewhat blurred – it is not clear whether the fact that enhances memory is the relative position of the individuals with respect to the boundary or the spatial alignment of the group that parallels the boundary (for a sample of the few studies that have tried to explore the influence of various kinds of map context on spatial memory, see Okabayashi and Glynn 1984). Personally, we suspect that the answer to a question about internal pattern vs. analogous position in an external framework may be "both, but for different individuals, or perhaps for the same individual under different circumstances." Some support for this idea comes from a handful of recent studies that deal with what their authors call a kind of context-dependent "blocking of spatial learning" or "facilitation of learning effect" (Pearce et al. 2006; for somewhat different takes on a related question about the existence of a separate "geometric module" in the brain that maintains a memory for analogous locations with respect to a surrounding frame, see Hartley et al. 2004; Cheng and Newcombe 2005).

Regardless of the outcome of those debates, there is little question that the notion of analogous position is of great importance in the development of a mental map that can accurately guide behavior (Huttenlocher and Lourenco 2007; Lourenco and Huttenlocher 2007; Möhring et al. 2014). A number of psychologists have tried various ways to measure how this process develops in young children, see DeLoache 1989; Blumberg and Torenberg 2003; Vasilyeva et al. 2004, 2007, Casasola et al. 2009; Morrison et al. 2011; Sturz et al. 2011; Frick and Newcombe 2012; Christie and Gentner 2014).

In light of these studies, note also that some recent research has examined the issue of iconicity, in order to assess the importance of graphic fidelity in the ability of young children to interpret graphic images as representations of real-world phenomena. As expected, children are willing to accept the representational nature of photographs at a very young age, but the research seems to indicate that children take only a few more months to develop the ability to interpret more abstract line drawings (Simcock and DeLoache 2006).



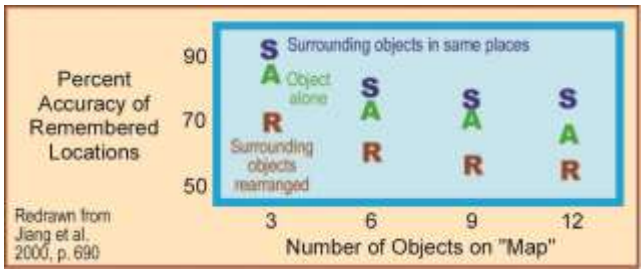
It would be useful to have some equally rigorous studies that examine the specific ages at which children seem to be able to interpret particular kinds of map symbols. One interesting beginning, for example, tried to figure out the age at which children begin to understand that a map can both lead and mislead (Dalke 1998).

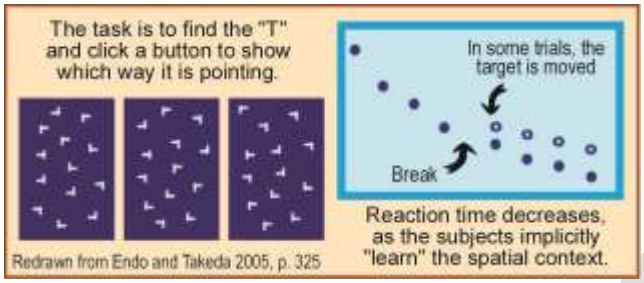
This is a good place to end this review – with the realization that research about spatial analogies is a kind of "psychological ratification" of a fundamental element in the geographer's creed, namely that a map is an analogy of the real world, in which relative position on a piece of paper or computer display indicates a similar relative position in the real world. People have long known that readers often remember the locations of particular ideas on a printed page, although that information is not necessarily significant (Zechmeister et al. 1975). Taken together, those ideas help us understand why maps are such powerful means of support for spatial thinking, in realms as dissimilar as designing virtual environments, assisting visually impaired people in personal wayfinding, identifying the causes of disease clusters, and disarming land mines in a war zone (all examples taken from an aptly titled book, *Applied Spatial Cognition: From Research to Cognitive Technology*, edited by Allen 2007).

As Richland and Morrison so aptly said, "analogy is not simply another measure of [mental] executive functions, rather it is a whole-brain activity, that is a profound test of our ability to think in everyday life" (Richland and Morrison 2010).

Overlaps between thinking about spatial analogies and other modes of spatial thinking.

As noted above, there is a major conceptual overlap between the concepts of pattern analysis and spatial analogies. It is true that any individual element in a spatial pattern has a distinctive analogous position with respect to other elements in that pattern. Observing and remembering that position can definitely aid memory for the objects (Jiang et al. 2000).





We suggest that this is just another example of the truism that the same phenomena can sometimes be explored with different modes of spatial thinking. Some people may prefer to organize their spatial memories in terms of analogies, while others are more comfortable with describing and remembering spatial patterns. In the brain, the processes seem to be clearly separate: pattern analysis engages a series of regions that originate in the primary visual cortex in the back and right side of the head, whereas reasoning by analogies involves a number of language areas around and above the left ear and in the corresponding frontotemporal areas on the right side (in most people).

A second possible source of confusion is between the ideas of spatial analogy and spatial association. Many spatial associations (e.g. the association of individual shadows with isolated clouds when viewed from an airplane) can also be interpreted as repetitive examples of analogous positions with respect to the primary feature (the cloud).

The difference (as noted in the discussion in the chapter on spatial associations) is primarily a matter of scale – analogies often look like associations when you zoom out to a wider view, and associations often look like analogies when you zoom in for a more detailed look. So be it – that observation provides a solid justification for an important principle that is built into every GIS, namely that viewing a phenomenon at several scales can reveal information that might be difficult to see at a single scale.

Issues with using a GIS to support thinking about spatial analogies

A typical GIS is exceptionally good at identifying places that have similar conditions – similar land cover, for example, or similar average income, life expectancy, or percentage of population under age 14. The ease of performing this kind of query and displaying the result is one reason why many GIS teachers do this as the second activity, right after students make a map that has a point symbol showing the location of a student's home or school.

It takes more thought and effort to identify and display places that have similar connections or relative positions. For example, the identification of even a simple climatic analogy (e.g., Los Angeles and Casablanca, as described earlier) requires the simultaneous application of multiple "filters" – e.g. latitude greater than 32 degrees and less than 35, proximity to polygon border around continent, direction toward high land between azimuth 45 and 175, direction toward ocean either west, northwest, or southwest. All of this is very easy to do visually and rather difficult (or at least time-consuming) to enter into the query structure of a GIS (for an insightful early review of the logical issues involved, see Keane and Bradyshaw 1988).

Moreover, omission of any one of those constraints may result in the selection of features that do not constitute a good spatial analogy. For example, leaving out the direction of the ocean will allow the query to identify a number of places that are on east or north rather than west coasts of continents, a fact that has tremendous climatic implications at that latitude (one has only to compare some images of Casablanca and Shanghai to appreciate that fact).

The situation with urban or settlement analogies is even more complex. For example, most urban analysts have a very clear mental image of a "Levittown-type" neighborhood of rapidly-built, more-or-less identical small bungalows of the kind that that were built in predictable locations near most American cities in the years after World War II. Trying to provide a precise mathematical description of their relative position with respect to the center of the city and the major transportation corridors, however, is a daunting task.

In short, of all the modes of spatial thinking, the process of reasoning by analogy is perhaps the one that most clearly illustrates the need for balance between the tremendous ability of a GIS to display data and perform various kinds of spatial analysis, on the one hand, and the advantages conferred (and limitations imposed) by the visual system, perceptual schemas, and prior knowledge of the viewer of the GIS display. It follows that explicit training in analogical reasoning is essential if we are to achieve maximum benefit from the use of GIS to support spatial thinking.

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