Sources of Information for Human Wayfinding on Planet Earth

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Few behavioral problems are more fundamental than getting from here to there. Humans and other mobile animals move about their environments in order to get to places with food, mates, shelters, cocktails, and other resources; they must also avoid threats and dangers such as predation, assault, exposure, and disco music blaring from a radio. Furthermore, animals must get from here to there efficiently; going far out of its way is no way to act for a creature with limited time, water, calories, and patience.

Navigation is coordinated and goal-directed movement through the environment by animals (including humans) or intelligent machines. It involves both planning and execution of movements, and may be understood to include the two components of locomotion and wayfinding. *Locomotion* is the part of navigation involving body movement coordinated to the local surrounds; it allows us to identify surfaces to stand on, avoid obstacles and barriers, direct our movement toward perceptible landmarks, and go through openings without bumping into the sides. *Wayfinding* is the part of navigation involving goal-directed planning and decision-making coordinated to the distal as well as local surrounds. Wayfinding requires a place goal, a destination we wish to reach. Frequently, this destination is not in the local surrounds. To a large extent, then, wayfinding must be coordinated distally, beyond the local surrounds directly accessible to our sensory and motor systems at a given moment. Hence, memory, stored internally in nervous systems and externally in artifacts such as maps, plays a critical role in wayfinding. When we wayfind, we solve behavioral problems such as choosing routes to take, moving toward distal landmarks, creating shortcuts, and scheduling trips and trip sequences.

Clearly, the great majority of acts of navigation involve both locomotion and wayfinding components to varying degrees; the distinction is less “either/or” than “part-this/part-that.” But evidence for the distinction’s validity is provided by the simple fact that you can have one without the other. They are generally components of an integrated system of navigation that can be separated only conceptually, but they are sometimes separable literally. One locomotes without wayfinding when pacing about the maternity ward. A passenger on a bus is locomoting without wayfinding, except when he or she makes decisions as to which bus to board and where to get off. Another example is provided by people with severe visual impairments, some of whom can effectively use a long cane or clicking sounds to coordinate movement to the immediate surrounds but have trouble maintaining orientation to distal goals. Conversely, the framework that sees navigation as combining locomotion and wayfinding includes trip planning at the kitchen table as part of navigation, even though actual movement is only imagined at that point. Effective wayfinding distinct from locomotion was also demonstrated by the Mars Rover autonomous vehicle—it stumbled badly when locomoting relative to nearby features (for example, confusing hills with holes, and falling into holes without any escape) but used its computer maps effectively for wayfinding. The balance of this essay focuses on human wayfinding, especially the role of environments and symbolic media in providing information to support human wayfinding.

Sources of Environmental Information

The information that supports human wayfinding is acquired from different sources that have different qualities. These differences have important implications for understanding wayfinding that go beyond (outside of?) what we learn from brain scanning. A complete understanding of wayfinding, and spatial cognition more generally, depends critically on a detailed and fairly sophisticated understanding of different sources of environmental information, including understanding the landscapes that make up our environmental surroundings. To a substantial degree, cognitive representations of the surrounds, like cognitive representations in general, mirror the reality they represent—that is why they may be called "representations" and why they work as well as they usually do.

Information about spatial and nonspatial properties of the world are derived from various sources (media). We can distinguish four: direct sensorimotor apprehension, static pictorial representations, dynamic pictorial representations, and language. Each of the four contains within it a diverse array of specific sources, with implications for understanding wayfinding and spatial cognition. Direct sensorimotor apprehension occurs in the real environment itself, but may involve any combination of vision, audition, proprioception (body movement senses), haptics, and even smell; it may result from stationary sensing (with head and eye movement) or locomotion; the locomotion may be crawling, walking, running, etc., and the locomotion may be mechanically-aided, with a skateboard, bicycle, car, plane, etc. The remaining three sources are indirect or symbolically mediated sources. Static pictorial representations are often flat, as in graphs, maps, drawings, or photos, but also include 3D models. Besides so often being flat, they are usually smaller images or objects than the environments they represent. Dynamic pictorial representations are typically smaller as well, but move, as in movies or animations. Finally, the fourth source is language; spatial knowledge can be acquired via speech, writing, or gesture. (Indigenous Australians sing environmental routes in their songlines.) Language may be natural, like English or Mandarin, or formal, like algebra or html. Sign language is natural language, but spatial knowledge might also be acquired from gestures or "body language" like pointing. As an interesting case in point (and important to those who research human wayfinding), virtual-reality systems are more like direct apprehension or dynamic pictorial representations, depending on details of the system such as whether it is immersive or operated on a computer screen with a joystick.

Different sources of environmental knowledge have different characteristics which have considerable implications for wayfinding and other spatial-cognitive tasks. First is the sensory and motor systems involved; an important case in point is whether whole-body movement takes place during navigation. A second characteristic is whether the source involves dynamic or only static information, both in terms of the information depicted and in terms of the presentation medium itself (e.g., a static map with arrows versus a route movie). Third, knowledge sources provide sequential or (relatively) simultaneous access to information; consider a traditional cartographic map providing near-simultaneous access to spatial relationships in the environment versus directly accessing them over time by walking around. Fourth, if a source is symbolic, its semiotic abstractness varies; they range from relatively iconic, resembling what they represent, to relatively arbitrary. For example, a drawing of a cat somewhat resembles the shape of a cat, but the word "CAT" is no way resembles the appearance, sound, smell, or feel of a cat. A fifth characteristic of sources relates to how spatial scale is communicated and whether a symbolic source requires scale translation for a person to grasp absolute scale (with dynamic displays, temporal scale is also relevant); cartographic maps, for example, are almost always smaller than the portion of the earth's surface they depict, and scale translation is a challenging cognitive task. A sixth characteristic is the viewing perspective by which sources present the environment; when walking around, one usually has a horizontal (terrain-level) view of the world but typical maps present a vertical (overhead or bird's-eye) view. A seventh characteristic is spatial precision; maps usually depict spatial properties such as distance and direction with great precision, but natural language rarely does—"the store is near the station." Finally, indirect sources of knowledge express varying amounts of detail; maps are schematic, omitting details of appearance or structure that are considered unnecessary, while photographs usually present these details.

The nature of cartographic maps as a source of wayfinding information is particularly interesting. Maps always omit, generalize, distort, and/or enhance spatial properties of the world. Understanding maps as sources of spatial knowledge and contributors to reasoning while wayfinding is challenging, not straightforward. Maps generalize—they simplify and filter out detail. They require scale translation to afford accurate judgments of size and distance. Representation and interpretation of the third dimension (elevation) is particularly challenging with maps. Contour lines are abstract and require training and practice to support perceptions of slopes and relative heights. When less abstract codes for elevation are used, such as slope shading, the vertical dimension is always exaggerated because otherwise, landform topography is remarkably underwhelming in appearance. With respect to symbol abstractness, relatively arbitrary symbols (like contour lines) can be hard to interpret and relatively iconic symbols can be easy to overinterpret (like distances on network subway maps). Cartographic maps can depict the world from a variety of perspectives, not just vertical, but when the typical vertical perspective is depicted, it must be transformed to match it with a horizontal or terrain-level perspective for tasks like wayfinding.

Variation in Physical Environments: Implications for Understanding Wayfinding

The nature of physical environments influences experience, cognition, and behavior, and this certainly includes wayfinding. Environments allow, facilitate, require, impede, or prevent various perceptions, thoughts, emotions, and acts. They do this physically, as in walls that block movement, sight, or sound; mentally, as in visual patterns that stimulate exploration or aesthetic responses; and socio-culturally, as in rules and norms suggested by signs that communicate who may enter a room or what properly takes place there. These influences operate via several cognitive and behavioral mechanisms. The appearance, layout, and structural features of physical environments affect sensory access—what can be seen and heard; attention—what is looked at and listened to; memorability—what is remembered about an environment; knowledge—how one reasons and makes decisions; behavioral affordance—where one walks, sits, and so on; affect—mood, comfort level, stress and fear, and aesthetics; and sociality—with whom one interacts socially, as a function of factors such as pedestrian flows, noise levels, social distances, and body postures.

We can distinguish broad classes of physical environments that differ in ways that likely have implications for wayfinding cognition. For instance, we can distinguish natural from built (anthropogenic) environments; this is critical to understanding wayfinding in cities versus wilderness environments. Built environments usually present more regular shapes and patterns, including straight lines, right angles, regular polygons, and regularly repeating structural elements. They usually appear less complex, with more homogeneous edges, lines, textures, shading, and fractal patterns. And built environments are usually more explicitly articulated, with more sharp boundaries and less continuous transitions. There are notable exceptions to each of these. Great regularity can be observed in natural environments, including the surfaces of frozen lakes, the structures of rock crystals, and the patterns of spider webs. Natural landscapes can be very simple in appearance, as in some composed of sand, snow, or water. At the same time, unplanned built environments such as the squatter settlements of large cities can be quite complex, even chaotic. Clearly, people articulate natural landscapes into landmarks and regions even when only subtle physical boundaries exist.

More important than exceptions to general characterizations of built and natural environments, however, is the substantial variation within each of these broad classes in any number of characteristics that influence wayfinding and other spatial cognitive processes of memory, reasoning, and verbalization. Landscape topography (hills and valleys) and vegetation influence the spatial extent of our perception and what is available for attentional discrimination and verbal labeling. For example, while there are linguistic and cultural differences in how commonly people use absolute reference systems, such as cardinal directions, in expressing directional information, evidence also suggests that speakers of American English are more likely to use cardinal directions when they live on the prairie than in the mountains. Built environments can be distinguished as indoor versus outdoor, rural versus urban, and suburban versus central city. Cities can be distinguished as organic versus planned, with high-rise versus low-rise construction, and having grid versus radial versus irregular street network patterns. These variations have implications for wayfinding because they relate to the nature and availability of landmarks, the presence or absence of other people as wayfinding cues, how the landscape is grouped into regions, the ease of maintaining orientation while moving about, and more. The pattern of connections of major and minor streets in urban street networks strongly influences the structural organization of the *cognitive map* of a city’s layout.

It is evident that physical environments provide context and content for wayfinding. It is also important to recognize the important role that people's prior beliefs about the spatial layout of environments can play. Knowledge about hydrology and geomorphology can help you interpret spatial patterns of branching river systems. Knowledge about land use and residential patterns within cities will help you predict which direction to travel in order to reach particular places. People vary greatly in the amount of knowledge they have about these structures and processes of geography. Even without specifically visiting a place, people have different degrees of prior knowledge about the spatial layout of the place. Even something as supposedly basic as using the sun to orient and wayfind actually depends on fairly subtle knowledge about the location and movement of the sun in the sky at different times of the year, times of the day, and latitudes. Even some readers of this article may not know where the sun is in the sky at 10:30am on October 23 in Winnipeg, Canada, other than an imprecise (and not wholly accurate) statement like "in the east." Of course, prior ideas undeniably affect spatial reasoning while wayfinding even when they are inaccurate. No doubt, people have gotten lost by misreading the sun. And where is that moss supposed to be?

Whether built or natural, physical environments can be analyzed generically in terms of four variables that demonstrably influence cognitive processing during tasks such as wayfinding and spatial learning. These include differentiation of appearance among different parts of the environment, the extent of visual access in different directions, the complexity of the spatial layout of the environment, and signage. The first three of these variables can apply to both built and natural environments; signage, by definition, is intentionally created by people and found only in environments that are at least partially built.

Differentiation of appearance refers to the fact that environments differ in the degree to which their parts are homogeneous or heterogeneous in appearance, with respect to size, shape, color, geology, vegetation, architectural style, and so on. Generally, people find differentiated environments easier to comprehend and wayfind in because the differentiated parts are more distinct and memorable – differentiation creates better landmarks. This can go too far, however, and become chaotic and disorienting. Differentiation is a subjective variable, to a degree; what we notice in an environment depends in part on our expectations, interests, training, and state of mind.

Visual access is the degree to which different parts of the environment can be seen from various locations. It also concerns the locations from which people can see particular parts of environments, including the pathways (roads, trails, hallways), destinations, and other potentially key landmarks or structural features. People have a greater sense of comprehension and can maintain their spatial orientation more easily when visual access is high. Greater visual access will decrease mystery and uncertainty. In a complex or unfamiliar environment, this will tend to reduce excessive stress, while in a simple or familiar environment, it will tend to reduce moderate stress to boredom. Of course, visual access is more informative of, or from, some locations than others. It can be systematically studied with the help of *viewshed* or *isovist* analysis. A viewshed or isovist is the collected spatial extent of all views or vistas from a single vantage spot.

Finally, *layout complexity* is probably the richest yet most poorly understood environmental attribute to consider from a cognitive perspective. There are various formal approaches to quantifying shape or network complexity, such as information theory, but these tend to ignore the fact that what constitutes a “complex layout” cognitively depends not only on the objective layout of an environment, but on the nature of human cognition in general and the cognitive characteristics of individual people specifically. This is like differentiation, but even more profoundly so. More articulated environments, broken up into more different “rooms” and pathways, are generally more complex, though the way the different parts are organized is critical. Certain geometric patterns of pathways influence cognitive complexity; for example, oblique turns are more complex than straight paths and orthogonal turns.