CHAPTER 2

Establishing and Maintaining Orientation for Mobility

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Learning Questions

- What are the three challenges in establishing and maintaining orientation without vision?
- How do travelers who are blind or visually impaired determine where they are?
- What strategies do travelers with visual impairments use to determine the correct route to their destination?
- What factors affect one's ability to establish and maintain orientation and mobility?
- What strategies do people who are blind or visually impaired use to explore a new environment or recover from unexpected problems, such as disorientation or a detour?
- What is a cognitive map, and how does it aid in orientation and mobility?
- What strategies are most effective in teaching young children who are blind or visually impaired the perceptual and cognitive skills they need to travel independently in familiar and new environments?

Most people give little thought to spatial orientation, including the information they use when planning and executing routes or reestablishing their orientation when they become disoriented. Generally, people with unimpaired vision indicate a reliance on visual cues, although they may have difficulty identifying the specific information and strategies they use. For these people, the prospect of walking from home to a nearby destination without vision is daunting from the perspective of both orientation and mobility tasks. However, many people who are blind or have low vision accomplish these tasks routinely, traveling independently and efficiently in both familiar and unfamiliar places. The information, the strategies, and the research that address these topics are the focus of this chapter.

In the field of orientation and mobility (O&M) for persons who are blind or have low vision, the term *orientation* has been defined as "knowledge of one's distance and direction relative to things observed or remembered in the surroundings and keeping track of these spatial relationships as they change during locomotion" (Blasch, Wiener, & Welsh, 1997, p. 750). Pick (1980) defined orientation as "knowing where objects are in relation to each other and in relation to ourselves" (Pick, 1980, p. 80). While having specific definitions in the profession of orientation and mobility, *orientation* is a common term that is used in various ways. In the field of psychology, one definition of orientation is "the process of familiarizing oneself with a new setting, so that movement and use do not depend on memory cues, such as maps, and eventually become habitual" (VandenBos, 2007, p. 656). A related term used in the field of psychology is *wayfinding*, which is defined as the planning and strategic components that guide action, deliberate movement, and the ability to reach a goal (Darken & Peterson, 2002). *Navigation*, another term commonly used in psychology, geography, and other fields, is defined as "the mechanisms used by an organism to find its way through the environment" (VandenBos, 2007, p. 612). A substantial body of basic and applied research has evolved during the past century regarding various aspects of spatial orientation, wayfinding, and navigation in humans and animals (for general reviews, see Golledge, 1999; Redish, 1999). A small subset of this research focuses on studies of people who are blind or have low vision and the way these individuals perceive, learn, and remember spatial information, and how they use this information to guide their travel in everyday life.

Fundamental Concepts of Orientation

Updating

Two fundamental concepts are important in understanding spatial orientation related to orientation and mobility. The first is spatial updating. This refers to the process of keeping track of the changing distances and directions to objects or places that result from self-movement. Consider two examples. An object that is directly in front of you is no longer directly in front after you turn in place. An object that is directly to your left and a few steps away before you begin walking is behind you and to your left after you walk forward several yards. These are simple examples. The task of keeping track of where various locations are in the neighborhood or community while you are walking is a more challenging version of these relatively simple tasks. How people relate self-movement to the locations of objects or places they cannot see, hear, feel, or smell, and the way they use this information to plan and execute routes, are fundamental aspects of orientation and mobility. Spatial updating is of theoretical and practical interest in psychology and in the field of orientation and mobility and has been studied by psychologists, geographers, and others (Kitchen, Blades, & Golledge, 1997; Klatzky, Golledge, Loomis, Cicinelli, & Pellegrino, 1995; Loomis, Lippa, Golledge, & Klatzky, 2002; Rieser, Hill, Talor, Bradfield, & Rosen, 1992; see also Chapter 1, this volume). For orientation and mobility specialists, assessing the ability of individuals who are blind or have low vision to keep track of changing self-to-object relationships that result from movement is a key aspect of the instructional process. Helping learners become better at spatial updating is fundamental to good O&M instruction. This instruction may be particularly critical in helping young children who are blind or visually impaired understand the effect of their movement on spatial relationships.

Frames of Reference

Egocentric Frame of Reference

The second fundamental concept is that of frames of reference. There are two general frames of reference involved in spatial thinking and acting. In an *egocentric frame of reference*, information is perceived, remembered, and acted on solely from the perspective of the individual's current location. Egocentric frames of reference are used by people every day as they travel familiar routes to and from school, work, and other locations in the community. Using an egocentric frame of reference, an individual may describe the location of the bank relative to where he is standing by saying "It's straight ahead and to the right." Both the terms *ahead* and *right* are egocentric; they indicate orientation in space relative to the individual's body and facing direction.

Allocentric Frame of Reference

When using an *allocentric frame of reference*, an individual relates the locations of objects or places to one another *independent* of his or her current location in space and uses an external rather than self-based frame of reference. In the psychological literature, an allocentric frame of reference is sometimes referred to as "survey-level" spatial knowledge (Noordzii, Zuidhoek, & Postma, 2006; Siegel & White, 1975). Inherent in this frame of reference is the understanding that the spatial relationships *among places* are invariant and are unaffected by self-movement. For example, the relation of one landmark to another is fixed and is independent of a person's perspective or viewpoint. Allocentric frames of reference are important in practical O&M terms because travelers often must recall the locations of various places *relative to one another* in order to plan and execute efficient, flexible routes. Consider a traveler at her home who wants to walk directly from the bakery to the drugstore. She has a mental map of the neighborhood and can locate the two destinations on that map. How would she plan her route? She must imagine herself at the bakery and then recall the straight-line distance and direction to the drugstore. She also may imagine the route she must walk given the straight-line distance and direction between the objectives and her knowledge of walkable paths in the area.

According to Thinus-Blanc and Gaunet (1997), when using mental maps (often called cognitive maps), individuals encode the "direction and distance relationships between places, whatever the path that links them and regardless of the person's position or direction of approach" (p. 23). Being able to think in allocentric terms about space is conceptually more challenging than using an egocentric conceptual framework but is potentially more useful when detours are required or when routes among various places must be planned and traveled. Because of the importance of an allocentric spatial perspective to orientation and mobility, O&M specialists work with their students to help them conceptualize space in terms of object-to-object relationships and to use maps, cardinal directions, and other externally referenced geographic systems, such as street grids. It is particularly important to challenge students who are blind or have low vision to think about space from an allocentric viewpoint. For example, O&M specialists may ask students to *imagine* themselves in front of the bank, facing the street, and then ask them to turn so they are facing the post office or other destinations, or facing the direction they would walk to move toward these destinations.

Blasch, Welsh, and Davidson (1973) described three types of information used in thinking about allocentric spatial relationships: (1) *topocentric* information, which refers to information about the locations of landmarks or unique features in a place; (2) *polarcentric* information, which refers to the use of compass directions to describe the directions among places in relation to magnetic north; and (3) *cartographic* information, which specifies the location of places in relation to a pattern, such as a grid pattern, a building shape, or a systematic numbering or labeling system. From a practical point of view, each of these three sources of information can be useful in establishing and maintaining orientation and in describing spatial relations. For example, consider a traveler who keeps track of her location using a combination of topocentric, polarcentric, and cartographic information. She walks north (polarcentric information) along a street, and as she walks she relates her movement to her position on the street grid (cartographic information). She knows that her destination is located to the east of the street she is walking along and that there is a distinctive landmark at that location (topocentric information). Knowing she is facing north (polarcentric information), she realizes that at some point along the route she must turn right, or east, to continue to her destination. As she walks, she updates her position relative to places around her, and she also may recall the allocentric relationships of off-route locations. She may use spatial descriptors such as compass directions, clock-face directions, the terms *left* and *right*, and prepositions such as *before*, *beside*, or *beyond*. Polarcentric information, cartographic information, and topocentric information are useful to travelers because they provide a framework, or "language," for thinking about and acting on their spatial representations (for example, their cognitive map). When they can relate their spatial representations to their perceptions of features in near (proximal) and far (distal) space, they are well prepared for efficient travel in both familiar and unfamiliar places.

Establishing and Maintaining Orientation

Perception: The Impact of Information Access on Spatial Orientation

Visual cues are the most efficient and reliable sources of information for accomplishing spatial tasks. Golledge, Klatzky, and Loomis (1996) noted that the absence of vision results in challenges in processing spatial data in an integrative manner. A traveler with unimpaired vision can readily perceive the distances and directions of many nearby and distant features, simultaneously grasp spatial relationships, focus on and recognize objects over a large field of view, and gather precise information about changes in self-to-object relations that occur with movement. Pedestrians with unimpaired vision simply see a destination in the distance and maintain visual contact with it and with intermediate landmarks as they move toward the destination. Imagine a sighted person walking from his house to the end of the driveway to retrieve his trash bin. From his front door, he can simultaneously perceive the distant trash bin and the path from the house to the destination and determine the relationship of these features to one another. Avoiding the flowerpot on the front steps, the car in the driveway, and other features between the two locations is easy because these features can be perceived more or less simultaneously.

In the same scenario, individuals who are blind use auditory and tactile information to avoid the flowerpot, the car in the driveway, and other features, and those with low vision may use visual information in addition to auditory and tactile cues. They also use their memory of the approximate distance and direction from the door to the trash bin to turn and move in the desired direction and to estimate when they are getting close to their destination. As they near the bin, they may directly perceive it using reflected sounds. They may probe with the long cane for particular features they know should be present along the route, and they may trail or follow surfaces with the cane, such as the boundary between the driveway and the yard. Hearing and touch, while effective for guiding travel, convey far less information than vision about self-motion, the relationship of objects to one another, and the self-to-object distances and directions to features in the environment. For example, compared to vision, tactile perception affords access only to proximal (that is, nearby) objects, and it has rather low resolution over a relatively small field of view. Auditory perception is more distal and is omnidirectional, which makes it useful as an “alerting” sense, but it often is transient, and, compared to vision, it provides less precision in localizing objects. Despite these limitations, many individuals who are blind or have low vision travel safely and efficiently in both familiar and unfamiliar areas, using nonvisual information to effectively maintain their orientation relative to a desired travel goal.

In cases where visual, auditory, or tactile information is unavailable to guide travel, individuals sometimes use a strategy called *dead reckoning*, in which *internal* proprioceptive and kinesthetic cues (that is, feedback from the movement of joints and muscles) permits them to keep track of distances walked and turns made (Loomis, Klatzky, Golledge, & Philbeck, 1999). For example, when walking a path in a large room where external cues are unavailable or unreliable, such as a hotel lobby, a traveler who is visually impaired likely is using a dead-reckoning strategy. The ability to accurately estimate degree of turning and distance walked is important when travel is guided only by internal cues.

Cognitive Strategies and Cognitive Maps in Spatial Orientation

Perceiving information relevant to establishing and maintaining orientation is important, but it also is important to be able to recall and use information about routes and about the spatial arrangement of places. The term *cognitive map* is used to describe the way that people create and recall mental images of the distances and directions to places out of range of their perceptual systems. The term is widely used, although with varying meanings. In general, it has been defined as an abstract, viewpoint-independent (that is, allocentric) mental representation of space that preserves spatial properties such as landmarks, paths, and directions, as well as the general relations among these elements (Golledge, 1999; O'Keefe & Nadel, 1978). The use of the word *map* in this context is more metaphoric than literal (Golledge, 1987). Internal mental representations are not analogous to a precise "map in the head" (Kuipers, 1982) but should more appropriately be thought of as a mental representation of space characterized by many "distortions, holes and exaggerations of the real world" (Golledge, 1987). Despite their limitations as “true maps,” cognitive maps are functionally important because they provide a means for quickly and flexibly accessing a representation of space as a traveler moves about. As noted earlier, this representation can guide route planning and complex spatial problem solving, such as determining detours, and can facilitate the task of communicating spatial information to others (Golledge, 1991; Peruch, Gaunet, Thinus-Blanc, & Loomis, 2000). An individual’s ability to flexibly access his or her cognitive map during navigation allows the map to serve as a memory aid while the individual is traveling. This is considered a higher, more flexible level of spatial ability than simply remembering a sequence of landmarks and associated actions.

Cognitive Mapping and Age at Onset of Visual Impairment

One factor that has been considered extensively in research about cognitive maps of persons who are blind is the impact of a critical period of visual experience early in life. This age-at-onset variable has been hypothesized to account for variations observed among the individuals who are blind in the performance of spatial tasks, and particularly complex spatial tasks (Millar, 1994; Rieser, Hill, Talor, Bradfield, & Rosen, 1992). As summarized by Thinus-Blanc and Gaunet (1997), this research reveals that the age at onset of visual impairment has little or no effect on spatial tasks that are fundamentally egocentric in nature, but when tasks require a more allocentric frame of reference, differences sometimes are found between groups of individuals who lost vision early in life and those who lost vision late in life.

These differences in performance may reflect an underlying fundamental difference in the "neurological organization" of spatial information between individuals who experienced an early onset of blindness and those who experienced a late onset of blindness (Millar, 1994). Alternatively, the differences may reflect the fact that individuals who experienced an early onset of blindness simply have not learned the strategies needed to perform higher-order spatial tasks at the level of individuals who experienced a late onset of blindness. The logic of this research is that the construction and use of an allocentric frame of reference, and the related ability to make higher-order spatial inferences, are facilitated by prior perceptual experience with distal information from visual access to the environment. Because the absence of vision dramatically reduces the amount of available distal information, and because the absence of vision from birth means that individuals have *never* experienced spatial information visually, researchers such as Millar (1994) have suggested that people who are blind from birth would tend to base their spatial knowledge more on proximal, body-centered information (such as proprioceptive and kinesthetic information) rather than distal information, and on nonvisual and therefore less precise sources of spatial information (for example, auditory cues). (For a review of this terminology, see Chapter 5, this volume.) Thinus-Blanc and Gaunet (1997) reflected this idea when they suggested that some people who are blind from birth may predominantly use spatial information organized as routes, and these individuals may be limited in performing spatial tasks requiring more map-like representations, such as planning detours or alternate routes. In contrast, people who became blind late in life and thus had some visual experiences that affected their development of spatial concepts would, as a group, be likely to mentally imagine spaces using a more map-like framework.

The investigation of the effect of visual experience on ways that individuals conceptualize space is complicated by the fact that there tend to be relatively large individual differences in spatial abilities, both within groups of individuals who experienced an early onset of blindness and within groups of individuals who experienced a late onset of blindness. This is evidenced by the fact that in one study of spatial learning after exploring new places, 14 of the 15 worst performers had experienced an early onset of visual impairment. However, some of the best performers (6 of 15) also had experienced an early onset of visual impairment (Hill, Rieser, Hill, Halpin, & Halpin, 1993). Because of these large individual differences in performance of complex spatial tasks, researchers cannot yet draw definitive conclusions about the relation of age at onset of visual impairment to the strategies for spatial thinking and the ability of individuals who experienced an early onset of blindness and those who experienced a late onset of blindness to perform complex spatial tasks. Also, as the research findings regarding individual differences reflect, many O&M specialists report that they have worked with individuals who experienced an early onset of blindness who possess excellent spatial abilities, including performance on tasks requiring higher-order spatial thinking. It appears that the age at onset of visual impairment is not the only factor influencing these abilities, a conclusion reflected in much of the literature on this topic (Klatzky, Golledge, Loomis, Cicinelli, & Pellegrino, 1995; Loomis et al., 1993; Loomis, Lippa, Golledge, & Klatzky, 2002).

Given the complexity of the age-at-onset issue in relation to spatial abilities, and the variability in the performance on spatial tasks among participants who are blind, it is difficult to identify a single factor (or even a set of factors) that helps or hinders orientation while traveling. The use of small research samples, laboratory tests that often have little real-world validity, and the lack of interdisciplinary discussion between behavioral scientists and O&M specialists have further hampered the interpretation and generalization of results (Kitchen, Blades, & Golledge, 1997). A coherent understanding of the spatial abilities of individuals who are blind has been complicated by the fact that most research does not control for the etiology of impairment, degree of impairment, or age at onset. Other variables that have not been well controlled are the amount and type of O&M instruction participants received. More research is needed to explore these issues in order to better understand how the onset of visual impairment, in conjunction with a host of other variables, influences the ability of individuals to think about space and to perform spatial tasks. Information about the teaching of orientation skills to children who are visually impaired is presented in greater detail in Volume 2, Chapters 2 and 7.

The Spatial Aspects of Traveling Routes

Landmarks

Most of the travel of both individuals who are sighted and blind occurs along familiar routes that lead to familiar destinations. Routes comprise sequences of instructions that specify distances and changes of direction while navigating. Identifying landmarks and recalling one’s location relative to a destination is a fundamental aspect of traveling routes. Hill and Ponder (1976) defined *landmarks* for travelers who are blind or visually impaired as familiar objects, sounds, odors, temperatures, or tactile or visual clues that are easily recognized, are constant, and have discrete, permanent locations in the environment that are known to the traveler.

Primary Landmarks

Although not mentioned in the Hill and Ponder definition of landmarks, there is a difference between primary and secondary landmarks. A primary landmark is always present in the environment and would be difficult to miss as one travels along a path. For a traveler who is blind or visually impaired, a change in surface texture underfoot that spans the width of a sidewalk is an example of a primary landmark. Unlike a sound, a surface change is unlikely to be transient, and unlikely to be missed, provided it is distinguishable from the surrounding sidewalk and of adequate size. Also, the particular change in texture must be unique, that is, it must not occur frequently in a specific environment.

Secondary Landmarks

Secondary landmarks are similar to primary landmarks. A box for depositing books after hours at a library in a particular neighborhood, for example, might serve as a secondary landmark. It is easily distinguished from other features in a place, is unique in a given environment, and is permanent. It is the only box of its type along a route. It is considered a secondary landmark only because it is possible to miss the box since it is to the side of the travel path rather than on it. Individuals who use a long cane must explore to the side where the feature is located to find it, and they can walk past it if probing with the cane on the other side, or not exploring to the side at all. Individuals who use dog guides must confirm that they are beside the box by reaching out to touch it or by using reflected sound to locate it.

Information Points

Like landmarks, *information points* also are useful for establishing orientation. They are features that, while not unique along a path and thus not considered landmarks, can be used in combination with other features to provide information about one's location. A parking meter adjacent to a fire hydrant may be an information point. Both objects are found in several places along a route, but they are located adjacent to each other in only one location. Confirming that both a parking meter and a fire hydrant are nearby thus can aid in confirming one's location and facing direction.

Landmarks and information points also aid in identifying locations along a walk where a change in the direction of travel is needed in order to continue toward a destination. Pedestrians who are blind or visually impaired, like pedestrians with vision, listen, touch, feel, and, to a lesser extent, smell, as they move about, and many individuals who have low vision also use vision to locate features along a route. The value of any particular environmental feature for establishing or confirming orientation depends on whether or not travelers can perceive it, and whether they can associate it spatially with other features and with the desired direction of travel. For effective travel, individuals must keep track of their position relative to the sequence of landmarks and information points they have passed, and they must also anticipate the upcoming landmarks and information points.

Problem Solving

Reestablishing Orientation

In general, establishing and maintaining orientation as one travels familiar routes involves a cycle of perception and action, with action guided by one's expectations regarding what perceptual information one should be encountering at a given point along a route. What one expects could be recalled from a cognitive map of this specific place or could be based on one's general familiarity with environments similar to the one being negotiated. When perceptions do not match expectations, information gathering and strategic action usually are necessary to reestablish orientation.

Reestablishing orientation is a problem-solving or hypothesis-testing activity. It can be described in four stages: (1) identifying that a problem exists; (2) identifying alternative strategies for solving problems; (3) selecting a strategy from the available alternatives and implementing it; and (4) evaluating the effectiveness of the selected strategy. Psychologists and educators have used this four-stage schema to study problem solving for a variety of everyday tasks, and it is applicable to orientation problem solving as well (Bransford & Stein, 1984; Dewey, 1916; Hayes, 1988). These four stages are applicable to activities as diverse as finding a room in a building, correcting a veer after a street crossing, and reestablishing orientation after getting off a bus at the wrong stop.

For visually impaired travelers and sighted travelers alike, the realization that an orientation problem exists usually occurs when their perceptions of the surroundings do not fit with their expectations based on experience. A landmark on the left should have been on the right, for example, or is not detected at all. Instead, a traveler unexpectedly contacts an obstacle that is unfamiliar. Each of these events may trigger the traveler's desire to evaluate where she is along a route and which way she is facing. If the traveler perceives that she is not on route and moving in the correct direction, she must decide what problem-solving strategies to use to become reoriented.

Individuals who are visually impaired have a number of strategies at their disposal when reorienting themselves. These strategies can be effective on both familiar and unfamiliar routes. First, they evaluate the available information and form a hypothesis about where they are, where the travel path is, and which way they are facing. They determine the direction they need to move in, in order to get back to the travel path and to resume walking toward their destination. To accomplish these tasks, travelers may attend to information such as the slope of ground, the sound of traffic, or an available line or border, such as a wall or a grass line. They also may explore systematically to locate a landmark with the cane or hand or may use distant sounds for reorientation. They also may solicit information from others about their location, the direction they need to walk to reach their destination, and the landmarks they will encounter as they travel. During O&M instruction, individuals are given guidance on various strategies for soliciting help effectively, including techniques such as pointing the direction indicated by a helpful pedestrian in order to confirm a location or direction of travel. If travelers and information providers are able to use cardinal directions along with their knowledge of the street grid instead of relying only on egocentric directions (for example, left or right turns), this may lessen the likelihood of left-right confusion that sometimes occurs when getting directions from others. The ability to use cardinal directions also may facilitate an individual's ability to follow a route and become reoriented when disoriented. If a person is relying only on an egocentric frame of reference, it may be more difficult to become reoriented when one's frame of reference is lost.

Sometimes travelers must follow routes that they have not traveled before. They may obtain route directions from a map or from another person, or they may create a bestguess route based on their cartographic knowledge of the street grid and the locations of various places relative to one another and their current location. When traveling an unfamiliar route, one's general knowledge of the environmental regularities that occur in most travel environments also can be useful for orientation. For example, curb ramps usually indicate that one has arrived at an intersecting street. The end of a building line often indicates that a driveway or intersection is just ahead. Also, streets often are either parallel or perpendicular to neighboring streets. These and other regularities in "built" environments may be useful in establishing and maintaining orientation in places where landmarks and information points are unknown.

Consider an example of an orientation-related problem and the application of the four-stage problem-solving schema. A pedestrian who is visually impaired realizes he is disoriented; he no longer knows where he is relative to any landmark in the environment. In addition, he realizes that the perceptual information he is "receiving" does not "fit" with what he expected to find on this particular five-block route. He must reestablish his orientation and determine which direction to walk to continue traveling toward his destination. He thinks the problem has occurred because he walked several blocks past a choice point along his route where he usually turns, although he is not certain of this. He evaluates the available information, focusing on what he feels under his feet, what he can locate with the cane, and what he hears. Although initially there is little information available to help him problem solve, he soon locates a row of parking meters with his cane. He recalls that the only parking meters in the area are along a street one block south and one block east of the information point that he missed along the initial route. Using the sun in late afternoon as a crude compass, he walks back to the north and then to the west toward the intersection where he originally intended to turn. Upon arriving there, he veers into his parallel street as he crosses, realizes it because of changes in traffic sounds, and turns toward the desired curb. Once on the curb, he continues in the direction he intended to travel initially. He has solved his disorientation problem by first identifying that he is disoriented, determining what perceptual and cognitive information he has at his disposal, and selecting, implementing, and evaluating a strategy successfully.

Drop-Off Lessons

To give students practice in solving disorientation problems, O&M specialists sometimes set up situations in which their students are dropped off in a familiar area but given no information about where they are in the area. The students typically are given a destination at the beginning of these lessons, and they must use various strategies to establish orientation and travel successfully to the destination. Students in drop-off lessons presumably have learned the location of several landmarks and information points in the environment during previous travel, and often they can travel efficiently once they have determined their initial location and their facing direction. Determining one's location and facing direction are the primary challenges of a drop-off lesson. Drop-off lessons are sometimes used near the end of O&M instruction because students who can solve drop-off problems presumably can identify and solve other less demanding travel problems, such as maintaining orientation while traveling to a destination in a familiar place from a known starting point (for example, from home to work). Drop-off lessons also can be very useful in teaching students to gather information and test hypotheses about where they are and how to get to a destination efficiently. When designed properly, drop-off lessons can be great confidence builders for students developing their orientation strategies.

Like the disoriented traveler in the previous example, an individual solving a drop-off problem uses a hypothesis-testing strategy. The traveler gathers information to establish and then test her hypothesis about her location. The position of the sun, the sounds of traffic and its direction of movement, and nearby landmarks all may be useful in establishing orientation and facing direction. As she moves, the student also must keep track of her location relative to the destination so she can travel to it efficiently. To accomplish this, she may remember the number of blocks she has walked in one direction and recall that she must turn in a certain direction at a certain point along the walk in order to continue walking toward the destination. She likely uses landmarks or information points as she moves along to check her progress and determine where changes in direction are required (for example, "I feel the gravel under my feet and know my turn is coming soon"). She also may simply recall the approximate length of time she needs to walk prior to turning (for example, "I've walked about as far as I usually walk to reach the next turn"). The absence of an expected landmark or information point can further prompt hypothesis testing about whether she is moving toward the goal or in some other direction.

Learning New Places

Most people, with or without sight or with low vision, have little difficulty maintaining their orientation and traveling efficiently in their house or neighborhood. However, accomplishing this task in new places with or without vision can be challenging, particularly when those places are large or complex (Ungar, 2000). This section focuses on how individuals who are blind learn about and travel efficiently in new places.

Like traveling along familiar routes, learning about and successfully moving through unfamiliar indoor and outdoor environments is a critical component of daily life for most people. As noted earlier, travelers in familiar places have the benefit of matching the flow of perceptual information to their memory of what they should encounter as they move about. They can compare the perceptions at a given location to what they expect to perceive and then implement problem-solving strategies if their perceptions and expectations are incongruent. When exploring new places, travelers usually do not have prior knowledge of landmarks and information points and thus must locate and remember them. Travelers may sometimes solicit landmark information from others before traveling in new places and thus may have some knowledge of landmarks prior to walking. Once acquired, landmarks and information points can aid an individual in traveling efficiently on subsequent walks, and they may become features of the traveler's cognitive map. The ability of students to explore in ways that aid them in remembering the features in a place and their spatial relationships, and the implementation of orientation-related strategies while traveling are two important skills often taught in O&M instruction.

Although it has not been studied in depth, investigating the strategies people use to explore and learn new environments is important for both theoretical and practical reasons. As noted earlier in the discussion of traveling routes, the lack of access to distal environmental information in unfamiliar environments means that individuals who are visually impaired often face challenges in accessing information during self-exploration to form a well-defined cognitive map of a new place. Lack of such knowledge does not preclude efficient travel along routes once landmarks and information points are learned, because individuals can travel routes by executing a prescribed sequence of actions. However, without access to an accurate global spatial representation in the form of a cognitive map, it is much harder to perform tasks such as making a detour, determining shortcuts, and reorienting if lost.

One way to learn about both egocentric and allocentric spatial relations of unfamiliar places is through the use of a tactile map (Golledge, 1991; Jansson, 2000). While using a map, individuals sometimes walk, identify features on the map and in the place, and remember both routes and straight-line distances and directions between environmental features, such as would be imagined in a bird's-eye view. In recent years, the use of *global positioning system (GPS)* satellite technology has become commonplace for aiding travel. With GPS, a user's location information is determined as they move by tracking the radio signals from the position of three or more satellites using a hand-held GPS receiver. The advent of this technology has been a great step forward in orientation and wayfinding for all travelers, sighted, blind, and visually impaired alike, and has made the exploration of and efficient movement in new places easier (see Chapter 10, this volume and Chapters 11 and 14, volume 2).

Evidence for the advantages of teaching an exploration strategy that emphasizes the acquisition of an allocentric frame of reference is found in several studies comparing spatial performance of individuals who were blind and those with sight. In studies by Rieser, Guth, and Hill (1982, 1986), participants were guided from a starting point to multiple targets in a room and were then asked to walk or point directly from the starting position to each target or along novel (not previously traveled) routes between the targets. Although both blind and blindfolded sighted participants were accurate at walking to target locations from the starting position after a guided walk, blind participants were significantly worse at pointing to or walking along routes between locations not directly experienced. These findings were interpreted as indicating that blind people can learn routes efficiently but may have difficulty integrating sequentially encountered locations into a common, allocentric frame of reference. Although these experiments did not test this hypothesis, it may be that changing the learning strategy used by individuals to accomplish spatial tasks would have a positive effect on performance. For example, it may be useful to encourage individuals who are blind to explore the environment and then imagine how the target positions are related to each other. This could be accomplished by having them create a tactile map of the environment or by imagining themselves at various locations and pointing to other locations. With access to a spatial display, such as a tactile map, that accurately depicts the object-to-object relations, individuals may significantly improve their understanding of the space and their spatial inference making.

Although most studies and training programs in spatial orientation do not examine spatial learning of unfamiliar places, a few studies have been conducted to investigate the role of exploratory strategies in learning. Three primary exploration strategies have been identified as being used by travelers who are blind or visually impaired for self-familiarization: *perimeter*, *gridline*, and *reference point* (Hill & Ponder, 1976). With a perimeter strategy, the traveler walks the outside border of a space and remembers the various features along the border (for example, the wall) in order, starting from a home-base location (often the door to a room). With a gridline strategy, a traveler systematically crosses back and forth in the interior of a space in order to locate landmarks. With a reference-point strategy, a traveler explores a place by walking from a known location (that is, home base) to various landmarks, returning to home base before walking to another landmark.

Tellevik (1992) conducted a study to investigate whether different exploration strategies yield different levels of knowledge, and whether specific strategies are preferable to others in facilitating the learning of object-to-object relationships. To evaluate perimeter, gridline, and reference-point strategies, Tellevik asked the 10 sighted participants, who were blindfolded O&M specialists, to find four objects in a room. Videotapes of the study were analyzed to learn about self-exploration strategies and their relationship to spatial-layout knowledge. The results indicated that people initially used perimeter and gridline strategies, but with additional exploration they tended to adopt a reference-point strategy to gain knowledge about object-to-object locations (Tellevik, 1992). Hill et al. (1993) extended Tellevik's work on self-familiarization strategies during exploration of novel places by participants who were blind. The authors videotaped 65 adults, some who experienced an early onset of blindness and some who experienced a late onset of blindness, as they explored a 15-foot-by-15-foot space and learned the location of five objects. Perimeter, gridline, and reference-point strategies were used, although not all participants used all of the strategies. The top 25 percent of performers and the bottom 25 percent of performers on spatial-layout knowledge as measured by a distance-estimation task between target locations (an allocentric spatial task) were evaluated for frequency of use of each strategy. The results demonstrated that participants with the best distance-estimation performance used more types of strategies than other participants. In general, they also located the five objects more quickly and tended to use the linking strategies of gridline and reference point rather than perimeter search strategies.

A final study investigating the use of exploration strategies in unfamiliar environments by individuals who experienced an early onset of blindness, those who experienced a late onset of blindness, and blindfolded sighted subjects found similar patterns of movement behavior to those observed in the previous two studies. Gaunet and Thinus-Blanc (1996) found that participants adopted two general patterns of exploratory behavior. As they began exploring, participants used a perimeter search strategy similar to that described in Tellevik (1992) and Hill et al. (1993). The subjects tended initially to travel between a sequence of landmarks, ending up at the same place they started. As they gained more experience exploring the space, they adopted a second search strategy, characterized by a back-and-forth pattern of movement between objects. The finding that route traversals between object locations increased with greater experience with the space is in agreement with the findings of the Tellevik and Hill studies showing the use of strategies linking objects to objects. Also, supporting the earlier findings of Hill et al., performance by participants who experienced an early onset of blindness tended to be more error prone than that of participants who experienced late onset blindness and blindfolded sighted subjects. Researchers attributed this behavior to reliance on a perimeter search strategy and less use of back-and-forth movement patterns by the subjects who experienced an early onset of blindness. Corroborating the previous findings, the best performers in the Gaunet and Thinus-Blanc study, independent of age at onset of visual loss, were those who adopted multiple, systematic patterns of exploratory behavior.

The studies cited earlier are important because O&M specialists and their clients need to know more about how various exploration strategies during self-familiarization with novel environments support spatial learning. This knowledge will have practical application because the exploration strategies that help people develop accurate cognitive maps will in turn facilitate efficient travel in new places. The studies highlight the need for greater focus on investigating how people interact with their environment and what movement strategies they adopt for learning unfamiliar places. Further research is needed to learn more about sources of individual differences in other subpopulations of individuals who are blind or visually impaired. For example, research in this area with children may be particularly important. The previous studies also were limited in that they addressed exploration only of room-sized layouts. More research is needed to investigate strategy selection for orientation in larger-scale and outdoor environments.

It seems likely that free exploration would be particularly beneficial to people who are blind or visually impaired when building a cognitive map of large-scale environments. The sensorimotor experiences of moving from place to place without following predetermined routes is thought to help integrate multiple discrete locations into an allocentric spatial framework (Giudice, 2004). Support for this hypothesis has been obtained from a series of studies investigating free exploration of buildings by individuals without vision (Giudice, 2004, 2006; Giudice, Bakdash, & Legge, 2007). In these studies, subjects who were blind or visually impaired and blindfolded sighted subjects were started at a random position in a complex large-scale building and asked to learn the space and find hidden target locations by freely exploring the environment. No information about routes was provided. Verbal messages given by an experimenter described the explorer's heading and the layout geometry (that is, intersections and corridor structures) at their location. A sample message was "You are facing south, at a three-way intersection. There are hallways ahead, to the left, and behind." An important aspect of these messages is that the information provided was context sensitive and dynamically updated, meaning that each verbal message changed depending on the traveler's position and orientation in the environment as the traveler moved. Thus, if the traveler made a 90-degree left rotation at the T junction just described, the verbal message would update the description and tell the traveler that he or she was now facing east, with hallways extending ahead, to the left, and to the right. The premise of these studies was that since the verbal descriptions provided real-time information about the person's position and orientation in the environment and conveyed all necessary information to support efficient travel, performance should not differ between groups as a function of visual status. The results of these experiments confirmed this prediction and revealed other important findings. First, dynamically updated verbal descriptions were found to be an effective mode of conveying environmental information. Access to these descriptions promoted efficient search behavior of both real layouts (Giudice et al., 2007) and virtual, computer-based environments (Giudice, 2006). These studies also demonstrated that free exploration led to the development of a cognitive map by people who are blind that supported subsequent wayfinding tasks at an equivalent level to sighted participants learning with vision. Taken together, these experiments demonstrated that (1) when an appropriate source of nonvisual information is provided, the spatial performance of individuals who are blind and that of individuals with vision does not differ, and (2) orientation is facilitated when people are allowed to learn new environments by free exploration, a finding that speaks to the importance of teaching search strategies.

Research and Practice Needs in Spatial Orientation

Some of the issues addressed by this chapter have been studied relatively extensively (for example, the issue of age at onset of visual loss in relation to spatial abilities); some issues have begun to be explored by researchers (for example, the issue of exploration strategies in relation to learning about spatial layout); and some issues have been virtually unexplored (for example, the frequency and characteristics of orientation problems that individuals who are blind or visually impaired encounter when traveling in familiar and unfamiliar places and the effectiveness of the strategies used to solve them). In addition to research about orientation, much has been learned from the experiences of O&M specialists and their students as they developed creative, practical approaches to addressing orientation-related problems. O&M specialists have developed strategies to teach young children the basic concepts underlying successful travel along familiar routes, to help them learn to explore new places, and to help them create, recall, and use cognitive maps (see Volume 2, Chapter 2). The use of tactile maps is an important part of the instructional tool kit for many O&M specialists (see Chapter 10, this volume and Chapter 11, volume 2). Professionals and clients have developed materials and strategies for using maps while traveling, and for using maps to probe how well individuals have encoded the distances and directions among features in a place. The use of tactile maps by individuals who are blind, both before and during travel, has been shown to facilitate spatial learning, orientation, and decision-making behavior and has received considerable attention from researchers (Andrews, 1983; Blades, Ungar, & Spencer, 1999; Espinosa, Ungar, Ochaita, Blades, & Spencer, 1998; Golledge, 1991; Holmes, Jansson, & Jansson, 1996; see also Chapter 10, this volume).

The Use of Maps and Map Instruction

Despite these benefits, map use and map instruction are probably not as widespread as they should be. One reason is that accessible maps are not readily available. However, new technologies for making accessible maps should help to remediate this problem. One example is the development of dynamically updated tactile displays. Also, new graphic embossers are making it easier to create a tactile map from a print map. Likewise, the “tmap” project, which allows a person to download a file to Braille on his or her own embosser about a specified environmental space, is very promising (Miele, Landau, & Gilden, 2006a). Instruction in map use and the use of orientation-related technologies among young children needs to be expanded, because their systematic and creative use likely will aid children in developing higher-order spatial knowledge and skill. For example, Blades, Lippa, Golledge, Jacobson, and Kitchin (2002) found improvements in route and map-like spatial performance as individuals gained experience, and found that building models, pointing to places while walking a route, and giving verbal descriptions of a route were effective tools for both assessing and improving spatial orientation.

The Use of New Orientation Technology

The creative use of compasses, global satellite-based positioning systems, and other technologies will likely aid in ameliorating the limitations in higher-order spatial-orientation abilities that sometimes are seen in people who are blind or visually impaired. GPS and other information-rich devices have demonstrated their usefulness as orientation aids, and these technologies will improve in part because there are many mainstream applications for which orientation information is beneficial. The technologies for use by individuals who are blind or visually impaired will, to some degree, follow this growing information demand. The advantage of GPS-based navigation technology is that it conveys information about the environment, such as street names and descriptions of intersection geometry, and provides dynamically updated orientation cues in the form of distances and directions. GPS-based navigation systems are currently limited to outdoor use, but in these environments they have the potential to improve mobility in new places and reduce the anxiety sometimes associated with travel in unfamiliar areas and with becoming disoriented. Remote infrared audible signage such as Talking Signs also can provide directional information by homing in on an infrared signal being transmitted from a landmark that offers an audible description of both indoor and outdoor environmental features. It is expected that these advances, in conjunction with other technologies currently being developed, will eventually support seamless access to environmental information for indoor and outdoor travel.

The Value of Teaching Strategies

How often and in what ways do O&M specialists ask questions of their learners that tap into or encourage higher-level spatial skills and flexibility in spatial thinking and action? For example, to what degree do O&M specialists encourage their learners to do such things as pointing to places they cannot directly perceive, pointing to places while imagining they are standing at various vantage points, describing spatial relationships using various types of spatial language, constructing maps and models of places, and in other ways evaluating the ability of their learners to think and act using allocentric frames of reference? What set of tabletop, room, and larger-space experiences will support the development of spatial skills that are generalizable to new environments and can be used spontaneously by individuals who are visually impaired when solving orientation problems? There has been little research about the sequencing of instruction in orientation and mobility, so the interplay of lower-level and higher-order spatial thinking during instruction is not well-known.

With regard to traveling routes, it would be useful to know more about approaches to the process of landmark selection and identification. What kinds of features do travelers seek when identifying potential landmarks along a route? Examining route-learning behavior in light of the features available along a route should help to answer this question (Ochaita & Huertas, 1993). How many landmarks can travelers recall, and when do memory tools need to be brought into play? How does learning a route vary according to a traveler's overall travel experience, visual status, familiarity with the environment, or ability to make higher-order spatial inferences? Research about questions like these should aid in developing instructional approaches to efficient guided learning and self-learning of routes.

Summary

This chapter describes three fundamental aspects of the challenge of establishing and maintaining orientation. The first is access to perceptual information that guides spatial decision making. Sometimes information is readily available, easily perceived, and unambiguous. In familiar situations, travelers also have the advantage of comparing what they perceive with their recollection of what "ought to be." In situations where information is unavailable, difficult to perceive, or ambiguous, travelers must make orientation decisions using the information set at hand, or they must seek ways to gather additional information. Using a GPS, asking for assistance, or exploring systematically are examples of information gathering that may be useful. In unfamiliar situations, travelers must shift their focus from acquiring route-specific information to a reliance on more general information. In other words, in areas where a pairing of percepts and specific expectations is not possible, travelers rely on more general cognitive strategies for establishing and maintaining orientation. Approaches to information gathering in familiar and unfamiliar areas have not been systematically explored. Research in this area may lead to a clearer understanding of the kinds of information that enhance spatial abilities in these two situations.

The second fundamental concept described in this chapter concerns the ability of individuals who are visually impaired to acquire information from their mental maps of places and to make strategic use of this information to guide their travel. The concept of a cognitive map was introduced as a metaphor for recalling, thinking about, and using spatial knowledge. The important distinction between thinking egocentrically and thinking allocentrically was highlighted, and the need to encourage allocentric spatial thinking was noted. Research regarding how the age at onset of vision loss impacts spatial abilities was briefly described, as well as the importance of considering a range of factors that may operate in concert with age at onset to affect spatial abilities.

The third fundamental aspect of spatial orientation discussed in the chapter was that of selecting strategies for gathering information and for orientation-related decision making. The examples of relocating the travel path and establishing orientation in a familiar area were used to highlight strategy selection. In selecting and implementing strategies for orientation, travelers who are visually impaired bring their information-gathering and cognitive-mapping skills to bear on the particular orientation challenge at hand.

O&M instruction is one key aspect of learning what strategies might be useful in a particular situation, in evaluating alternative strategies, and in assessing the effectiveness of these strategies. As with the concepts of information gathering and the use of cognitive maps, more research is needed on strategy selection. How, for example, do novice and expert travelers differ in their ability to select the optimal strategy? The studies cited in this chapter regarding exploration of new places suggest that strategy selection is important for efficient (oriented) travel, but much more research is needed to catalogue the various strategies and their situational effectiveness. O&M specialists can play an important role in working with researchers as they investigate the complex issues surrounding information gathering, the use of cognitive maps, and the selection of strategies for establishing and maintaining orientation in familiar and unfamiliar places. Researchers and O&M specialists alike have a role to play in helping to advance our understanding in this important and practical area of orientation and mobility.

Implications for O&M Practice

1. There are four fundamental aspects of spatial orientation: information gathering, the use of strategies for following familiar routes, the use of cognitive maps, and the application of strategies to solve problems.

2. People who are blind or visually impaired use both auditory and tactile information to establish and maintain orientation.

3. Spatial orientation has been studied extensively, and much is known about the spatial orientation of individuals with typical vision.

4. In recent years, researchers have focused on the spatial-orientation abilities of people who are blind, with emphasis on the impact of age at onset of visual loss on spatial abilities.

5. *Egocentric* and *allocentric* are the two fundamental frames of reference for thinking about spatial relations. An allocentric frame of reference allows individuals to be more flexible in their thinking about the locations of objects relative to one another. This frame of reference is the basis of what is referred to as a *cognitive map*.

6. In familiar areas, travelers can rely on their anticipation of specific types of information in specific places. In unfamiliar areas, travelers must rely on their more general knowledge of the way places are usually arranged, rather than relying on specific information. These differences may yield the selection of different strategies for solving orientation problems.

7. Exploring new places is an important task for a traveler who is blind or who has low vision, and the approaches travelers use for exploring new places can be studied to determine whether some strategies are more useful than others.

8. There is a great need for additional research about the spatial orientation of individuals with visual impairment. The need is particularly great for research about the kinds of experiences that enable children to become independent travelers and to develop high-level spatial skills that support independent travel in both familiar and unfamiliar places.

Learning Activities

For students with low vision, it may be useful to occlude their vision as they complete the activities below.

1. Practice the skill of updating your position in space by walking without vision along two legs of a triangle and then trying to return to the starting point. Point to several landmarks you encountered along a walk while standing at the end of a route or at one of the landmarks. What terms can you use to describe the relationship among

landmarks, using both egocentric and allocentric frames of reference?

2. Explore rooms and neighborhoods while blindfolded. Use different strategies for exploring and remembering the features of a place, and think about how these differences relate to your knowledge of a place as measured by your ability to make a map, determine a detour, or create novel routes.

3. Think about the information available in a typical office building, a residential area, and a small-business environment. What strategies would you use in each environment to establish and maintain your orientation? Walk around in a large room, such as a gym, that has three to five objects in it. Walk to each object and describe the relationships of objects to one another. Estimate how far it is from the various objects to other objects. Build a map or model of the objects, preserving the spatial relationships among them. Develop a strategy for teaching these skills to young children. Travel a familiar route, but stop halfway to the destination to identify an alternate route that leads to the destination, and then follow it.

4. Using an array of objects similar to those in the previous activity, learn the relationships among the objects and then imagine yourself standing at one of them and pointing to the others. Is this a harder task than simply pointing to objects while standing at one object?

5. Use a set of note cards, recorded notes, or other means to reconstruct a sequence of landmarks and turns that are too long to remember. How many landmarks can you remember? Do memory aids help you to remember them? What spatial language do you use to describe the spaces in the previous activities?

6. Explore a BrailleNote GPS or Trekker, or other accessible GPS-based wayfinding technology. How might the information it provides be useful to travelers who are blind?

7. Experiment with mental exercises that tap higher-order spatial knowledge. Ask yourself, “If I am at point A, how would I plan a route to point B, and what would I do if I found myself at Point C?” Mental exercises like this may be useful to aid learners in thinking about space and can facilitate the development of spatial problem-solving skills.

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