JVIB

June 2007 • Volume 101 • Number 6

Mental Effort in Mobility Route Learning

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Abstract: This study examined the mental effort required to monitor landmarks and the effect of the type of route on mobility-route training. The results revealed that the features of landmarks and competence in travel were significantly related, indicating that some environmental factors related to height and width are more easily learned when people can travel independently. A similar result was found when types of travel were compared.

Orientation and mobility (O&M) refers to the ability both to move smoothly through space without disruption because of accidental contact with obstacles and to orient with the environment to achieve purposeful or goal-directed movement (Foulke, 1971). Efforts to assist people who are visually impaired (that is, those who are blind or have low vision) to acquire mobility skills have involved the development of sensory aids and associated training techniques whose aim is to help pedestrians learn about specific environmental factors, avoid obstacles, and determine whether a clear path exists ahead (Blasch, De l'Aune, & Coombs, 1999).

For purposeful movement, the traveler must know where things in the environment are and what they are. The informational constraints that are associated with visual impairment suggest that one way in which visual impairment affects mobility skills is by increasing the mental effort required to maintain safe and efficient performance. This mental effort is dependent on environmental accessibility and skill in negotiating the environmental challenges that are met in travel. In learning to travel from one place to another, various degrees of skill with O&M are required, depending on the nature and difficulty of the travel environments

(Long & Hill, 1997). In assessing and planning mobility routes, the O&M instructor needs to consider how environmentally and behaviorally accountable events affect mobility performance when a student is learning to travel mobility routes. The study presented in this article focused on what is easy or difficult in learning mobility routes by investigating how environmental features and problem-solving strategies affect mobility performance in travel.

A common finding of research on sensory-motor skills is that the quality of human performance is often determined by general limitations of the capacity to perform mental work. As people learn a skill, they appear to do a task with less and less physical and mental effort, possibly because they learn to perform with more efficient movements or because they process information more efficiently. Such limited processing capacity often prevents people from responding quickly and accurately to unpredictable events (Kahneman, 1973; Schmidt & Lee, 1999). In the performance of skills, the ability to anticipate plays an important role. The stimuli emerging from the environment allow people to preview upcoming events that can be used to prepare anticipatory actions so as to complete a task like finding or avoiding an object in a path. For travelers who are blind, it has been demonstrated that when anticipation is possible, either through a direct preview of imminent events or by prediction based on memory, their performance is generally smooth and accurate (Shingledecker, 1983). Several studies have demonstrated that skillful performance depends on the ability to anticipate behavioral requirements by observing the features of the situation in advance of the time when some action will be required (Barth & Foulke, 1979; Blasch, LaGrow, & De l'Aune, 1996; Foulke, 1985; Poulton, 1957). Anticipatory responses may be used as an indirect measure to investigate which environmental features and types of travel are more easy or difficult to learn.

The effects of mental effort by people who are blind were demonstrated by Shingledecker (1978), who studied mental effort by recording the participants' reaction times and how many mistakes the participants made on alternative tasks in three conditions. One group walked a route on which they had received previous practice, a second walked a completely unfamiliar route, and a third walked the identical route, but received previews of selected environmental events as they did so. Shingledecker found that the participants who were unable to anticipate upcoming events failed to respond to the alternative stimuli more often than those who received preview information or those who could predict environmental events from memory. He also found that errors and reaction time on alternative tasks varied with the complexity of the routes, defined according to what is commonly used to describe levels of training difficulty in O&M programs. When each route was examined for individual sections, errors and longer reaction times were associated with environmental and behavioral events, particularly for routes with moderate and high complexity. Shingledecker argued that these results indicate that the secondary task was responsive to variations in the demands of the primary mobility task that could not be deduced from observation of the participants' mobility performance or from a subjective analysis of the difficulty of a route.

The effects of various mobility-task demands have also been demonstrated in other studies. Turano, Geruschat, and Stahl (1998) found that participants with retinitis pigmentosa (RP) had longer reaction times than did sighted participants when they walked a complex route. The reaction times for both groups of participants were the same for a simple route, indicating that the complexity of a route is critical in determining whether walking requires more mental effort for persons with RP than for sighted persons. Tellevik, Martinsen, Storliløkken, and Elmerskog (2000) demonstrated that in learning to travel a mobility route, anticipatory responses to landmarks occurred more frequently and earlier than did anticipatory responses to other environmentally significant events like shorelines, indicating that anticipatory responses to environmental features may be associated with various mental constraints in learning a route. These results indicate that mental effort may vary for environmentally and behaviorally significant events.

In our study, mental effort in relation to such events was studied by using anticipatory responses as an indirect measure to investigate which environmental features and problem-solving strategies are easier or more difficult to learn in mobility-route training. Travel environments are generally classified according to the skill or problem-solving strategy that is required to negotiate them (Hill & Ponder, 1976). In our study, we hypothesized that mental effort and learning would be affected by several environmental factors, such as the type of route, the length of the route, environmental features (like the height and width of landmarks), and the type of travel skill used to negotiate travel environments.

Method

Participants

Of the 16 congenitally blind children who participated in the study, 10 were totally blind and 6 were categorized as functionally blind, meaning they had low vision that was not useful for mobility. The participants ranged in age from 3 to 14, with a mean age of 8.2 years. They all attended local preschools or schools, and each received O&M training in their home environment by a local instructor. These 16 local instructors all participated in the study. All the participants were also clients of a national resource center for special education of children who are visually impaired. The local O&M instructors were trained and supervised by mobility instructors from the national resource center. The participants used white canes when they found them convenient for travel.

Design and Procedure

The participants were chosen from among the recently referred clients of the national resource center. In the Norwegian support system, the resource center was thus responsible for the supervision of the local professionals and the parents. The participants, the local teachers and instructors, and the parents attended three courses at the center, one at the beginning, one in the middle, and one at the end of the project. The courses focused on theory and practice in mobility; and how to assess, plan, and implement remedial action for the clients involved. The instructors from the resource center visited the individual children, together with their teachers, instructors, and parents, in their home environment four times during the project. In addition, on two to four occasions, videoconferences for supervision were arranged in between the meetings at the center and the local milieus. The research was approved by the institutional review board of Tambartun National Resource Center for the Visually Impaired. All the participants and their parents or guardians were provided with information and signed the consent forms.

Training of instructors

The local instructors were given the study guidelines for O&M and mobility-route training and specific training in how to instruct the participants in traveling a mobility route, recording the instruction given in each section of the route, recognizing anticipatory behavior, and recording anticipatory responses in relation to the landmarks of the route. Video recordings were made of each participant while traveling the routes. The recordings were used in training the instructors to recognize anticipatory behavior and to characterize the instruction given to the participants, and in giving advice to and supervising the instructors. To make the instructors aware of the many forms that anticipatory responses may take, we made a list of 67 examples of behaviors that are associated with anticipatory behaviors at landmarks and a similar, and partially overlapping, list for shorelines.

For each participant, at least two mobility routes were described and prioritized for mobility training. For each route, landmarks and shorelines were described for each section of the route. The local instructors recorded the instruction given for each section of each route and the operationally defined anticipatory behavior occurring in relation to the landmark.

Each participant walked a mobility route until he or she was able to travel it independently; that is, no instruction was given except for a prompt to start at the beginning of the route. Monitoring the progression of learning in mobility routes was assessed by observing the participants' directed attention to salient parts of the route and performance of the route (Tellevik et al. 2000). To make the instructors aware of the effects of various kinds of interventions, we asked them to record the effects of their actions on the participants' behavior by assigning the participants' initiatives with regard to landmarks and shorelines to different levels of attention. To make the instructors sensitive to shifts in attention in the participants' behavior, it was necessary to give a variety of specific examples of how help could be given at each level of attention. Participants may be helped through verbal instruction about the landmark or shoreline, but this kind of instruction may also be given physically, depending on the participants' attention. The main point was to enable the instructors to choose the appropriate instruction according to the participants' attentional behavior. For each attention level, we provided examples of how types of instruction (physical, auditory, or verbal) may be applied.

The mobility routes

In each segment of the mobility routes, landmarks and shorelines were defined. A *segment* was operationally defined as the distance between two landmarks. Each segment was given a unique identification number according to its order of occurrence in the route. The mean number of meters for segments was 2.3 (about 7.5 feet) for indoor routes and 21.8 (71.5 feet) for outdoor routes.

A *landmark* was operationally defined as an object or environmental feature that identifies a particular position in a route. Each landmark was given a unique identification number according to which route it occurred in and the identification number of the segment preceding it. Landmarks were assigned to different groups according to their height and width. Height was operationally defined as low (at ground level), medium (at hand level), and high (above hand level). Width was operationally defined as narrow (like trees and poles), medium (like doors and gates), and wide (like walls and houses). Landmarks were divided into nine categories: edges (such as curbs, road edges, and borders between grass and gravel); doors or gates; fences, rails, or hedges; houses or walls; corners; stairs; trees or poles; furniture; and others.

A *shoreline* was operationally defined as an object or environmental feature that may give the traveler who is visually impaired continuous information while traveling between two landmarks. Shorelines were divided into six categories: edges; fences, rails, or hedges; houses or walls; stairs; furniture; and others.

The participants were trained in 48 mobility routes: 17 indoor routes and 31 outdoor routes. The mean length of the routes was 180.3 meters (about 197 yards). The mean length of the indoor routes was 18.8 meters (about 62 feet), and the mean length of outdoor routes was 262.3 meters (about 287 yards). For all 48 routes, a total of 542 landmarks and 379 shorelines were recorded, with a mean of 11.5 and 7.7, respectively. The mean number of landmarks and shorelines was 8.7 and 6.6 for indoor routes and 12.1 and 7.6 for outdoor routes. The mean lengths of shorelines for indoor and outdoor routes were 2.1 meters (about 7 feet) and 34.2 meters (about 112 feet), respectively.

Types of travel

To investigate which types of travel were easier or more difficult to learn, we classified types of travel according to the level of skill required to negotiate travel environments. Generally, there are three types of skills: self-guiding (when the line of travel runs parallel to objects or sounds that are used for alignment), trailing distinct shorelines, and open-area travel (usually divided into crossing and free travel). We refer to them as self-guiding, trailing, and crossing.

MEASURES

Attention levels

Progress in learning on mobility routes was assessed by observing the participants' directed attention toward salient parts of the route and performance on the route. When the system for monitoring this progression was designed, *attention levels* were operationally defined in relation to how a participant's attention is directed by the instructor toward the landmarks and shorelines on the route. These levels were defined on an ordinal scale related to the help given to the participants, ranging from full guidance to self-sufficiency.

Attention levels were described on an 8-point Guttman scale. In this type of scale, levels are ordered so that a person who performs at a certain level also manages all previous levels. Attention levels may thus be considered a measure of learning progression, assuming that they correlate with different levels of competence in mobility. This system is shown in Table 1.

Attention levels were computed for all landmarks on the route using a form for recording behaviors related to this system. The scores were made according to how an O&M instructor helped a participant direct his or her attention toward landmarks and shorelines. The participant's attention level was always recorded in relation to the forthcoming landmark. Instruction related to the forthcoming landmark might be given at one landmark before travel toward the next landmark was initiated or after travel from that landmark toward the next landmark was initiated (that is, between landmarks).

Mental effort

Attention level, anticipatory responses, and type of travel to the forthcoming landmarks were recorded on each segment of the route. Two criteria for mastering the travel in question were applied. One related to anticipatory responses and one to attention levels 4 (L1) and 6 (L2). An earlier study found that the presence of a qualitative shift in mobility route learning-anticipatory responses to the forthcoming landmark was generally first observed at attention level 4, and that independence in travel, as operationally defined, corresponded to attention level 6 (Tellevik et al., 2000).

We measured mental effort in relation to landmarks and travel using two criteria: the relative number of trials and the number of anticipatory responses. To investigate mental effort, the number of trials to learning criterion L1, operationally defined as attention level 4, and learning criterion L2, operationally defined as attention level 6, were recorded. The relative number of trials was computed as trials to criterion X 100 divided by the total number of trials in the route.

We assumed that characteristics of landmarks like height and width may affect what is easy or more difficult to learn. To investigate which landmarks were easier or more difficult to learn, we compared the number of anticipatory responses to landmarks, defined in height as low (edges at ground level), medium (objects at hand level), and high (objects from hand level and above like walls and houses), and defined in width as narrow (like trees and poles), medium (like doors and gates), and wide (like walls and houses). We also conducted pairwise comparisons of which landmarks within each route were learned first or simultaneously across groups for height and width.

The major limitation of the study was the lack of interobserver agreement. No attempt was made to establish agreement among the instructors. Each O&M instructor applied his or her own interpretation to the operational definitions. The data represent the scores obtained by the participating instructors.

Results

ROUTE DATA

Table 2 shows that edges, doors, or gates were frequently used as landmarks both indoors and outdoors, doors being particularly frequent for indoor routes. For outdoor routes, edges or borders (such as curbs, borders between grass and gravel, tarmac and paving stone, and road edges) were frequently used as the next landmark, particularly for crossing streets. Walls and edges or borders were most frequently used as shorelines. In mobility-route training, such environmental distinctions are often applied as tactile-haptic shorelines.

The routes were traveled 17.9 times, on average, with a range of 2 to 132 trials. An independent samples *t*-test was conducted to evaluate the hypothesis that outdoor routes required more trials to a learning criterion, that is, independent travel ($M = 17.1$, $SD = 26.88$), than did indoor routes ($M = 14.7$, $SD = 15.10$). The test was not significant, $t(541) = 1.11$. An independent samples *t*-test was also conducted to evaluate the hypothesis that long routes, operationally defined as routes with more than 10 landmarks ($M = 18.7$, $SD = 29.22$), require more trials than do short routes, defined as routes with fewer than 10 landmarks, ($M = 12.9$, $SD = 11.23$). The test was significant, $t(541) = 2.80$, $p < .005$, indicating that shorter routes were easier to learn than were longer routes.

LANDMARKS AND MENTAL EFFORT

We assumed that mental effort would be affected by features of landmarks, depending on the participants' attention level. To investigate mental effort, we recorded the number of trials to learning criterion L1, operationally defined as attention level 4, and learning criterion L2, operationally defined as attention level 6. Pairwise comparisons of which landmarks within each route were learned first or simultaneously across groups for height and width were then conducted. The results are shown in Table 3.

A two-way contingency analysis was conducted to evaluate whether a learning criterion (L2) associated with independent travel would be more affected by features of landmarks. The two variables were the height and width of landmarks with pairwise comparisons on three levels (height: low versus medium, low versus high, and medium versus high; width: narrow versus medium, narrow versus wide, and medium versus wide) and learning level with two levels (L1 and L2).

Both height and width and learning level were found to be significantly related for all the comparisons, as follows:

Height: low versus medium (Pearson X^2 [2, N = 440] = 91.01, $p < .001$, Cramer's $V = .45$); the proportions of landmarks learned first or simultaneously were .36, .44, and .33, respectively., Height: low versus high (Pearson X^2 [2, N = 290] = 32.69, $p < .001$, Cramer's $V = .33$); the proportions of landmarks learned first or simultaneously were .11, .51, and .36, respectively., Height: medium versus high (Pearson X^2 [2, N = 500] = 89.03, $p < .001$, Cramer's $V = .42$); the proportions of landmarks learned first or simultaneously were .36, .91, and .29, respectively., Width: narrow versus medium (Pearson X^2 [2, N = 159] = 21.84, $p < .001$, Cramer's $V = .37$); the proportions of landmarks learned first or simultaneously were .50, .73, and .34, respectively., Width: narrow versus wide (Pearson X^2 [2, N = 554] = 129.17, $p < .001$, Cramer's $V = .37$); the proportions of landmarks learned first or simultaneously were .52, .32, and .34, respectively., Width: medium versus wide (Pearson X^2 [2, N = 518] = 44.52, $p < .001$, Cramer's $V = .29$); the proportions of landmarks learned first or simultaneously were .84, .17, and .38, respectively..

[Editor's note: For more information on categorical variables, please see the Research Sidebar that accompanies this article.]

The results indicate that what is easy or difficult to learn seems to depend on the participant's learning level. When attention level 4 (L1) was used as a learning criterion, neither height nor width seemed to have any particular relevance for learning. When attention level 6 (L2) was used, however, landmarks of medium width seemed easier to learn than those classified as narrow or wide. This finding may indicate that landmarks of medium width are more useful as a reference for navigation than are landmarks that are wider or narrower. A wide landmark, like a wall, may be less suitable as a reference point because it may be associated with a field. A narrow landmark may create another problem; it may be difficult to locate and hence may necessitate particular search strategies to find it. In any case, there is a risk that the landmark will lose its basic function as a reference point for navigation. Similarly, high landmarks seemed easier to learn than did low landmarks or those of medium height. It is likely that higher landmarks are easier to learn because they may function as auditory, visual, and tactile-haptic landmarks, while lower landmarks generally function as tactile-haptic landmarks. Thus, higher landmarks are more useful than are lower landmarks, particularly when travel becomes goal directed and more efficient.

Mental effort in travel

We assumed that the mental effort that is involved in travel may be investigated by recording anticipatory responses to landmarks and thus indirectly measuring the relative difficulty of the types of travel. The type of travel on each segment of a route was assigned to three basic categories--self-guiding, trailing, and crossing--according to the problem-solving strategy required to negotiate it. The type of travel and anticipatory responses to the forthcoming landmark in each lap were recorded. Table 4 shows how often landmarks were anticipated, depending on the kind of travel that preceded them.

The results in Table 4 indicate that self-guiding travel involves the least mental effort, whereas crossing involves the most mental effort. A chi-square test was conducted to assess whether the number of anticipatory responses was different across types of travel. The results of the test were significant, $X^2 (2, N = 297) = 6.10$, $p < .05$. The proportions of self-guiding, trailing, and crossing travel were .77, .51, and .42, respectively. Frequent anticipatory responses in self-guiding travel may not necessarily indicate that this type of travel is easier; rather, they may indicate that the kind of orientation behavior that is usually applied to this type of travel makes it easier to anticipate the landmark. In this type of travel, the student has few cues regarding how to move efficiently and safely and how long it takes to reach the next landmark. Attention is usually directed to the landmark by the instructor at the beginning of the segment, and it seems reasonable for the student to use protective techniques and to search for the landmark from the beginning.

To investigate mental effort for types of travel, we recorded trials to learning criterion L1 and learning criterion L2. Pairwise comparisons of the type of travel learned first or simultaneously within each route across groups (self-guiding versus trailing and crossing versus trailing) were then conducted. A comparison between self-guiding and crossing could not be conducted, however, because there were no observations on these types of travel within the same route. The results are shown in Table 5.

The results indicate that self-guiding seems to be mastered before trailing, at both levels that were studied. That self-guiding should be mastered first before trailing is in line with the results for anticipatory responses and types of travel. The differences between the two types of travel were, however, not statistically significant. The results also indicate that crossing was mastered earlier than trailing. A chi-square test was conducted to assess whether crossing is easier than trailing in L1 and L2. The results were significant for L1, $X^2(1, N = 217) = 18.29$, $p < .001$, and L2, $X^2(1, N = 222) = 5.83$, $p < .02$. These results are different from those shown in Table 4. They may reflect the fact that both instructors and students usually consider crossing to be more risky, particularly where there is traffic, than trailing. Thus, both the student and the instructor may pay more attention to crossing, which may have influenced the results.

Discussion

The study tried to assess the mental effort involved in relating to landmarks and mastering different types of travel. The assumptions on which it was based were that landmarks and routes that are easier to learn and mastery of the type of travel in question are attained earlier when less mental effort is involved. The results generally indicated that longer routes are more difficult to learn than are shorter routes and that outdoor routes are more difficult than indoor routes. Since both outdoor routes and longer routes usually contain more landmarks than do indoor routes and shorter routes, these results indicate that routes are more difficult to learn when the number of landmarks increases. Furthermore, on outdoor routes, more lower edges are generally used as landmarks and shorelines than on indoor routes. That higher landmarks are easier to learn than are lower ones may explain why indoor routes are easier to learn than are outdoor routes. It is likely that higher landmarks are easier to find because both auditory and tactile-haptic information may be available, whereas for lower landmarks, tactile-haptic information is more available. Landmarks that seemed easier to learn were those with some width that seemed easier to find. Compared to narrow landmarks, like poles and trees, wider landmarks usually do not require additional search strategies that demand mental effort to find them.

The question of which landmarks are easier or more difficult to learn is further dependent on the learning criteria that are used. The results showed no effect of the height and width of landmarks when a weaker learning criterion (L1) was used, while high landmarks and landmarks of medium width seemed easier to learn when a stronger learning criterion (L2) was used. The fact that high landmarks and landmarks of medium width were easier to negotiate when a stronger learning criterion was used indicates that such environmental features are particularly relevant for orientation and information processing when independent travel is established. Independent travel seems to be associated with the development of spatial representation when declarative knowledge related to the route is represented in a cognitive map. One indication of spatial understanding is the ability to take shortcuts in traveling a mobility route. As Tellevik et al. (2000) demonstrated, the appearance of shortcuts in the route generally correlated with independence in learning, operationally defined as attention level 6. It is likely that when landmarks are too wide or too narrow, they are not as easily represented as a reference point on a cognitive map as are those that are narrower. Independence in travel may also change the information-processing demands placed on participants. Cognitive economy in information processing may make other kinds of information, like auditory information, more available. High landmarks, which are easier to attend to with echolocation, may therefore be easier to negotiate when independence in travel is attained.

When the types of travel were compared, self-guiding travel seemed to involve less mental effort than did trailing and crossing when anticipatory responses to the forthcoming landmark were considered. With regard to the difference between crossing and trailing, the presence of anticipatory responses to the landmark point to trailing as the easier of the two types of travel.

Self-guiding travel also seemed easier than did trailing when the attainment of L1 and L2 were used as an indirect measure of the mental effort that is involved. A statistically significant difference favoring crossing compared to trailing as the easier of the two types of travel indicated that crossing is relatively easier to learn than is trailing. This result is contrary to the common understanding among O&M instructors. In O&M, it is commonly assumed that crossing is more difficult than trailing and that self-guiding travel is easier than the others. Crossing is considered relatively difficult because of the absence of a shoreline to relate to in travel. In contrast, self-guiding, in which shorelines are not actively used in travel, is considered easy because it is assumed that the student will find the landmark regardless of veering and dislocation when traveling the segment. It is likely that assumptions rely on the instructor naturally relating to the probability of success in finding the landmark, which is high for self-guidance compared to crossing and trailing. Comparing types of travel is generally an evaluation of the use of shorelines in mobility routes. Shorelines may be considered a tool to reach goals and subgoals (landmarks) on the route. The ability to use shorelines as a tool appears rather late in mobility-route learning, corresponding to the attainment of independent travel (Tellevik et al. 2000).

Generally, it seems that the assessment of the mental effort involved in different types of travel is a fruitful strategy for future research. It may be argued that the measures of mastery and mental effort were not sufficiently sensitive in the study partly because of the relatively low number of possible comparisons between the different types of travel. This approach may, however, give important information for planning, evaluation, and studies of O&M training.

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