

Multisensory Virtual Environment for Supporting Blind Persons' Acquisition of Spatial Cognitive Mapping – a Case Study

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Abstract: Mental mapping of spaces, and of the possible paths for navigating these spaces, is essential for the development of efficient orientation and mobility skills. Most of the information required for this mental mapping is visual information (Lynch, 1960). Blind people lack this crucial information, thus facing great difficulties (a) in generating efficient mental maps of spaces, and therefore (b) in navigating efficiently within these spaces. The work reported here is based on the assumption that the supply of appropriate spatial information through compensatory channels (conceptual and perceptual), may contribute to blind people's spatial performance. A multisensory (haptic, auditory) virtual environment simulating real-life spaces has been developed and tested. A description of the learning environment and results from a pilot study are presented.

Rationale

The ability to navigate space independently, safely and efficiently is a combined product of motor, sensory and cognitive skills. This ability has direct influence in the individuals' quality of life. Mental mapping of spaces, and of the possible paths for navigating through these spaces, is essential for the development of efficient orientation and mobility skills. Most of the information required for this mental mapping is visual information (Lynch, 1960). Blind people lack this crucial information, thus facing great difficulties (a) in generating efficient mental maps of spaces, and therefore (b) in navigating efficiently within these spaces. A result of this deficit in navigational capability is that many blind people become passive persons, depending on others for continuous aid (Foulke, 1971). More than 30% of the blind do not mobilize independently outdoors (Clark-Carter, Heyes & Howarth, 1986).

The work reported here is based on the assumption that the supply of appropriate spatial information through compensatory sensorial channels, as an alternative to the (impaired) visual channel, may contribute to the mental mapping of spaces and consequently, to blind people's spatial performance. Research on blind people's mobility in known and unknown spaces (Golledge, Klatzky & Loomis, 1996; Ungar, Blades & Spencer, 1996), indicates that support for the acquisition of spatial mapping and orientation skills should be supplied at two main levels: perceptual and conceptual levels.

At the perceptual level, the deficiency in the visual channel should be compensated with information perceived via other senses, e.g., touch and hearing. Haptic information appears to be essential for appropriate spatial performance. Haptics is defined in the Merriam-Webster dictionary as "of, or relating to the sense of touch". Fritz, Way & Barner (1996) define haptics as "tactile refers to the sense of touch, while the broader haptics encompasses touch as well as kinesthetic information, or a sense of position, motion and force." Haptic information is commonly supplied by the cane for low-resolution scanning of the immediate surroundings, by palms and fingers for fine recognition of objects' form, textures, and location, and by the legs regarding surface information. The auditory channel supplies complementary information about events, the presence of other people (or machines or animals) in the environment, materials which objects are made of, or estimates of distances within a space (Hill et al., 1993).

At the conceptual level, the focus is on appropriate strategies for an efficient mapping of the space and the generation of navigation paths. Research indicates two main scanning strategies used by people: route and map strategies. Route strategies are based in linear (therefore sequential) recognition of spatial features. Map strategies, considered to be more efficient than the former, are holistic in nature, comprising multiple perspectives of the target space (Fletcher, 1980; Kitchin & Jacobson, 1997). Research shows that blind people use mainly route strategies while recognizing and navigating new spaces (Fletcher, 1980).

The Proposed Study

Advanced computer technology offers new possibilities for supporting blind people's acquisition of orientation and mobility skills, by compensating the deficiencies of the impaired channel. Research on the implementation of haptic technologies within virtual navigation environments reports on its potential for initial training as well as for support and rehabilitation training with sighted people (Giess, Evers & Meinzer, 1998; Gorman, Lieser, Murray, Haluck & Krummel, 1998), as well as with blind people (Jansson, Fanger, Konig & Billberger, 1998; Colwell, Petrie & Kornbrot, 1998).

In light of these promising results, the main goals of this study are:

- The development of a multisensory virtual environment enabling blind people to learn about different (real life) spaces that they are required to navigate (e.g., school, work place, public buildings).
- A systematic study of blind people's construction of cognitive maps of real spaces by means of the virtual environment.
- A systematic study of the contribution of this mapping to blind people's spatial skills and performance in real environment.

The Virtual Environment

Developer/Teacher mode

The multisensory virtual environment simulating real-life spaces comprises two modes of operation: Developer/Teacher mode, and Learning mode.

The core component of the developer mode is the virtual environment editor. This module includes three tools: (a) 3D environment builder, (b) Force feedback output editor, (c) Audio feedback editor.

By the 3D-environment editor, the developer can define the environment characteristics: size and form of the room, and objects (e.g., doors, windows, walls, rectangle, cylinder). The Force-feedback output editor allows attaching Force-Feedback effects (FFE) to all objects in the environment. Examples of FFE are vibrations produced by ground textures (e.g., stones, parquet, grass etc), force fields surrounding objects, friction sensation. The audio feedback editor allows the attachment of appropriate audio units to the objects, e.g., "first window", "turn right".

Figure 1 shows the environment-building editor screen, by which the researcher/teacher can build new navigation environments, according to the users' needs in progressive levels of complexity.

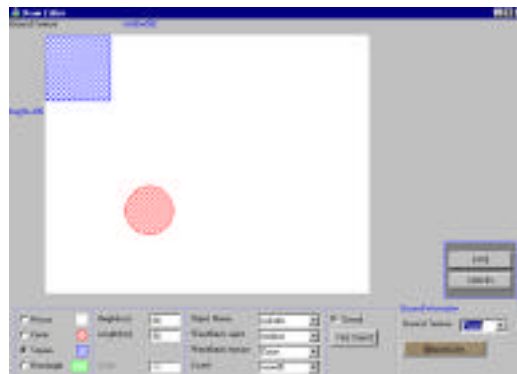


Figure 1: 3D environment builder

Learning mode

The learning mode includes two interfaces: User interface and Teacher interface.

The user interface consists of a virtual environment that simulates real rooms and objects. The subject navigates this environment using the Microsoft Force Feedback Joystick (FFJ). The feedback received while navigating the room includes sensations such as friction, objects' force fields and vibrations. By using the FFJ the subject can get foot-level information, equivalent to that she/he gets by his feet as he walks in the real space. In addition auditory information is generated by a "guiding computer agent", aiming to provide appropriate references whenever the subject gets lost in the virtual space. Figure 2 shows the user-interface screen.

The teacher interface integrates series of features serving teachers during and after the learning session. Several monitors on the screen present updated information on the subject's navigation, e.g., position, objects reached. An additional function allows the teacher to record the subject's navigation path, and replay it to analyze and evaluate her/his performance (Figure 3).

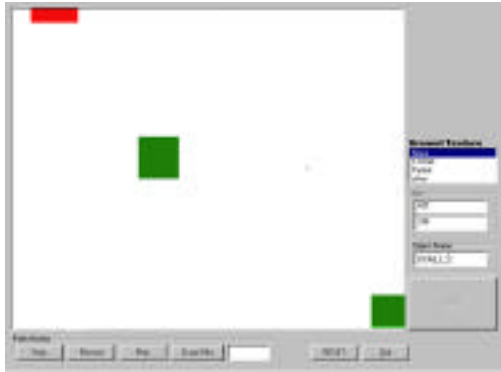


Figure 2: The user interface



Figure 3: The teacher interface

The Case Study: A blind subject's performance within the Force Feedback Virtual Environment and in the real environment

The pilot case study aimed to analyze a subject's performance regarding five main aspects:

- (a) Technical issues in using the virtual environment (e.g., use of FFJ, response to FFE).
- (b) Ability to identify the virtual environment's components (e.g., identification of objects, recognition of spatial features).
- (c) Navigation and mobility within the virtual environment.
- (d) Construction of a cognitive map of the simulated room.
- (e) Performance in the real environment.

Method

Subject

G., is a twenty-five years old, a late blind (G. became blind at the age of twenty). He is a computer user for more than three years, using voice output.

Procedure

The study consisted of three stages: familiarization with the virtual environment, navigation in the virtual environment, and navigation in the real environment.

At the beginning of the familiarization with the virtual environment stage the subject received a short explanation about its features and how to operate the FFJ. A series of tasks were included regarding: (a) FFE and audio feedback; (b) mobility within the virtual environment (at varied levels of complexity). Data on the

subject's performance was collected by direct observation, and by video recording. This first stage lasted about three hours.

The navigation in the virtual environment stage included three tasks: (a) exploration and recognition of the virtual environment; (b) a target-object task (e.g., walk from the starting point to the blackboard in the room); (c) a perspective-taking task (e.g., walk from the cube -in a room's corner- to the rightmost door -the usual starting point). Following the exploration task the subject was asked to give a verbal description of the environment, and to construct a scale model of it (selecting appropriate components from a large set of alternative objects and models of rooms).

Several data-collection instruments served this stage: a computer log recording mechanism, which stored the subject's movements within the environment; video recording; recording of the subject's verbal descriptions; the physical model built by the subject. The second stage lasted about three hours.

The navigation in the real environment stage included again two tasks: (a) a target-object task (e.g., reach and identify an object on the rectangular box); (b) a perspective-taking task (e.g., walk from the rightmost door to the cylinder). Data on the subject's performance was collected by video recording and direct observation. The third stage lasted about half an hour.

Results

Familiarization with the virtual environment components

G. Learned to work freely with the force feedback joystick within a short period of time, walking directly and decisively towards the objects. Regarding mobility, G. could identify when he bumped into an object, or arrived to one of the room's corners. From the first tasks G. could walk around the object's corner and to walk a long the walls, that by using the FFE and the audio feedback.

Navigation within the virtual room

Exploration task

G. navigated the environment in rapid and secure movement (Figure 4). He first explored the room's perimeter, walking along the walls. After two circuits he returned to the starting point, and began to explore the objects located in the room. Figure 4 shows the intricate walk paths in the exploration task. The exploration session lasted about 43 minutes.



Figure 4: Subject's navigation in the virtual environment

Target-object task

To get to the required object G. navigated the environment applying the object-to-object strategy. From the door (the starting point) G. walked to the cube and from the cube to the target - the blackboard (Figure 5). G.

reached rapidly the target -in 20 seconds- by choosing a direct way.

Perspective-taking task

Here once again G. applied the object to object strategy (Figure 6): he went from the cube (the starting point in this task) to the box, and then to the target, the door (which was the starting point in the previous tasks). G. choose a direct way, and completed the target in 52 seconds.

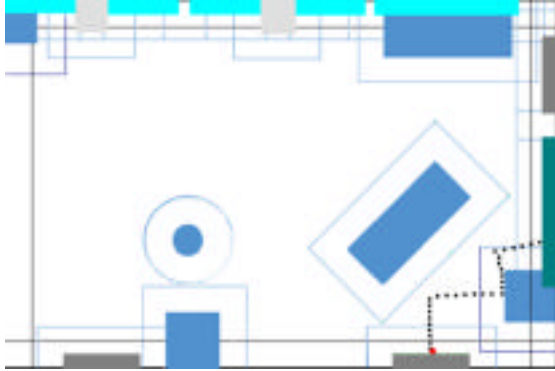


Figure 5: Target-object task

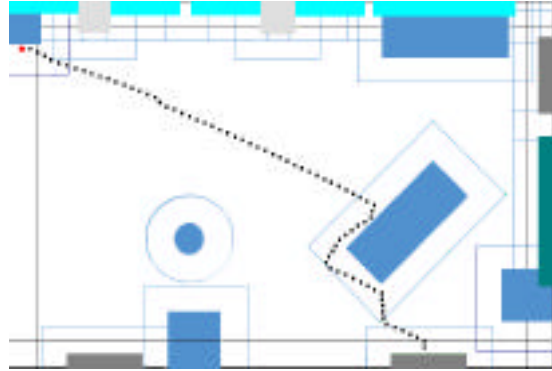


Figure 6: Perspective-taking task

Cognitive map construction

After completing the virtual environment exploration task G. was asked to construct a model of the environment. As shown in the picture of the model composed by G. (Figure 7), the subject acquired a highly accurate map of the simulated environment. All salient features of the room are correct (form, number of doors, windows and columns), as well as the relative form and size of the objects and their location in the room.



Figure 7: Subject's model of the virtual environment

Navigation in the real environment

The subject walked through the real environment from his very first time in it in a secure and decisive behavior. At the first task (reaching a target object: the leftmost box), G. Used the entrance door as initial reference, and walked along the walls in direct way to the box. He complete the task in 32 seconds. At the second's task (perspective-taking), G. applied the object to object strategy, and completed successfully the task in 49 seconds.

Discussion

The case study reported in this paper is part of a research effort aimed to unveil if and how the work with an haptic virtual environment supports blind people's construction of spatial cognitive maps and their navigation in real environments.

The case study results are encouraging. The subject, G., mastered in a short time the ability to navigate the virtual environment. He developed a fairly precise map of the simulated environment, and the completeness and spatial accuracy of this map became evident in two revealing situations. The first was the physical model built by G. after navigating the virtual room - the simulation of a space he did not know. The second was his impressive performance in the real environment. He entered the real room which he had not known until then, and which he was not given the opportunity to explore, and completed efficiently and in a very short time the different navigation tasks.

Based on these and other preliminary results, a systematic empirical study (involving 30 subjects) of the effects of the haptic environment on blind people's navigation abilities is currently being conducted. The results have potential implications at varied levels, for supporting: blind people's acquaintance with new environments; their acquisition process of spatial knowledge and skills; their learning of concepts and subjects for which spatial information is crucial.

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