CyberPsychology & Behavior
Volume 9, Number 2, 2006

Using Virtual Environment to Improve Spatial Perception by People Who Are Blind

ORLY LAHAV, Ph.D.

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. Visual ability is a crucial component to effective mental mapping. People who are blind consequently find it difficult to generate useful mental maps of spaces and navigate competently within them. The research studies reported in this paper assume that the supply of appropriate spatial information through compensatory sensorial channels as an alternative to the visual channel may contribute to the anticipatory mental mapping of unknown spaces and consequently may improve spatial performance for people who are blind.

INTRODUCTION

Walking and discovering new environments are activities that combine motor, sensory, and cognitive skills. Mental mapping of spaces and of the possible paths for navigating these environments is gathered through the visual channel.[1] People who are blind lack this information, and consequently they are required to use compensatory sensorial channels and alternative exploration methods.[2] The ability to navigate in unknown environments independently, safely, and efficiently directly affects an individual's quality of life, role, and integration in a community and increases their self-confidence. Because of these benefits, one of the main tasks in a rehabilitation program for people who are blind is teaching Orientation and Mobility (O&M) skills. The studies reported herein is based on the assumption that the supply of appropriate spatial information through compensatory sensorial channels as an alternative to the visual channel along with conceptual support may help people who are blind explore unknown environments. The exploration and learning of a new environment by people who are blind is a long process and requires the use of special information-technology devices, passive and active aids. Passive aids provide the user with information before his/her arrival to the environment. Examples of these include verbal descriptions, tactile maps, and physical models. Active aids provide the user with information in-situ, for example, Sonicguide[3]; Kaspa[4]; Talking Signs, embedded sensors in the environment[5]; and Personal Guidance System (PGS), which is based on satellite communication.[6] Research results on passive and active aids indicate a number of limitations that include erroneous distance estimation, underestimation of component size, low information density, or symbolic representation misunderstanding.

Virtual reality has been a popular paradigm in simulation-based training, game, and entertainment industries. It has also been used for rehabilitation and learning environments for people with sensory, physical, mental, and learning disabilities.[7] Recent technological advances, particularly in haptic interface technology, enable individuals who are blind to expand their knowledge by using an artificially made reality that is built on haptic and audio feedback. Research on the implementa-

The Touch Lab, RLE, MIT, Cambridge, Massachusetts.

tion of haptic technologies within virtual environments (VE) has reported the potential of supporting the development of cognitive models by people who are blind.[8–11]

The study reported in this paper is part of continuing research that assumes that the supply of compensatory perceptual and conceptual information via technology may contribute to improved spatial cognitive mapping by people who are blind. This study was based on a previous study that focused on the contribution of a VE haptic environment (Fig. 1) to the construction of spatial cognitive maps and the use of them during performances in real space (Fig. 2). A detailed presentation of the VE and the findings of this study can be found in Lahav and Mioduser.[8,12] The study upon which this paper is based took place 16 months after the first study and explored the participants' long-term spatial memory based on the cognitive persistence of the constructed map.

The results of the former study led to our main research questions for this study:

a. What structural components and relationships were included in the participants' cognitive map after a long term of being unexposed to the target environment?
b. How did the constructed cognitive map contribute to the blind person's orientation in the real space after a long term of being unexposed to the target environment?

METHODS

Participants

This study consisted of four adults selected from the first study's experimental group. The participants were selected because of their successful performance on the two real-space orientation tasks in the first study. The group consisted of two women and two men, one congenitally blind and three late blind, with an age of 26–58 years old.

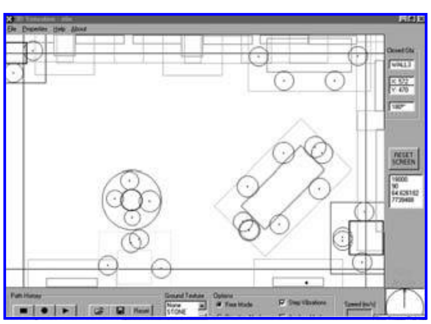

FIG. 1. User-interface screen.

FIG. 2. Real space.

Research instruments

This study's five main instruments were identical to those in the former study. The target space included a real physical space and components, a 54-m^2 room with three doors, six windows, and two columns (Fig. 2). There were seven objects in the room, five of them attached to the walls and two placed in the inner space. Each participant was asked to perform two orientation tasks in the real space. In the target-object task, the participant was asked to find an object in the space; in the perspective-taking task, the participant entered the room from a different entrance and was asked to find an object. The participants' task performances were observed and video-recorded. An open interview was used for collecting the participants' verbal spatial descriptions, which were video-recorded and transcribed. The last research tool included evaluation and coding schemes to analyze the participants' O&M skills and acquaintance with the space.

Procedure

All participants worked and were observed individually. The study was carried out in two stages. In the first stage, the participants were asked to give a verbal description of the environment as they remembered it. In the second stage, the participants were asked to perform two orientation tasks in the real target space that were identical to those in the first study—a target-object task and a perspective-taking task. For both tasks, all participants' performances were video-recorded.

RESULTS

Question 1: What structural components and relationships were included in the participants' cognitive map after a long term of being unexposed to the target environment?

The participants were not allowed to walk in or explore the room before being assigned the orientation tasks. Their verbal description was given as they were standing inside the target room at the entrance door. Before they entered the room, the participants continually repeatedly said that they did not remember the environment and its components. Nevertheless, as they were standing at the entrance just inside the room and they started to describe the room's structure and components, all four participants included most of the components and their locations. Their marks for verbal description were similar to the average of the participants in the experimental group in the first study. However, none of the participants included object sizes or object positions. Also, all four participants described the space simply as a list of items, whereas, in the first study they used richer verbal descriptions.

Question 2: How did the constructed cognitive map contribute to the blind person's orientation in the real space after a long term of being unexposed to the target environment?

After giving the verbal description, the participants were asked to perform two orientation tasks in the real space. It should be recalled that the participants had not had the ability to enter and re-explore the real space during the previous 16 months. Five variables were examined—successful completion of the tasks; use of direct paths to the target location; time spent on each task; number and duration of pauses; and total length of the path. Two participants successfully performed both orientation tasks, the third participant performed only the perspective-taking task successfully, and the fourth participant did not succeed in the target-object task and during this task she found the target in the perspective-taking task. As a result, the researchers did not ask her to perform the second task. In seven task performances, the participants used direct path to the target location in three performances; they used indirect path in two other tasks; and two times they searched for the target. Comparison of the participant's results in the two studies showed that in the second study the participants spent more or less the same time, walked the same length of the path, and used less pauses.

CONCLUSION

This study focused on the participants' ability to recall and perform orientation tasks using long-term memory. Similar to the results of other studies,[13] spatial memory about the target environment started to be visible and accessible after entrance to the room. Although the participants could not see or touch objects or old landmarks, physically entering the room influenced and contributed to their recall. Their cognitive map descriptions focused on functional structure. In their verbal descriptions, they used an item-list strategy to describe the spatial components and their locations in the space. This type of strategy allows the participants to navigate in the real space and avoid obstacles. During their performance the participants appeared assertive and secure walking in the room. The participants reported they felt they knew the room although they had spent less than ten minutes in it 16 months before and had not had the ability to explore it subsequently. Their later performances were based on their earlier exploration using the VE. This ability to recall long-term spatial memory and to navigate by using it expands the ability of people who are blind to use VE orientation tools similar to the research apparatus.

This study's implications are particularly important for future research and practical implementation. For future research, examples of additional variables to be considered include a comprehensive look at the required exploration time within the VE and the mapping process of orientation tools of different resolution and granularity levels of spatial information and their contribution to performance. As for implementation, as haptic devices are rapidly becoming affordable for individual use, this study's insights might be applied for different purposes. One possible application is the development of models for diverse spaces that will enable pre- and post-actual visit exploration and mapping of unknown spaces by people who are blind, just like sighted people use map systems. A different application would be the development of haptic-based tools for supporting learning processes in K-12 academic curriculum subjects.

REFERENCES

1. Lynch, K. (1960). *The image of the city*. Cambridge, MA: MIT Press.
2. Jacobson, W.H. (1993). *The art and science of teaching orientation and mobility to persons with visual impairments*. New York: American Foundation for the Blind.

3. Warren, D.H., & Strelow, E.R. (1985). *Electronic spatial sensing for the blind*. Boston: Martinus Nijhoff.
4. Easton, R.D., & Bentzen, B.L. (1999). The effect of extended acoustic training on spatial updating in adults who are congenitally blind. *JVIB* 93:405–415.
5. Crandall, W., Bentzen, B.L., Myers, L., et al. (1995). *Transit accessibility improvement through talking signs remote infrared signage, a demonstration and evaluation*. San Francisco: The Smith-Kettlewell Eye Research Institute, Rehabilitation Engineering Research Center.
6. Golledge, R., Klatzky, R., & Loomis, J. (1996). Cognitive mapping and wayfinding by adults without vision. In: Portugali, J. (ed.), *The construction of cognitive maps.* The Netherlands: Kluwer, pp. 215–246.
7. Schultheis, M.T., & Rizzo, A.A. (2001). The application of virtual reality technology for rehabilitation. *Rehabilitation Psychology* 46:296–311.
8. Lahav, O., & Mioduser, D. (2000). Multi-sensory virtual environment for supporting blind persons' acquisition of spatial cognitive mapping, O&M skills. Presented at the 3rd ICDVART, Alghero, Sardinia, Italy.
9. Sanchez, J., & Lumbreras, M. (1999). Virtual environment interaction through 3D audio by blind children. *Journal of CyberPsychology & Behavior* 2:101–111.
10. Semwal, S.K., & Evans-Kamp, D.L. (2000). Virtual environments for visually impaired. Presented at the 2nd International Conference on Virtual Worlds, Paris.
11. Sjotrom, C., & Rassmus-Grohn, K. (1999). The sense of touch provides new computer interaction techniques for disabled people. *Technology & Disability* 10:45–52.
12. Lahav, O., & Mioduser, D. (2004). Exploration of unknown spaces by people who are blind, using a multisensory virtual environment. *Journal of Special Education Technology* 19:15–23.
13. Gibson, J.J. (1979). *The ecological approach to visual perception.* Boston: Houghton-Mifflin.

Address reprint requests to:
Dr. Orly Lahav
The Touch Lab, RLE
MIT
77 Massachusetts Ave.
Cambridge, MA 02139-4307

E-mail: lahavo@mit.edu