Virtual Reality Rehabilitation of Spatial Abilities after Brain Damage

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Abstract. Current rehabilitation of navigation and spatial orientation ability after brain damage is generally focused on training within the rehabilitation hospital or the patient's home as part of common physio- and occupational therapy sessions. To further promote generalization of gained abilities and to quantify functional improvements, this project aims at developing a virtual reality (VR) application that can be used for training and assessment of spatial orientation and navigation skills in brain-damaged patients. The training is administered after the standard hospital rehabilitation training is completed. Additionally, the program will be used as an assessment tool to quantify the participants' wayfinding performance. The data will be compared with real-world navigation performance in tasks of similar complexity to evaluate real-world transfer of the VR training. Currently, the application is under development and basic functionality and data acquisition are being implemented.

Keywords: Virtual Reality, Neuropsychological Rehabilitation, Navigation

1. Introduction

Cognitive processes that contribute to navigation and spatial cognition are widely distributed in the human brain. Consequently, deficits in wayfinding ability are common after brain damage [1]. Nevertheless, after the initial neuropsychological assessment at the rehabilitation hospital, no explicit training of navigational skills is currently in use. Navigation practice and assessment are integrated into occupational- or physiotherapy sessions. Quantification of progress in navigation ability is based on patient observation. This approach is very time-consuming, makes it difficult to assess parameters like goal-distance, redundant routes or orientation behaviour (e.g. head-movement), and generalization of regained abilities across different locations is limited. To overcome these limitations, accurately measure patient progress throughout the training across several contexts, and to provide a dedicated training-tool for wayfinding ability, a VR training application is proposed.

2. Methods

The proposed study is planned as a multiple baseline single-case design with up to 10 patients. For each patient an AB-design with additional follow-up testing will be employed after the standard rehabilitation of the health care provider is finished. Multiple baseline design refers to the concurrent testing of patients where each patient starts the experimental training at a different point in time while all other patients continue with their current testing procedure (baseline or experimental treatment).

The patients will be recruited from two local rehabilitation hospitals. Recruitment is based on patient performance during the neuropsychological assessment at the respective hospital and referral by the treating health-care professional. Standardized measures of general spatial ability (e.g. Mental Rotations Test, Surface Development Test [2]) and wayfinding ability (e.g. Object Perspective Taking Test [3]) together with a real-world navigation task and a comparable VR navigation task are used for assessment throughout the experimental sessions. A full list of all outcome measures can be found in table 1. Primary outcome measures test navigation ability while secondary outcome measures assess generalization towards spatial abilities in general.

The VR training is more complex than the virtual navigation task used for assessment and consists of several walkthrough scenes of houses and environments with increasing complexity. Participants have to make themselves familiar with the scenes to find several target locations and point to unseen objects (adopted from [4]). All user performance is recorded and analyzed in regard to navigation errors, timing and orientation behaviour. As the training progresses, the environmental context changes slowly and the difficulty of the scene increases to promote generalization of gained abilities. Higher difficulty is established by more demanding tasks and naturalistic features like detours, locked doors or poor lighting conditions. Rehabilitation principles like cueing, direct feedback and reinforcement of behaviour are also integrated into the application.

The training is created using Quest 3D[1] and projected on a 120° stereoscopic three-screen-setup[2]. For increased usability and data acquisition, user-movement will be tracked using an A.R.T. tracker[3]. Furthermore, a space traveler mouse[4] is planned as input device. This setup warrants high immersion and intuitive user interaction, thus providing a realistic training experience that is comparable to a real-life scenario.

Table 1. Order of experimental phases (left to right) and tests for each individual patient.

	Standard Rehabili-tation Service	**Pre-Treatment Assessment**	**Virtual Reality Trai-ning**	**Post-Treatment/Follow-Up Assessment**
Primary Outcome Measures		- Money Road-Map Test [5] - Zoo Test [6] - Object Perspective Taking Test [3] - Virtual Reality Navigation Task - Real-World Navigation Task - Santa Barbara Sense of Direction Scale [7]		Identical to Pre-Treatment
Secondary Outcome Measures		- Mental Rotation Task [2] - Card Rotation Task [2] - Surface Development Task [2]		Identical to Pre-Treatment

[1] Quest 3D VR Edition; version 4.2.3.; www.quest3d.com

[2] VisionSpace; HIT Lab New Zealand; www.hitlabnz.org

[3] www.ar-tracking.de

[4] www.3dconnexion.com

3. Results and Conclusions

At the moment, the VR application is under development. The program currently consists of few stereoscopic 3D environments that feature recording and playback of all user-movement (Figure 1). These recordings are used to quantify the user's navigation ability and visualize performance for wayfinding or pointing tasks. More scenes, difficulty settings for each environment and verbal and visual instructions for therapists and patients are being added at the moment. A space traveler mouse is implemented for navigation within the 3D-world. Other input devices are also evaluated to guarantee simple and intuitive user interaction that is suitable for patients with no or little computer experience who recently suffered from stroke or traumatic brain injuries. First data will be collected as soon as the first patients are finished with the standard rehabilitation service of their health care provider and enough environments and difficulty settings are implemented to occupy several training sessions.

Compared to the standard training, the VR application provides more possibilities to manipulate the complexity of the training environment, thus it is expected that the patients will show further improvement and generalization in wayfinding ability beyond the effects of the standard rehabilitation. It is also predicted that the virtual navigation task is a suitable assessment tool for wayfinding ability and provides similar results to the assessment with a comparable real-world navigation task.

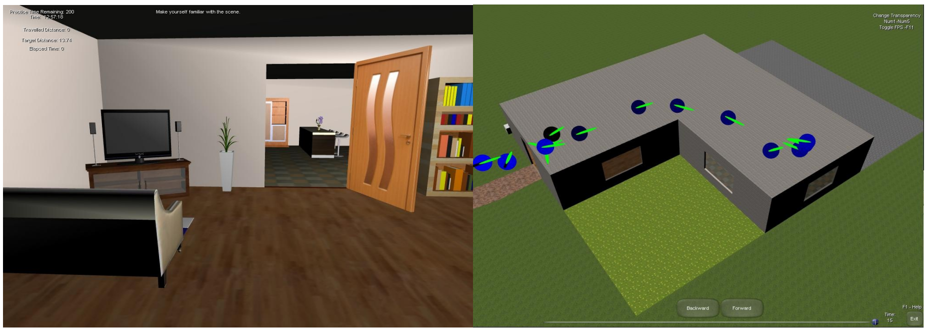

Figure 1. Training scene (left) and data visualization/playback (right).

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