

Learning from Rehabilitation: a Bi-manual Interface Approach

S. Hoermann

Departments of Medicine (DSM)
and Information Science

J. Collins

Department of Information
Science

H. Regenbrecht, *MIEEE*

Department of Information
Science

University of Otago, Dunedin, New Zealand

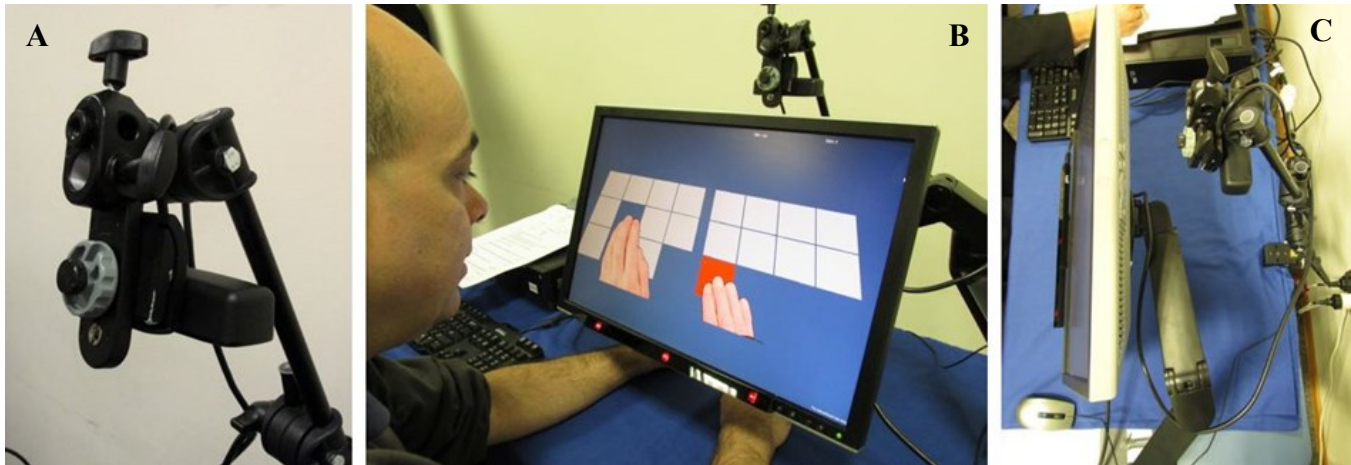


Figure 1: The user plays a virtual memory game where he tries to find matching pairs of 3D models on the left and the right side of the virtual board; he interacts by pointing with his hands at the tiles on each side; his hands are hidden from his direct view but video-captured by a camera and integrated into the virtual environment; an eye tracker is mounted on the lower part of the monitor's frame

ABSTRACT

Providing portable and affordable virtual reality systems for upper limb stroke rehabilitation is still a challenge.

Here we present a simple user interface that allows the integration of various upper limb stroke exercises that can be autonomously performed by patients without the presence of a therapist, yet is portable and assembled using affordable off-the-shelf hardware components. In particular, the system integrates a bi-manual memory game where the user has to engage in meaningful therapeutic reaching exercises.

We evaluated the user interface with a wide range of normal subjects and found that participants perceived the system as easy to use, they had no problems with the interaction and had an overall enjoyable experience with the system.

This opens up possibilities of combining therapeutic reaching movements with goal-directed tasks to improve motivation and to enhance and increase rehabilitation outcomes for post-stroke patients. Beyond therapeutic use, our approach can also be applied to other 3D user interfaces for bi-manual interaction.

Keywords: Stroke, Therapy, Augmented Reality, Visual Illusion

Index Terms: J.3 [Computer Applications]: Life and Medical Sciences—Health; H.5.2 [Information Interfaces and Presentation]: User Interfaces—User-centered design, Graphical User Interfaces (GUI), Evaluation/Methodology

* {simon.hoermann, jonny.collins, holger.regenbrecht}@otago.ac.nz

1 INTRODUCTION

Engaging patients in therapeutic exercises during early and later stages post-stroke has been shown to benefit and improve functional outcomes. To support this, various technological approaches have been proposed. Virtual reality (VR) systems have been shown to be useful for stroke rehabilitation and their effectivity in improving function has been evaluated in a recent meta-review by Laver et al. [1].

Although there is no empirical evidence on which form of virtual reality system and limb movement representation is most efficacious, visualizations closer to reality seem to have some advantages. For example in a study by Dukes et al., participants had difficulty with the virtual arm representation of their, with Microsoft Kinect sensor tracked, real movement. They reported “that it was difficult for stroke survivors to realize that their physical movements controlled the virtual arm” [2, p. 50].

In this paper we propose an augmented reality system where users can see and interact with their computer mediated real hands. This visualization has been shown to enable users to take ownership of the represented hands [3], [4]. We developed a system and therapeutic exercise, based on a concept previously shown to be feasible for post-stroke therapeutic use in a clinical setting [5]. While in the previous research patients performed exercises guided by a therapist in collaboration with an operator on a stationary installed system with custom built hardware, here we present a system strictly made using off-the-shelf hardware and focus our evaluation on the user experience with the 3D interface.

2 SYSTEM

2.1 Hardware

A 22 inch screen (Dell 2208WFP) is mounted in front of the user with a monitor arm (see Fig. 1C). This allows the users to put

their hands underneath while blocking their direct line of sight. A camera (Senz3D, Creative) is mounted behind the screen positioned perpendicular to the users' hands (see Fig. 1A). The camera is attached to a standard camera stand fixed with a universal mount on the table (both Manfrotto). An eye tracker (Tobii Eyex) is placed on the bottom part of the monitor frame. The computer is a Dell Optiplex 9020. A blue cloth on the table is used to enhance background subtraction.

2.2 Software

Unity3D (v4.5.3) was used as the 3D-engine, with the Tobii Eye Experience SDK (v0.8.17.1196 alpha) and the related Unity plugin (v0.23.325 alpha) on Windows 7 Enterprise 64bit SP1. The eye tracker software was configured to track both eyes and set to "GazePointDataMode.LightlyFiltered" within the code.

A customized plugin was developed using the Intel Perceptual SDK (v1.8.13842) to interface with the camera and OpenCV (v2.4.9) for further image manipulations. The system performs with 13 fps and a noticeable end-to-end latency of about 150ms.

2.3 Therapeutic Exercise

The user interacts with the virtual memory game using hand-movements only (Fig. 1B). Two virtual boards with 12 (4×3) virtual tiles (i.e. memory cards) each are part of the virtual environment. Tiles, coloured in grey, are displayed upside down.

By moving their hand(s) over the tiles, users activate a colour change from grey to red. When the user places a hand over an individual tile and pauses there for one second, the tile flips over to reveal the content assigned to it. Moving the hand away returns the tile to its inactive (grey) state. Twelve different 3D models of food items were randomly assigned to the tiles at each side.

The user plays the game with the goal of finding matching pairs of food items on the left and the right board. The game finishes when all 12 matching pairs are found. The number of attempts made to find matching pairs, and the elapsed game time are recorded and displayed on screen throughout the session.

2.4 Hand Tracking Algorithm

The hand tracking algorithm that allows interaction with the system works in two stages. First the blue cloth background on the table is subtracted from the image; this results in an image with only the pixels of the hand remaining. From this image the tile at which the user is pointing is determined.

3 USER STUDY

Participants

Data from 53 (54 for eye-tracking) consenting participants (31 male, 22 female, mean age 38) was collected at a booth during a local science exhibition for the general public.

Game performance

The mean game completion time was 123sec ($SD = 30$ sec) with all participants completing the game in less than four minutes. The average number of tries was 40 ($SD = 8$).

Overall user experience

The overall ratings for the user experience were good with most ratings for the individual categories clearly above midpoint and 79% of users stating that they enjoyed the system and had fun.

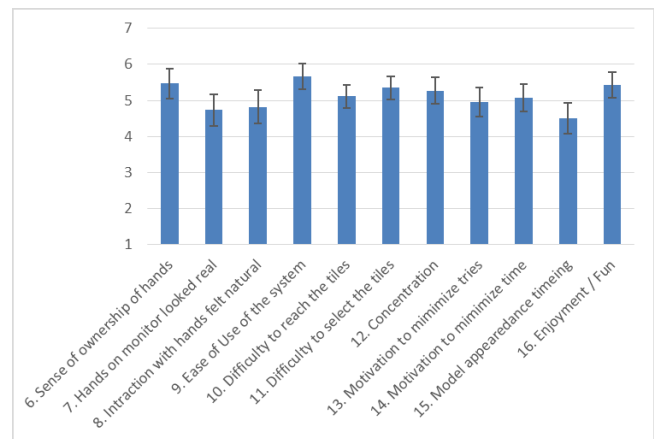


Figure 2: Results of user experience questionnaire from 1 – 7; with "1" the lowest and "7" the highest

Eye Tracking

The eye tracker provided face-valid results for all but 2 users. On average, 85% of the time data was returned. For 41 users, face-valid gaze data was obtained at least 75% of the time. The users' gaze was mostly on the area of the two game boards with a tendency to the upper right quarter.

4 DISCUSSION & CONCLUSION

The data showed that overall the system is feasible for further studies with actual patients with motor impairments after a stroke. Users did not have problems with the system, considered themselves motivated, actively tried to excel in the game and enjoyed it.

The placement of the camera and the resulting view angle of the hands should be considered in future systems as well as a reduction of the latency of the system, as a few participants did not feel that the hands on the screen looked real to them.

The integration of an eye tracker provided mixed results and has to be improved (e.g. placement, calibration and SDK) before meaningful and reliable use can be expected with this system.

5 ACKNOWLEDGEMENT

The authors thank Patrick Ruprecht, Dr. Carl Leichter and Umair Mateen for their support with the development of the system.

6 REFERENCES

- [1] K. E. Laver, S. George, S. Thomas, J. E. Deutsch, and M. Crotty, "Virtual reality for stroke rehabilitation," *Cochrane Database Syst. Rev.*, no. 9, p. Art. No.: CD008349, 07 2011.
- [2] P. S. Dukes, A. Hayes, L. F. Hodges, and M. Woodbury, "Punching ducks for post-stroke neurorehabilitation: System design and initial exploratory feasibility study," in *IEEE Symposium on 3D User Interfaces (3DUI)*, 2013, pp. 47–54.
- [3] S. Hoermann, E. A. Franz, and H. Regenbrecht, "Referred Sensations Elicited by Video-Mediated Mirroring of Hands," *PLoS ONE*, vol. 7, no. 12, p. e50942, Dec. 2012.
- [4] H. Regenbrecht, S. Hoermann, C. Ott, L. Muller, and E. Franz, "Manipulating the Experience of Reality for Rehabilitation Applications," *Proc. IEEE*, vol. 102, no. 2, pp. 170–184, Feb. 2014.
- [5] S. Hoermann, L. Hale, S. J. Winsler, and H. Regenbrecht, "Augmented reflection technology for stroke rehabilitation – a clinical feasibility study," in *Proceedings 9th International Conference on Disability, Virtual Reality & Associated Technologies*, Laval, France, 2012, pp. 317–322.