Augmented Reflection Technology for Stroke Rehabilitation – A clinical feasibility study

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ABSTRACT

This paper presents a clinical feasibility study of a novel Augmented Reflection Technology system, called TheraMem. The feasibility of the system for physical rehabilitation of the upper limb and the potential to improve motor impairments following stroke were evaluated. Five patients participated in a total of 20 sessions of upper limb training with the system. Tailored support for patients performing the exercises was provided based on the severity and level of their impairment. Various configurations of the system were evaluated and adjusted to best match the patient's preferences as well as the therapeutic requirements. We found that all patients were able to successfully participate and complete the TheraMem intervention. Patients' engagement and motivation was high over the course of the therapy sessions.

Keywords: Computer Mediated Visual Feedback, Augmented Reality, TheraMem

1   INTRODUCTION

The use of virtual reality and other forms of computer mediated visual feedback can be beneficial for patients in the therapy of motor impairments after stroke, for the improvements of arm function as well as in activities of daily living. (Laver, George, Thomas, Deutsch, & Crotty, 2011)

Our research group has used computer mediated visual feedback, Augmented Reflection Technology (ART), to fool users about the properties and capabilities of their hands. Users place their hands in two black boxes where webcams video-capture the hands and transmit the video-streams to a computer. These video-streams are then manipulated and displayed on a screen on top of the boxes. (Regenbrecht, Franz, McGregor, Dixon, & Hoermann, 2011) In Figure 1 a sketch of the system is shown as it would be experienced by the patient; the additional screen for the operator or therapist is omitted in this sketch.
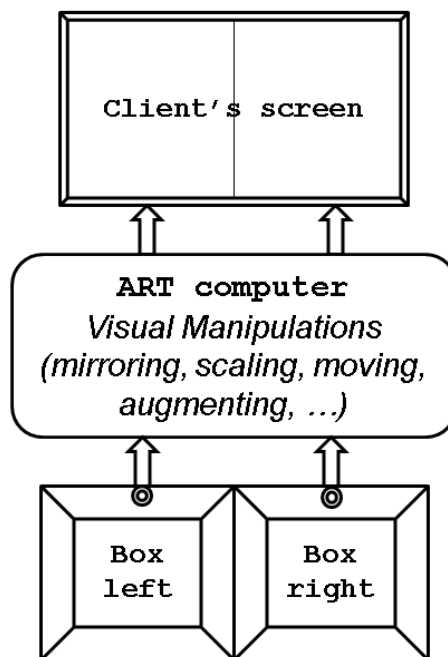
Figure 1. A sketch of the ART System used for TheraMem

Various visual manipulations are possible with ART. The fooling of healthy participants into believing their right hand displayed on the left side of the screen is their left hand was extensively evaluated (Regenbrecht, Franz, et al., 2011). The augmentation with virtual backgrounds or the 3D models in the ART system are also possible. Yet another manipulation possibility is the spatial manipulation of the displayed hand by the therapist or operator, which allows change in the position of the user's hand vertically or horizontally in addition to the user's own movement (Regenbrecht et al., in press).

TheraMem can be described as an augmented reality memory-game. Users move their hand on the floor of the black boxes but experience the video-output on the screen as a three-dimensional environment with 12 tiles on each side of the screen; they try to find matching pairs of plants for the left and the right side by turning these virtual tiles (see Figure 2). The movement of the hand is tracked using a finger-tracking extension specifically added to ART; it determines the position of the hands and flips only the tiles at which the user is pointing at. In addition, TheraMem contains a feature that allows the therapist or operator to amplify the movement of the hand by displaying larger movements on the screen than the user actually performed in the box. The details of this manipulation, the technological background of TheraMem, as well as a detailed study with healthy participants is presented in Regenbrecht, McGregor, et al. (2011).

In this study we use the TheraMem system with individuals with stroke to evaluate two capabilities of ART: (1) the augmentation of the visualization of the user's hand within a virtual environment, and (2) manipulation of the displayed hand movement on the screen. The aim is to clinically evaluate the feasibility of using TheraMem for people with chronic (> 6 months) stroke in a physiotherapeutic setting.
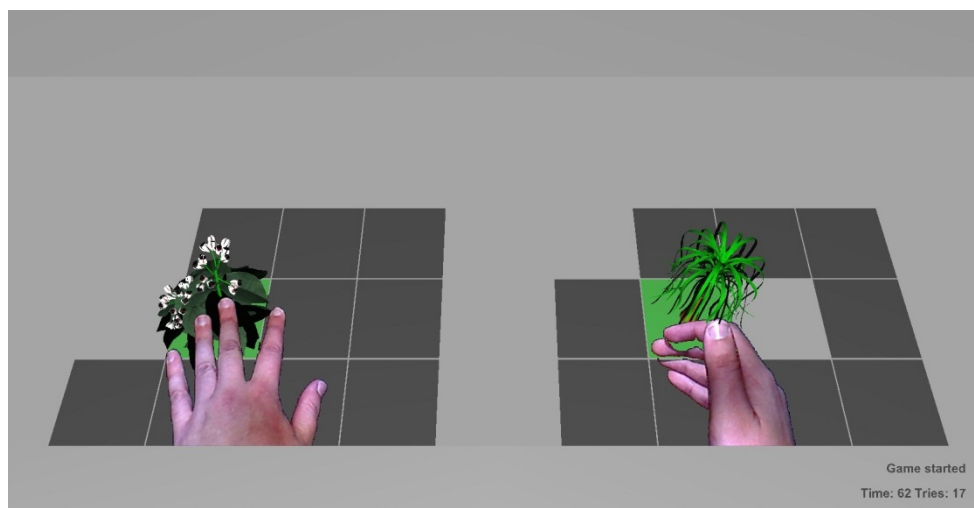
Figure 2. *Gameplay of TheraMem for a patient with an impaired right hand*

2   METHOD

The usability of the system was evaluated with five people with stroke under the guidance of a physiotherapist and with the help of a system-specialist who operated the system (see Figure 3). This study was preceded by a preliminary study with two subject-matter experts, in which the protocol was tested and fine-tuned. The two experts, of whom one was a trained physiotherapist and the other a human-computer interaction expert, acted as patients but were actively engaged in providing feedback during the session.

2.1   System & Clinical Setting

The ART system was placed in a local Physiotherapy Clinic. An undisturbed room was dedicated for the entire period of the study. The system was placed in a way to allow a quick change between the settings for left and right side impaired people. This was necessary because the physiotherapist was required to sit at the side of the participant's impairment to provide support if required and to get a better picture of how the participant was performing during the exercises.

The technical operator sat on the left side behind the physiotherapist and the participant. This allowed the operator a good overview and facilitated communication between himself and the physiotherapist without involving the participant too much. Figure 3 shows a picture of the setting for a participant with a right handed impairment.
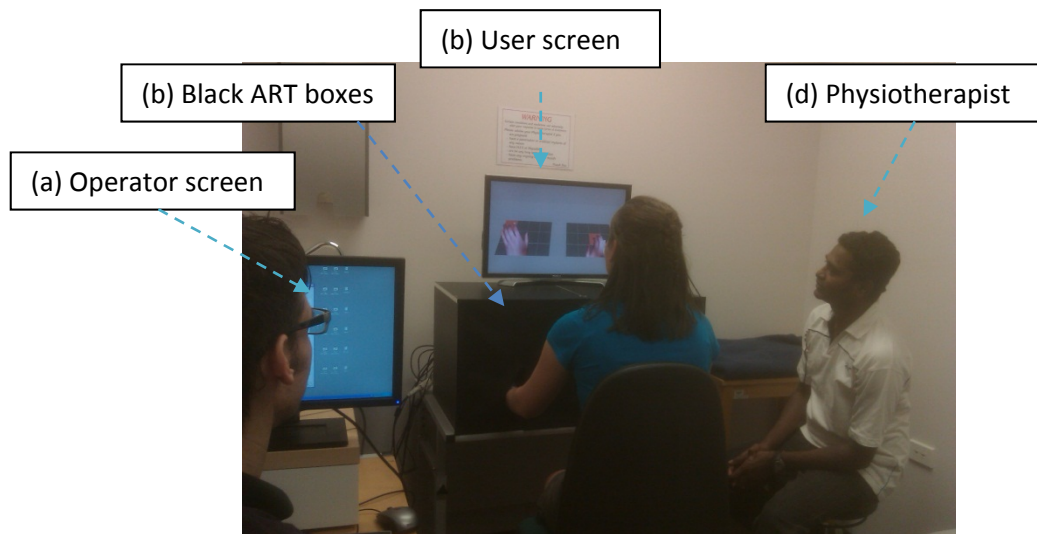
Figure 3. *Clinical System Setup: (a) Operator screen, (b) Black Boxes, (c) User screen, (d) Physiotherapist*

2.2 Procedure and Experimental Design

Hand exercises were administered to all participants at the start of each 60 minute session. For participants with severe spasticity a brief session of warm-up exercises including manual stretching, 'weight bearing' exercises and gentle manual vibration at the shoulder were applied to reduce tightness of the limb.

Each participant was clinically assessed during the first session using the following outcome measures: 1. Fugl Meyer measure for wrist and hand (Fugl-Meyer, Jääskö, Leyman, Olsson, & Steglind, 1975), 2. Motor Assessment Scale (MAS), arm, hand and advanced hand sections (Carr, Shepherd, Nordholm, & Lynne, 1985), 3. Muscle tone assessment with the Modified Ashworth scale (Bohannon & Smith, 1987), 4. Nine Hole Peg test (Mathiowetz, Weber, Kashman, & Volland, 1985). In addition, an assessment of light touch, pain and proprioception sensation in the affected upper limb was undertaken. The same tests were repeated after the fourth session to evaluate the outcome of the intervention. Tests and treatment were administered by the same physiotherapist.

Patients were also interviewed after each trial with TheraMem about their experience with the exercise and equipment. This interview was to explore their motivation and engagement with the technology and what they consider important to change and improve the system settings. After the last session, patients were interviewed about their general experience with the system as well as asked to suggest possible improvements and applications.

2.3 Participants

Five participants with different types of stroke and varying levels of impairment severity of their upper limbs were recruited from the local stroke club. All patients were > 5 years since onset of stroke. A detailed description of each participant is provided in

Table *1*. All participants gave written informed consent. The study was approved by the Regional Health and Disability Ethics Committee (Otago, New Zealand).

In the initial assessment, three participants scored a total of 0 in both the Fugl-Meyer measure (wrist & hand) (Fugl-Meyer et al., 1975) and the Motor Assessment Scale (upper arm, hand, and advanced hand) (Carr et al., 1985). The other two participants had moderate ratings in Fugl-Meyer and high ratings in the Motor Assessment Scale.

Table 1. *Participant characteristics at admission*

Code	Age	Sex	Time since stroke	Cause for stroke and diagnosis	Employment status	Upper limb status
PT0	43 y	F	42 y	Infantile left hemiplegia of unknown cause	Independent, Employed	Moderately impaired, uses affected limb for stabilising
PT1	65 y	M	5.5 y	Right hemiplegia due to CVA	Requires moderate assistance, Retired	Severely impaired. Severe spasticity and deformities involving elbow wrist and hand
PT2	63 y	M	6 y	Left hemiplegia due to CVA	Requires moderate assistance, Retired	Severely impaired. Minimal movements available at the shoulder
PT3	47 y	M	45 y	Right hemiplegia of unknown cause	Independent. Employed	Moderately impaired. Active movement available at all the joints of UE
PT4	53 y	M	15 y	Right hemiplegia due to CVA	Independent. Employed	Moderately impaired. Active movement available at all the joints of UE

2.4   Nonclinical Measures

The physiotherapist rated the patients' engagement and performance: the ability to understand the instructions, the execution of movements, the participation in activity, the effort, attitude and the acknowledgement of benefits from the participants on a 6 point scale (with 1 being the lowest).

The system-specialist observed and noted technical details, commented on technical problems and asked participants about their experience during the exposure, for example the perceived difficulties and enjoyment experienced.

3   RESULTS AND DISCUSSION

All participants were able to play TheraMem and complete the game in less than four minutes. The average game time was 190 seconds (range: 120 to 320 seconds); the two less impaired participants were able to complete the game faster with an average of 147 seconds (see Figure 4). Earlier tests with healthy participants (Regenbrecht et al, 2011) reported an average of 134 to 142 seconds; our participants in general were slightly slower. The amount of tries that participants required to complete the game was, on average, 56.4 tries (SD 8.4), which was similar to the 53.5 to 55.6 tries achieved by healthy participants in the earlier study.
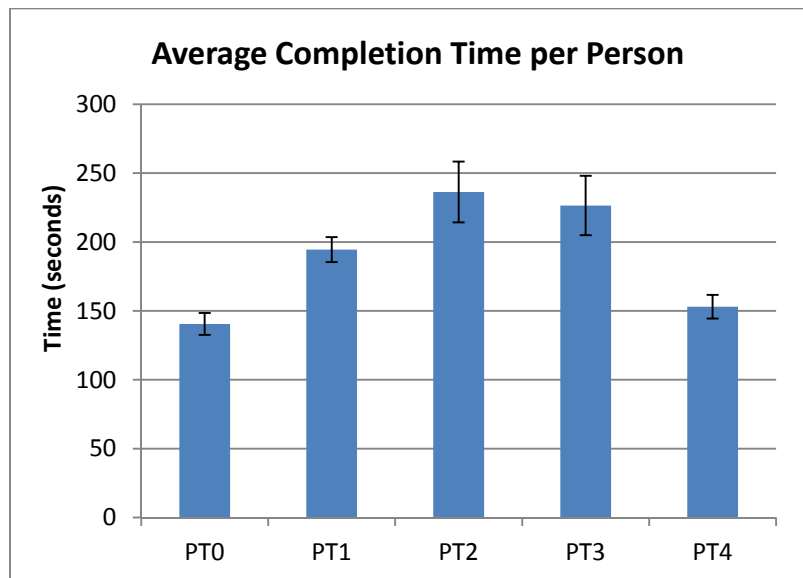
Figure 4: *Average time and std error to successfully complete one TheraMem game*

Based on the therapist's ratings on patients' engagement, the average was above 5 on a 6 point scale. Accordingly, four of the five participants always found it easy to understand the exercise, demonstrated a very positive attitude towards the exercise, and actively participated in the exercises at their maximal effort, whereas one patient did so only for "most of the time". The two participants with less impaired hands were always able to perform the exercise in a therapeutically reasonable way (demonstrating normal motor patterns) whereas the more impaired participants were "most of the time" able to perform the exercise in a reasonable way but also needed some extra support.

Three support systems were introduced to assist participants with more severe motor impairments in performing the exercise. First was the use of the TheraMem built-in movement amplification, where the performed movement of the participant was amplified so that small movements appeared larger in the game. Second, an elbow-splint was used; it was put on the participants' arm after an initial stretching session and this helped the participant to keep the arm in a relatively straight position. Third, a pointing-device was applied - a wooden stick (tongue depressor), which was given to the participants to hold with their impaired hand to facilitate pointing (see Figure 5). This was necessary because these three participants were not able to keep their affected hand flat on the floor of the box due to muscle contractures / spasticity and were therefore not able to point with their fingers at a specific tile but instead had to use their entire hand to select the tile.
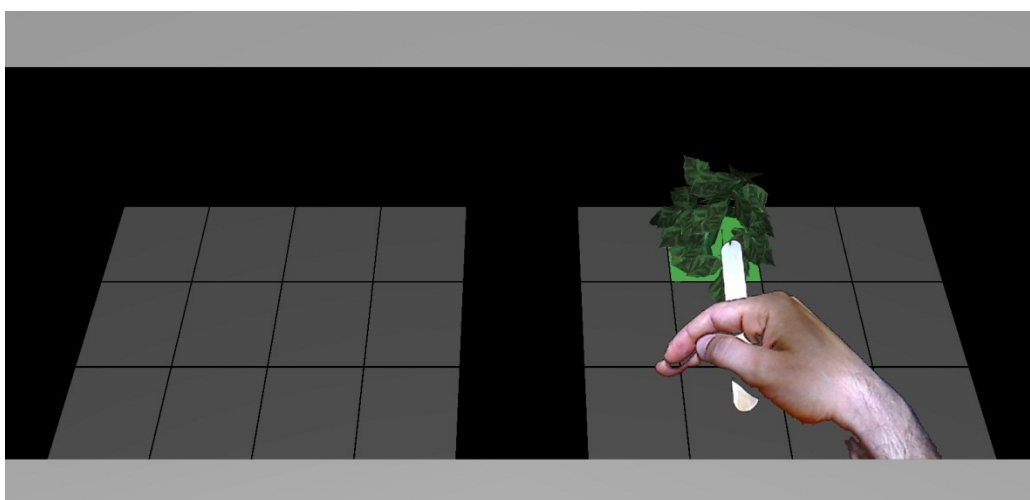

Figure 5: The use of a pointing-device to support the selection of tiles

Improvements in the clinical outcome measures after the last session were found for two participants. These were the participants with moderate ratings in the first assessment. One participant improved in the Fugl-Meyer measure (hand) from 4 to 9 (/14), in the Motor Assessment Scale (upper arm) from 5 to 6 (/6) and in the Motor Assessment Scale (hand) from 3 to 4 (/6). The other participant improved in the Fugl-Meyer measure (wrist) from 7 to 8 (/10).

In the final interview all participants expressed the opinion that the ART system has therapeutic potential for the rehabilitation of motor impairments after stroke. They suggested exercises with the ART system be incorporated in the standard set of therapeutic activities that people with stroke are asked to perform during their rehabilitation phase. In addition, participants expressed their interest in continuing this intervention after the last session. This is especially interesting as two of the participants had not undergone physiotherapy for more than a decade.

The difficulty and variety of the game should be modifiable. Participants, especially the two with less motor impairment, asked for more challenging gameplay. The current setting with 12 tiles, even though the content was randomized after each trial, was decreasingly less challenging for them after they had played the game a couple of times. In addition, participants asked for more variety of games and suggested the use of more and different sets of 3D models "under" the tiles.

All participants felt comfortable and safe in using the system in the clinical environment. In the final interview three stated that they could imagine using the system autonomously without the permanent presence of a physiotherapist and one participant even suggested the use of the system at home. The acquisition of an ART system for the local stroke clubs was also suggested.

4   CONCLUSION

The results of this study showed that the ART system and specifically its TheraMem extension are feasible for use in the rehabilitation of upper limb movement following stroke. The participants were overall, highly engaged and motivated.

The relatively small improvements for the individual participants in the clinical outcome measures were expected and can be explained by two reasons. Firstly, undergoing only four sessions of intervention might not allow enough time for a significant change. Secondly, all participants were in the chronic phase after stroke and therefore the chances and amount of improvement was limited.

In order to evaluate the clinical outcomes, a larger-scale controlled trial with more sessions and a longer intervention period is recommended. In such a trial we would expect larger improvements especially for people who have had a stroke more recently.

5   REFERENCES

Bohannon, R. W., & Smith, M. B. (1987). Interrater Reliability of a Modified Ashworth Scale of Muscle Spasticity. *Physical Therapy*, *67*(2), 206–207.

Carr, J. H., Shepherd, R. B., Nordholm, L., & Lynne, D. (1985). Investigation of a New Motor Assessment Scale for Stroke Patients. *Physical Therapy*, *65*(2), 175–180.

Fugl-Meyer, A. R., Jääskö, L., Leyman, I., Olsson, S., & Steglind, S. (1975). The post-stroke hemiplegic patient. 1. a method for evaluation of physical performance. *Scandinavian Journal of Rehabilitation Medicine*, *7*(1), 13–31.

Laver, K. E., George, S., Thomas, S., Deutsch, J. E., & Crotty, M. (2011). Virtual reality for stroke rehabilitation. *The Cochrane Library*. John Wiley & Sons, Ltd. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD008349.pub2/full

Mathiowetz, V., Weber, K., Kashman, N., & Volland, G. (1985). Adult Norms For The Nine Hole Peg Test Of Finger Dexterity. *OTJR*, *5*(1), 24–38.

Regenbrecht, H., Franz, E. A., McGregor, G., Dixon, B., & Hoermann, S. (2011). Beyond the looking glass: Fooling the brain with the Augmented Mirror Box. *Presence: Teleoperators and Virtual Environments*, *20*(6), 559–576.

Regenbrecht, H., Hoermann, S., McGregor, G., Dixon, B., Franz, E., Ott, C., Hale, L., et al. (in press). Visual Manipulations for Motor Rehabilitation. *Computers & Graphics*. doi:10.1016/j.cag.2012.04.012

Regenbrecht, H., McGregor, G., Ott, C., Hoermann, S., Schubert, T., Hale, L., Hoermann, J. M., et al. (2011). Out of reach? – A novel AR interface approach for motor rehabilitation. *Proceedings of the 10th IEEE International Symposium on Mixed and Augmented Reality* (pp. 219–228). Presented at the 10th IEEE International Symposium on Mixed and Augmented Reality, Basel, Switzerland.