TheraGame – a home based virtual reality rehabilitation system

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ABSTRACT

The limitations of existing virtual reality (VR) systems in terms of their use for home-based VR therapy led us to develop "TheraGame", a novel video capture VR system. TheraGame operates on a standard PC with a simple webcam. The software is programmed using a Java-based visual interaction system. This system enables a quick and easy definition of virtual objects and their behavior. The user sits in front of the monitor, sees himself and uses his movements to interact with the virtual objects. The objective of this presentation is to present the system, a number of the current applications, and some initial pilot usage results. Results from a study of 12 healthy elderly subjects showed moderate to high levels of enjoyment and usability. These scores were also high as reported by 4 participants with neurological deficits. Some limitations in system functionality were reported by one person with stroke who used TheraGame at home for a period of 2.5 weeks. Overall, TheraGame appears to have considerable potential for home based rehabilitation.

1. INTRODUCTION

Clinicians who work in rehabilitation aim to enhance clients' functional ability as well as their ability to participate in community life. These goals are achieved by intensive intervention aimed at improving motor, cognitive and meta-cognitive abilities. Regrettably, for economic reasons the duration of subacute rehabilitation is getting shorter. Therefore supervised self-training at home is necessary in order to achieve maximal functional independence. In addition, during the last decade, there is growing evidence that neurological patients should receive maintenance therapy after rehabilitation in order to preserve the achievements gained while in hospital as well as to prevent deterioration. Moreover, several studies have shown that improvement of impairments and reducing participation restriction can be achieved by training even in the chronic stage (Liepert et al, 2000; Pang et al, 2006).

Virtual Reality-based therapy has well-known assets including the opportunity for active learning in challenging but safe and ecologically-valid environments, while maintaining strict control over stimulus delivery and measurement, and the capacity to individualize treatment needs, while gradually increasing the complexity of tasks (Rizzo et al, 2002; Rizzo et al 2004) Although the advantages of Virtual Reality (VR) are becoming widely recognized within the clinical community, the rehabilitation team faces a challenge when looking for a home-based, affordable VR system that suits the implementation of therapeutic objectives.

Video capture VR consists of a family of camera-based, motion capture platforms that differ substantially from the HMD and desktop platforms in wider use (Weiss et al, 2005). When using a video-capture VR platform, users stand or sit in a demarcated area viewing a large video screen that displays one of a series of simulated environments. Users see themselves on the screen, in the virtual environment, and their own natural movements entirely direct the progression of the task, i.e., the user's movement is the input.

Currently, the main video capture platforms that have been used for rehabilitation are GestureTek's (formerly know as VividGroup) GX and IREX (Interactive Rehabilitation EXercise) (www.irex.com) systems. For the past three years, the Sony PlayStation II EyeToy applications have begun to be used as an intervention tool as well. The GX-IREX platforms have been adapted for rehabilitation but are considerably more expensive than the EyeToy, and require a more elaborate setup including a chroma key blue/green backdrop behind the user and bright, ambient lighting. Sony's EyeToy is an off-the-shelf, low-cost gaming application that may be run under almost any ambient conditions. However, the EyeToy cannot be graded to suit clients' cognitive and motor impairments especially when those impairments are severe.

The limitations of both of these systems in terms of their use for home-based VR therapy led us to develop "TheraGame", a novel video capture VR system. TheraGame is an innovative virtual reality system for dynamic, low-cost rehabilitation treatment with tele-medicine capabilities. It is suitable primarily for use in hospitals, local clinics, chronic care facilities and at home. It enables patients to engage in computer simulation-based, gaming activities that improve their motor, cognitive and meta-cognitive abilities while measuring performance. The system is based on low-cost, technically simple components and thus it is accessible to a wide range of consumers in different cultural settings. Furthermore, it can increase the amount and intensity of simple, repetitive tasks that patients can do on their own or with minimal supervision, hence releasing the therapist from constant supervision of rote exercise, and reducing the overall cost of rehabilitation. At the same time, the system provides an accurate outcome measure that assists in tracking the patient's condition and generating individualized programs for each patient. An equally important application of this product is its use by the healthy population of all ages, enabling them exercise and maintain a healthy life style in an enjoyable manner.

TheraGame aims at combining the strengths of both the GX and the EyeToy system – it is low cost (similar to the EyeToy) while maintaining the flexibility and the ability to program and change the system (similar to the GX system).

The objectives of this paper are: 1. to present the system, and a number of the current applications, and 2. to present initial pilot usage results of an ongoing study, with elderly people as well as people with neurological disabilities.

2. METHODS

2.1   Participants

To date, 12 healthy elderly participants, seven female and five male, have experienced TheraGame. Their mean ± standard deviation (SD) age was 70.6 ± 4.4 years and ranged between 65 to 78 years. Ten of these participants reported that they use a computer on a regular basis for a mean 2.2 ± 2.3 hours per week.

A second group included four participants, aged 65-76 years, who experienced TheraGame for one session; three were post stroke and one had had a spinal stenosis. All of the participants had a weak upper extremity; three participants could use both hands while one could use only one hand. In addition, one participant, a 53 year old man who had a stroke two years prior to the study, used a system that was installed on his own computer at home for a period of two and a half weeks. This participant suffered mainly from cognitive deficits such as memory loss and meta-cognitive deficits such as impaired executive functions.

2.2   Instruments

2.2.1 VR system – TheraGame. TheraGame operates on a standard PC with a simple webcam. The software is programmed using a Java-based visual interaction system. This system enables a quick and easy definition of virtual objects and their behavior. The user sits in front of the monitor, sees himself and uses his movements to interact with the virtual objects. As illustrated in Figure 1, the controllers (i.e., virtual buttons or arrows) are displayed in a separate area on the screen which also displays the user. In this way users receive visual feedback regarding when and how long they have touched the controllers. The controllers operate a game which is presented on a larger portion of the same screen. In addition to providing a platform for the development of new games for TheraGame, the system enables embedding of existing Flash games. To keep the interaction simple, the games need to have basic controls of up to six different keys (usually the arrow keys and the space bar). The number, color, size and location of the controllers may be defined in addition to the game parameters such as speed and level of difficulty. Thus, the level of the games may be graded to the client's level. Since the operation of TheraGame is easy and the cost is relatively low, the goal is for clients to purchase TheraGame following the rehabilitation process, to be used at home independently (with periodic supervision) in order to improve motor, cognitive and meta-cognitive deficits.

Examples of games include Touch-tetris (see Figure 2), virtual ball games, different maze applications, and TheraSlide-Show where a set of pictures (family photos or other pictures or photos) are loaded into the system and presented. The user can use the left and right arrow to scan the photos to look at them or arrange them in order. The principle of all of the applications is similar with that of the other video capture VR systems (Weiss et al., 2005) which is to provide enjoyable and motivating tasks that require varying combinations of motor and cognitive skills. The different games encourage clients to use both or one of their arms (instead of using a mouse and a keyboard) while they are engrossed in another task which diverts their attention away from the difficult motor task and encourages the use of cognitive abilities such as memory,

planning, and visual scanning. It is anticipated that this will result in more active movement of the impaired limb than would occur during traditional, rote exercises. Outcome measures include the number of points, levels per game and time of engagement. In addition the system registers the date and time the user played the games.
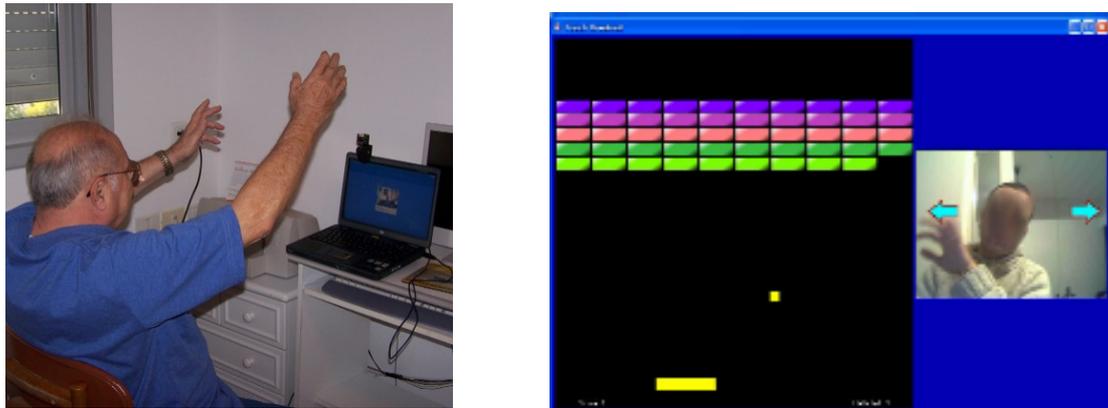
Figure 1. *Inside Motion Tetris (right) and outside (left) a game (Motion Music) in TheraGame.*

The healthy participants experienced two maze like applications which required planning and problem solving: "ColorSok" (see figure 3, right) – where pairs of color blocks must be pushed together and "Frogs" (see figure 3, left), where the user has to help the frog jump on to all of the Lilies in order to make them all disappear.

The stroke participants experienced three differences games including Virtual ball games, Motion music game and Touch-tetris. The patients post-stroke at home experienced Frogs, Touch Tetris, and another two planning games.
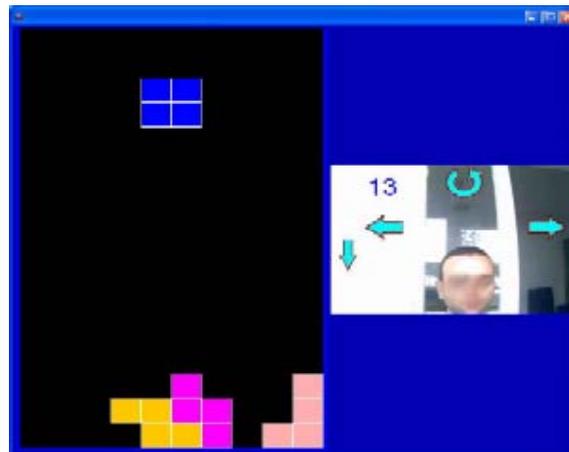
Figure 2. *A screenshot of touch-Tetris in TheraGame.*
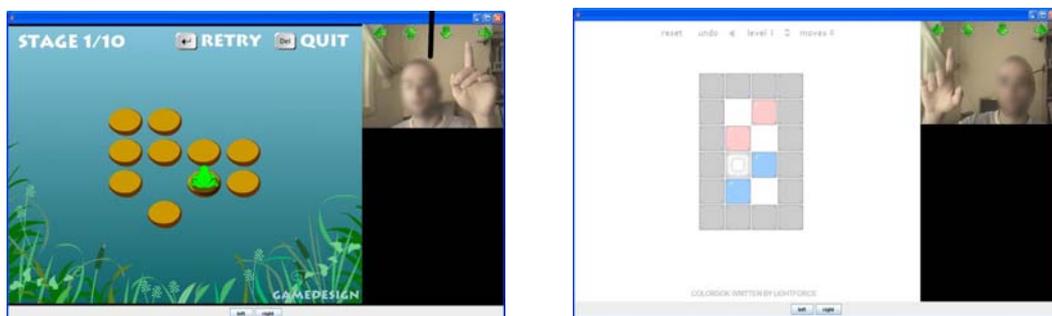
Figure 3. *A screenshot of Frog (left) and ColorSok (right) in TheraGame.*

2.2.2 Short Feedback Questionnaire (SFQ) (Kizony et al, 2005). This is a 7-item questionnaire designed to obtain information about the subjective responses of the participants to the VR experience in each scenario. It queries the user's sense of presence, perceived difficulty of the task and any discomfort that users may have felt during the experience. The first six items of the questionnaire were formulated as an abbreviated alternative to the longer Presence Questionnaire developed by Witmer and Singer's [20]. These items assess the participant's (1) feeling of enjoyment, (2) sense of being in the environment, (3) success, (4) control, (5) perception of the environment as being realistic and (6) whether the feedback from the computer was understandable. The seventh item queried whether participants felt any discomfort during the experience. Responses were rated on a scale of 1-5 where 1 = "not at all" and 5 = "very much". In this paper, responses from questions 1 and 6 are reported.

2.2.3 Borg's Scale of Perceived Exertion (Borg, 1990). This scale was used to assess how much physical effort the participants perceived that they expended during each VR experience. This is a 20-point scale that participants rated from 6 (no exertion at all) to 20 (maximal exertion).

2.2.4 System Usability Scale (SUS) (Brooke, 1986). The SUS includes ten items which provide a global view of subjective assessment of a system's usability. Each item was rated on a 5-point scale from 1 (disagree totally) to 5 (agree totally). Five items are positive statements, such as "I think that I would like to use this system frequently" and "I thought the system was easy to use" and the other five items are negative, for example, "I found the system unnecessarily complex" and "I think that I would need the support of a technical person to be able to use this system". The item scores were totaled as described by Brooke (1986) to give an overall score ranging from 10 to 100 points.

2.3   Procedure

The healthy participants experienced the system for one 20-30 minute session. Each participant was trained to use the virtual arrows within the system using a simple application before the actual experience. After training each participant played two games for 5 minutes each. After each game they completed the SFQ and rated their level of exertion on the Borg scale. To assess the usability of the system the examiner demonstrated how to operate the system (i.e., how to commence a new game); upon completion of the second game the participants were asked to repeat this action, after which they filled in the SUS. The group of 4 participants with neurological deficits also experienced the system, operated by an occupational therapist, for one 30 minute session and played three different games. For the other participant with stroke, a system with four games was installed at his home. Following the installation, an occupational therapist trained the participant and his wife how to operate the system. They were asked to record in a journal when, for how long and what games he played with the system. After a period of two and a half weeks the therapist returned to the participant's home and carried out a structured interview with the couple. The wife also completed the SUS.

3. RESULTS

The reported level of enjoyment was 3.8 ± 1.0 and ranged between 2 and 5. The mean Borg scale for the two games was 11.2 ± 1.8 indicating that the perceived exertion level was low. The mean level of usability according to the SUS was 73.8 ±14.5 and ranged between 55 and 100, indicating a relatively high level of usability.

The level of enjoyment for the group of 4 participants with neurological deficits was 5. They also reported that the feedback provided by the computer was very clear (SFQ scores of 4-5). Their perceived exertion ranged between 10 (very easy) and 13 (somewhat hard). All participants said they would like to use such a system in their own homes. In addition, they requested an increase the size of the screen and a display of the scores for all the games. On some occasions they had difficulty touching the correct arrow, since their hand touched another arrow by mistake.

The participant who used the system for the extended period of time (2.5 weeks) used it for 10 sessions over 16 days for a total of 213 minutes. He does not suffer from motor impairments but does have memory problems and meta cognitive deficits. His wife's responses to the SUS indicated a high level of usability (score = 82.5/ 100 points). Their responses to the structured interview were variable. When asked "how much did using the system contributed to motor and cognitive training or providing leisure activities?" the participant said that he felt the experience contributed more to motor aspects whereas his wife said it contributed to cognitive aspects such as memory and planning. She also mentioned that it contributed to leisure activities and to rehabilitation in general. Both of them said that it would be better to activate the system with a keyboard and a mouse and not with the virtual arrows. The wife explained that the virtual arrows are distracting. In addition

they both said that there is a need to improve the system and to increase the number of games available for the user.

4. SUMMARY AND CONCLUSIONS

The results of this study demonstrate the usability of TheraGame for healthy elderly people and for a small number of people who are post-stroke. This finding is important as a first step prior to the implementation of this type of system in home-based rehabilitation services, especially for people who have had a stroke. Since a large number of stroke survivors suffer from cognitive and motor deficits they could be expected to have difficulty operating such systems on their own, at least initially, and would need help from their spouse who is usually also elderly. The usability of the system with people who have had a stroke or brain injury should be further studied in order to determine the minimum cognitive and motor abilities necessary to operate TheraGame independently.

One of the primary reasons for using VR in rehabilitation is that the gaming factors enhance enjoyment and motivation for treatment (Rizzo and Kim, 2005). Tauer and Harackiewicz (2004) have suggested that intrinsic motivation involves the desire to participate in an activity for its own sake, is marked by high levels of enjoyment during the task and should help the person to stay interested in the activity for a long period of time. They also suggested that task enjoyment influences performance since a person who enjoys what he is doing spends more time developing his skills in a given activity. Bach-y-Rita, et al. (2002) also indicated the importance of a patient's motivation in order to achieve active participation and functional improvement. The results of this study, although they should be interpreted with caution due to the small sample size, showed that the elderly participants reported a moderate level of enjoyment. This finding is similar to the results of a study using games run with the Sony PlayStation II EyeToy system (Rand et al., 2004). The level of enjoyment reported by the participants who had a stroke was higher, and corresponded to the results reported by Rand et al (2004) in the same study. These findings are also in accordance with level of enjoyment reported by people who had a stroke using the GestureTek GX system (Kizony et al., 2004).

This ongoing study is the first step towards showing the considerable potential that TheraGame appears to have for home-based rehabilitation. However, the results are still preliminary and data collection with additional participants who have had a stroke and are still in hospital as well as others who are already at home is currently underway. Future studies will examine the usability of the system with more clinical populations and will study the effects of additional TheraGame applications and improvements to its outcome measures.

5. REFERENCES

P Bach-y-Rita, S Wood, R Leder, O Paredes, D Bahr, Wicab, E Bach-y-Rita and N Murrilo (2002), Computer-assisted motivating rehabilitation (CAMR) for institutional. Home and educational late stroke programs, *Topics in Stroke Rehabilitation,* **8**,(4), pp.1-10.

G Borg (1990), Psychophysical scaling with applications in physical work and the perception of exertion. *Scandinavian Journal of Work Health,* **16***,* pp. 55-58.

J Brooke (1986), SUS: A quick and dirty usability scale, *In Usability evaluation in industry* (P W Jordan, B Thomas, B A Weerdmeester & I L McClelland, Eds), Taylor & Francis, London, pp. 189-194.

R Kizony L Raz, N Katz, H Weingarden and P L Weiss (2005), Using a video projected VR system for patients with spinal cord injury, *Journal of Rehabilitation Research & Development,* **42**, pp. 595-608.

R Kizony, N Katz and P L Weiss (2004), A model of VR-based intervention in rehabilitation: Relationship between motor and cognitive abilities and performance within virtual environments for patients with stroke, *Proc, Intl. Conf. on Disability, Virtual Reality and Associated Technology*, P Sharkey, CS Lanyi, P Stanton (Eds); September, Oxford, UK.

J Liepert, H Bauder, W H R Miltnse, E Taub and C Weiller (2000), Treatment-induced cortical reorganization after stroke in humans. *Stroke*, **31**, pp. 1210-1216.

M Y Pang, J E Harris and J J Eng (2006), A community –based upper extremity group exercise program improves motor function and performance of functional activities in chronic stroke: a randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*, **87**, pp. 1-9.

D Rand, R Kizony and P L Weiss (2004), VR Rehabilitation for All: Vivid GX versus Sony Playstation II EyeToy. *Proc, Intl. Conf. on Disability, Virtual Reality and Associated Technologies,* P Sharkey, CS Lanyi, P Stanton (Eds), September, Oxford, U.K

A A Rizzo, J C Buckwalter and C Van der Zaag (2002), Virtual environment applications in clinical neuropsychology. In: K. Stanney (Ed*.). The Handbook of Virtual Environments*. Erlbaum Publishing, New York, pp. 1027-1064.

A A Rizzo and G J Kim (2005), A SWOT Analysis of the Field of VR Rehabilitation and Therapy**.** *Presence: Teleoperators and Virtual Environments,* **14**, pp. 119-146.

A A Rizzo, M T Schultheis, K Kerns and C Mateer (2004), Analysis of assets for virtual reality in neuropsychology. *Neuropsychological Rehabilitaion,* **14**, pp. 207-39.

J M Tauer and J M Harackiewicz (2004), The effects of cooperation and competition on intrinsic motivation and perfromance. *J Personal Soc Psycho*, **86**, 849-861.

P L Weiss, D Rand, N Katz and R Kizony (2005), Video capture virtual reality as a flexible and effective rehabilitation tool. *Journal of NeurEngeeniring and Rehabilitaiton,* **12**,1. Available at: www.jneuroengrehab.co /content/1/1/12.