Evaluation of a computer-assisted 2D interactive virtual reality system in training street survival skills of people with stroke

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ABSTRACT

The rationale, procedures and results of pilot study of the VR system in training street survival skills of people with stroke were presented and discussed. The following main study was also refined from the outcomes to make it more feasible and potentially beneficial to the patients.

1. INTRODUCTION

Stroke is a focal or global neurological impairment of sudden onset, and lasting more than 24 hours (or leading to death) and of presumed vascular etiology (WHO, 1978). Resulted cognitive deficiencies represent substantial sources of disability. The functional limitations in the activities of daily living, work and leisure could be resulted from those impaired functioning. Therefore, a systematic functionally oriented services of cognitive rehabilitation based on assessment and understanding of individual deficits were used to compensate for the cognitive deficits and promote functional adaptation in daily living (Gontkovsky et al, 2002). The traditional methods have involved the various paper-and-pencil tasks, manipulation of blocks and real-life activities. Learning theory, cognitive theory and neuropsychology are used to direct the development of the treatment and explain the results. Since the technological developments over the past few years had led to the use of computers in the rehabilitation, there are numerous computer-based cognitive rehabilitation programs for different purpose. Particularly, using Virtual Reality (VR) as a medium in rehabilitation has becoming more popular and was progressing in a rapid way.

Virtual Reality (VR) can be viewed as an advanced computer interface that allows the user to interact and become immersed within computer-generated simulated environments (Rizzo et al. 1997). Rapid development in modern technology and sophisticated computer systems have made it possible for desktop computers to display complex visual images that change in response to instructions from users (Christiansen et al. 1998). According to Rose et al. (2000), the virtual environments demonstrate many of the characteristics of an ideal training medium. The virtual environments are especially valuable when training in real life situations will be impractical, dangerous, logistically difficult, unduly expensive or too difficult to control. The person can actively interact with the simulated world by using interface devices. Its realism and versatility makes VR a suitable and innovative approach in rehabilitation. A number of researches have supported the use of VR in rehabilitation, both assessments and treatments, among physical, cognitive and psychological conditions. The immerse VR can offer higher level of presence and realism while the non-immerse one is more affordable and accessible to patients due to simpler computer requirements and more suitable for the patients feeling nausea in the immerse VR. The essence of VR gives the person a sense of immersion and presence in a virtual environment but like acting in real world (Hoffman et al, 2001). Since VR is a kind of advance computer applications, it has all the advantages in other software programs such as modifiability, adaptability, customizability and portability (Rizzo et al, 1997). Therefore, with the appropriate programming, VR can create a world with specific purpose. Currently, VR has been used successfully to train flight pilot, surgeons and treat patients with phobias while the use of VR in rehabilitation is comparatively limited (Campbell, 2002; Christiansen, et al, 1998; Grealy et al, 1999; Olasav et al, 2002; Rizzo et al, 1997).

2. MAIN STUDY

The present study will evaluate the effectiveness of a newly developed 2D non-immerse VR in training street survival skills of people with cognitive deficits. Besides street survival skills training, the present 2D VR strategy can also be used in assessing and training various community survival skills like transport skills, road safety skills, wheelchair accessibility, etc. Such a rehabilitation development would complement hospital-based rehabilitation and community services, and might guarantee success in achieving a better quality of life. A 2DVR based street survival skills training program and a corresponding psycho-educational package will be developed for the present study. The training contents are the concepts of street survival skills including road crossing, use of MTR and money management.

2.1 Research Objectives

The present study will develop and compare the effectiveness among a non-immerse flat screen 2DVR method, a conventional psychoeducational method and control group in training street survival skills of people with stroke. The project objectives are:

- To develop a 2DVR system as a training modality for street survival skills
- To evaluate the effectiveness of a 2DVR system as a training modality for street survival skills in terms of behaviours, self-efficacy and functional performance
- To compare the effectiveness of the virtual reality-based and conventional psycho-educational strategies in training street survival skills

2.2 Design

A randomized control group pre-test and post-test design will be adopted. The subjects will be randomly assigned into 3 treatment groups. 20 subjects will receive street survival skills training using a newly developed 2D VR based computer program and learn the skills through interaction within an interactive virtual environment. Another 20 subjects will receive the same skills training using a psycho-educational package using demonstration, role-play, and immediate feedback with verbal reinforcement. The remained 20 subjects will be in the control group. The measurement will be taken at the beginning of the training and the end of the training. There are 10 sessions and each last 1-hour. Each treatment group will be subdivided into 4 smaller groups of 5 subjects for the ease of training in terms of the equipment, the space and effective group size. The pilot study was done prior to the main study in which the treatment contents, the instructional strategies and the outcome measures can be tested and refined to formulate a better research design with lesser flaws and more effective treatment results. The usability testing and the qualitative evaluation will also be performed in addition to the quantitative measurement. These useful information and valuable feedback from the subjects can be used to modify the research design in the main study, so that the confounding or extraneous variables can be minimized to improve the reliability and the validity of the research study.

2.3 Sampling

The blocking is adopted in the sampling process. In the stage 1, 4 local organizations are selected and contacted for the potential population of stroke patients. In the stage 2, the patients within each block are randomly allocated into 3 groups by random assignment. The randomization is done by using the random number generation in SPSS 10. Each subject has an equal chance of being assigned to any group, impendent of personal judgment and bias. A total of 60 subjects with strokes will be recruited. At a sample size of 60, an alpha of 0.05, the number of level (k) of 3 and an expected effect size of 0.5 (medium effect size) for the interventions, the power is 0.93 (Cohen, 1987) in the statistical power analysis for the behavioral sciences.

2.4 Selection criteria

- Persons age 40 to 70 who suffer from stroke
- Medically and emotionally stable
- Able to follow simple instruction, write with a pen in Chinese or English
- Have good visual tracking, discrimination and figure-ground skills
- Have sustained attention span at least 10 minutes
- No previous psychiatric history and no computer-phobia

2.5 Outcome Measures

A behavioral checklist will be developed according to the results of content-specific task analysis. The performances of the skills are broken down into 22 small steps that can be rated from 0 (dependent) to 3 (independent). The subjects will go through the same assessment procedures in the real setting before, after and at one-month follow-up. The checklist is used to obtain the baseline performance, the initial performance and the retention performance. Therefore, it can be made valid and reliable comparisons among the groups and within the group as well as the measurement of the retention of the skills and the generalization of the skills into the real life situation.

Self-efficacy scale will be developed according to Bandura's principles (1997) for the study. It is a measurement of self-perception in the ability of specific tasks. The scale was created to assess a specific sense of perceived self-efficacy with the aim in mind to predict coping with street survival as well as adaptation after experiences in different kinds of life events. The scale is self-administered and comprehensive questionnaire. The patients mark their perceived self-efficacy on a 10-point Likert scale. The scoring is done by summing up the responses to all 11 items to yield the final composite score with a range from 10 to 110. The higher scores mean better self-efficacy.

Formative evaluation will be done throughout the study by observations in behaviours, verbal expressions, comments, feelings, participation during the treatment. Both close-end and open-end questions will be used in the qualitative analysis. The qualitative evaluation can give valuable information that can complement the quantitative data. It is used as triangulation and the crosschecks of the results.

3. PILOT STUDY

The pilot study and the usability testing of the VR programs were implemented at the same time. There are three aims in the pilot study:

1. To obtain preliminary data for evaluating the effectiveness of VR programs and psychoeducational group in training street survival skills of people with stroke
2. To compare the effectiveness among groups
3. To test the usability of newly developed VR programs in training street survival skills

Figure 1. *Screenshots from the VR programs*

The pilot study has recruited 11 subjects in total and randomly allocated them into 3 groups: VR group psychoeducational group and control. They met the criteria used in the main study. The training contents were the same in two intervention groups but different in the media. In VR group, the subjects went through 6 sessions of 1-hour training in street survival skills with the newly developed VR programs. These programs were installed in a desktop personal computer (PC) with 17" monitor, keyboard, mouse and joystick. The subjects could choose their preferred input devices for navigating and interacting within the virtual environment so that they had more self-directed actions during the training. The PCs were placed in a quiet and comfortable room to minimize the distractions so that the subjects can concentrate on the training.

For the program development, these programs were based on real life photo in Hong Kong and compiled by using LivePicture and C++ programming to create the virtual environment. Two major tasks in the virtual environment were crossing road safely and using underground railway (MTR). The VR programs compiled by LivePicture could provide the overall flow in the virtual environment. The virtual journey started at home and required the subjects go to a destination at the end. Inside the virtual environment, the subjects could freely navigate through the panorama (a 360 degree scene) and look around the environment. They were required to walk along the streets to find out the suitable place to cross the road safely and identify the MTR entry. After going down to the concourse, the subjects should buy tickets and pass through the gate. Then went down to the MTR platform where the train will come. They would take on the MTR and arrive at a designated station where they would take off. Then they would get out from the MTR station through the concourse. Finally, the subjects had to walk along the streets and find the way to arrive at the entrance of a building. Besides this VR program, the others compiled by C++ programming were also developed to allow more specific training in two major tasks. The subjects could control a virtual person to practice crossing road and using MTR separately. They could do more delicate motions within that virtual environment. The first session was to introduce the learning aims, methods and contents as well as provide the time for the subjects to get familiar of the user interfaces and input devices. The baseline assessment had been conducted in this session. The second and third session allowed the subjects freely explore and navigate within the virtual environment. Also, the therapists have discussed with the subjects for the possible problems and try to work out the potential solutions. The forth and fifth session required them to perform several specific actions as a task-specific training. The post-treatment assessment in real life situation was done for outcome measures in the sixth session.

In psychoeducation group, the training contents were the same as the VR group. The PowerPoint would be presented to the subjects so that they could learn the ideas of the skills. Psychoeducation approaches would be adopted in which demonstration (photo, video or therapist), role-play practices, coaching, feedback and homework assignment were provided to facilitate the learning of the skills. The arrangement of the sessions were similar of those of VR group that started with baseline assessment and ended up with post-treatment assessments. In control group, only the pre and post assessments have been done.

In the pilot, the independent variable was the different groups in the persons with stroke as well as other demographic information. The dependent variables were the subjects' knowledge and skills and their self-efficacy in applying those learned skills in their daily functioning. They were in terms of the results of the self-efficacy scale, behavioural checklist and the formative evaluation. Descriptive statistics have been used to describe the demographic data and the performance at different time and non-parametric tests have been used to analyze the performance within and among groups.

Since the VR programs were newly developed for the research, the information about their usability was almost unknown. It was necessary to conduct the usability testing to investigate in this aspect and the insights gained could help to improve the VR programs so that the potential clients could use and learn the programs easier. As the clients become more motivated in the VR programs, the training results should be easier to be effective and therapeutic. Usability is a quality attribute that assesses how easy user interfaces are to use. It also refers to methods for improving easy-to-use and easy-to-learn during the design process (Nielsen, 2003). The usability testing could provide substantial improvements in the program design and it is especially effective in the early stage of development. 5 subjects were enough for the users testing. The number of usability problems found in a usability test with n users is: $N(1-(1-L)^n)$, where N is the total number of usability problems in the design and L is the proportion of usability problems discovered while testing a single user. The typical value of L is 31%, averaged across a large number of projects they studied (Nielsen, 2003). With a single test user, researchers learn almost a third of all there is to know about the usability of the design. As adding more and more users, new information would become less and less. After the fifth user, it is a waste of time by observing the same findings repeatedly but not learning much new (Nielsen, 2003). During the usability testing, the subjects were observed while they were actually using the VR programs. Special notes was made on what they succeed, what they fail, how they deal with the problems and so on. After the testing, the subjects were interviewed in a semi-structured manner in which special issues or constructive feedback could be solicited. The data were tabulated and analyzed in terms of brief description of the task, usability question, quantitative goal, quantitative goal achieved, descriptive statistic, problems identified and suggested solutions. The results were used to refine the 2DVR programs that will be used in the main study.

4. RESULTS

11 subjects, 6 males and 5 females with mean age of 46.5±5.0 and mean suffered year of 2.2±0.6, were recruited in the pilot. 5 were left hemiplegia and 6 were right hemiplegia. Most of them were ADL independent with secondary school education level. 3 knew very little about computer and others have basic to moderate computer knowledge. All of them were mobility independent with adequate functions in hearing, vision, communication and comprehension. They were randomly allocated in 3 groups and resulted in 3 in control, 3 in psychoeducation and 5 in VR group. For control group, pre self-efficacy mean was 98.3±3.5; post self-efficacy mean was 98.3±3.5; pre behavioural skills was 58.0±2.6; post behavioural skills was 58.0±2.6. For psychoeducation group, pre self-efficacy mean was 97.0±4.4; post self-efficacy mean was

102.0±8.9; pre behavioural skills was 57.0±1.7; post behavioural skills was 59.7±0.6. For VR group, pre self-efficacy mean was 99.0±8.4; post self-efficacy mean was 103.0±5.7; pre behavioural skills was 53.6±8.0; post behavioural skills was 64.8±1.8.

Due to small sample size, non-parametric Kruskal-Wallis test was used to compare among groups. It had shown that pre self-efficacy, post self-efficacy and pre behavioural skills had no significant difference among groups but post behavioural skills had the significant difference among groups (Chi-Square=8.073, df=2, p=.018). It meant that the groups were homogeneous prior to the treatment and the substantial difference in post behavioural skills was found after treatment. To further investigate the difference between groups, Mann-Whitney U test was performed and the significant differences in post behavioral skills were found in control vs VR (U=.000, Z=-2.291, p=.022) and psychoeducation vs VR (U=.000, Z=-2.306, p=.021). It meant that VR could result in higher behavioral skills. Wilcoxon signed ranks test was used to compare pre and post measurements within groups. Both control and psychoeducation group had no significant difference in pre-post comparisons of self-efficacy and behavioral skills. Only VR group has shown significant difference in pre-post behavioral skills comparisons (Z=-2.032, p=.042) while the self-efficacy were not significant (Z=-1.826, p=.068). It meant that VR could improve the behavioral skills.

All 5 subjects in VR group have also performed the usability testing and the descriptive statistics were conducted. A number of usability tasks were requested to perform to test the user interface and the control devices. The tasks included moving with keyboards, changing view with mouse, following model, mouse actions and zooming. Accomplished times were measured with stopwatch from the instruction announced to the finished tasks. Generally, the subjects could do the tasks within reasonable time. Zooming involved coordinated use of mouse and keyboard simultaneously, so it could be harder and the accomplished times were longer.

Table 1. *Descriptive statistics of usability tasks*

Tasks	Move U/D	Move L/R	View U/D	View L/R	Follow model	Mouse click	Mouse drag	Mouse release	Mouse move	Zoom in	Zoom out
Min	2.00	2.00	3.00	3.00	3.00	2.00	3.00	1.00	3.00	3.00	3.00
Max	3.00	3.00	4.00	4.00	5.00	3.00	5.00	3.00	5.00	7.00	7.00
Mean	2.6000	2.6000	3.4000	3.4000	3.6000	2.2000	3.8000	1.6000	4.0000	4.8000	4.8000
SD	.5477	.5477	.5477	.5477	.8944	.4472	.8367	.8944	.7071	1.4832	1.4832

The common feedbacks from the subjects about use of VR programs in training were interesting, realistic, funny and new. Most of them found the control was easy but some of them wanted a third person view instead of the first person view used in the pilot study. They thought that it would be easier to judge the distance. After the treatment, most of them felt a bit tired but no motion sickness or other side effects were reported. Some of them said that the VR programs could make them became attentive to signs in real life situation and familiarized the procedures of ticket machines. Most of them wanted the expansions in VR programs such as more locations or buildings, more transportation methods and map readings. A few of them wanted harder tasks such as banking, shopping and sports.

5. DISCUSSIONS

Because of small sample size in the pilot, the power of study may not be adequate to show the significant difference among groups and within group. Only VR group shown significant difference in behavioural skills during group and pre-post comparisons. The main study with larger small size and insights from pilot should yield more fruitful results. By the way, transfer of skills from a virtual environment to the real world is possible and it helps cognitively impaired individuals relearn important daily living skills (Burdea et al, 2000; Riva et al, 2000; Riva, 1998). Moreover, immerse virtual kitchen was developed in which patients with TBI can perform a meal preparation task involving 30 steps (Christiansen et al, 1998; Zhang et al, 2001). Persons with TBI consistently demonstrated a significant decrease in the ability to process information, identify logical sequencing and complete the overall assessment, compared with persons without TBI (Zhang et al, 2001). The acceptable reliability and validity supports further development of virtual environment as an assessment and treatment tool.

6. CONCLUSIONS

In the near future, more researches will be conducted for investigating the use of VR in rehabilitation since VR is an effective tool for rehabilitation, with its own superiority. The computer graphics are better now and the 3D rendering techniques become more mature, thus contributing to the reality. The software programming has all-round abilities thus contributing to the versatility. The other advantages include that VR can provide a controlled and structured environment. It provides unlimited opportunities for acquiring and processing information, exploring and learning. The patients can do the tasks repeatedly under little supervision. Immediate feedback, prompts, cues in various sensory modalities can also be incorporated into VR so that it can reinforce the desirable response and motivate the patients to continue rehabilitation. Moreover, VR offers a safe environment with little threats so that some barely possible practices in the real world can be done within VR before actual performance. Modifiability and customizability can provide a tailor-made, optimal learning situation for each patient, thus enhancing the generalization of the learning. The advantage of recording each action can be used for further retrieval, analysis and documentation of the patient's progress. For these reasons, virtual reality should be a suitable and effective tool for the stroke rehabilitation.

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