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Telemedicinal Virtual Reality for Cognitive Rehabilitation

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Cognitive rehabilitation and assessment of cognitively impaired patients has traditionally been performed using paper and pencil psychometeric tests. These tests are becoming increasingly dated and do not involve real world tasks. This paper describes a virtual reality kitchen designed to help patients relearn important daily living skills. Some important issues concerning virtual reality and the disabled are discussed. Additionally we describe the development of a prototype networked system to enable a doctor to monitor remotely the rehabilitation of a group of patients.

Keywords: Virtual Reality; Telemedicine; Cognitive Rehabilitation; Brain Injury

1. Introduction

A virtual environment (VE) is a computer generated interactive 3D scenario usually displayed on a computer monitor or a head-mounted-display (HMD). Typically a user has some degree of interaction such as an ability to navigate or pick and move objects. Many recent research papers have focussed on the promise that VEs hold for the treatment of patients with psychological disorders and cognitive impairments [1,2,3,4]. These disorders can be caused by traumatic brain injury (TBI) or through stroke and disease. It has been estimated that, in the US alone per year, 100000 people suffer varying degrees of permanent disability from TBI[5]. Most victims are young males aged between 14 and 24 years and so the requirement for effective rehabilitation to ensure a meaningful future life becomes very important. Common disabilities associated with TBI include memory loss, concentration problems, spatial disorientation, problems with vision, hearing, smell, taste, speech, and emotional difficulties such as anxiety and depression.

A VE enables the patient to be assessed and rehabilitated in a life-like situation in which there is total control over all content. Importantly, all movements and interactions can be recorded in a database and analyzed when required. Additionally, recent improvements in communications technology and the explosive growth of the internet have ensured that telemedicine will be a major means of improving health care in the next century. This paper describes our prototype system, which combines both virtual reality (VR) and telemedicine, and which enables a doctor/specialist to monitor, from a remote location, the rehabilitation of 1 or more patients.

2. Important Issues Concerning VR and the Cognitively Impaired

Cybersickness is the common name to describe adverse effects of exposure to a VE. Some symptoms include motion sickness, visual disturbance and problems with coordination and balance[6]. Fatigue is another common result reported by users[7]. A major cause for many of the problems is the delay in updating the image within the HMD upon head rotation by the user. This delay is caused by a number of factors, most importantly the inherent latency in the position tracking system, but also the graphics display refresh rate and the speed of the workstation. The end result is that a sensory conflict arises due to the vestibular system detecting a head rotation which is not reflected in a corresponding visual update. This is compounded when the head stops rotating because now there is no movement but the visual display changes as the graphics display "catches up". There appears to be little published research on the effects of VEs on the cognitively impaired. One study in fact, by Pugnetti et al, finds no difference in the VR side-effects between neurologically impaired subjects and un-impaired subjects[8]. Bloom, however, raises questions about the suitability of using VR therapy for treating patients with mental disorders[9]. Clearly further research is required to analyze such factors as types of impairment, duration of immersion etc.

Another important point to consider for disabled individuals is the means of user interaction within the VE. Commonly a mouse, joystick or the keyboard are used to control input ie. move forwards, backwards, rotate etc. Since all these methods involve use of the hands this may be unsuitable for certain individuals. Alternatives can be considered such as HMDs, foot pedals, voice recognition, and even "chin" joysticks[10]. If there are serious problems with communicating with the VE then there may be a loss of motivation and also reduced effectiveness of rehabilitation due to the extra effort required.

3. VR Kitchen

Many traditional methods of assessment for the cognitively impaired use either simple motor tasks or pencil and paper psychometric tests such as the Vandenberg Mental Rotations Test. For example, in cases of visual neglect, the patient is asked to indicate the centre of a straight line or to mark all cases of a specific symbol on a sheet of paper, as quickly as possible. One common criticism of these tests is that the patient is not being tested in a real world task. A study by Andrews et al. supports the lack of ecological validity in current assessment tests[11].

To this end we have developed a VR kitchen to help stroke patients and victims of TBI relearn daily living tasks. This VE contains common kitchen items and equipment including a sink, kettle, cup, coffee jar, microwave, power sockets, cupboards and drawers. We have modeled the various tasks required to prepare a cup of coffee and plan to implement a whole series of kitchen tasks such as preparing a microwave meal and using a stove. Our kitchen is fully interactive. The user can turn the tap and fill the kettle with water. The kettle can be powered on, and the water boiled, by connecting the cable to the power socket. The hot water can now be poured into a cup (fig. 1). To make the experience as close to real life as possible we have accurately modeled water flow rates and water boil times. The time to boil water will depend on the volume of water and whether the water was boiled recently.

A kitchen environment can present considerable dangers to a cognitively impaired individual such as the danger of being burnt from scalding water or hot steam, or switching on a kettle that contains no water. A VE enables a patient to become familiar with important tasks in a safe learning environment. The patient can use the VE unsupervised with the program monitoring the patient's progress and giving aural or textual hints as required (fig. 2).

Fig 1. Pouring water using VR glove

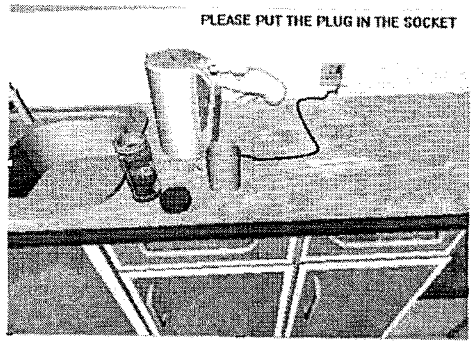

Fig.2 User is prompted after a certain time

Attentional difficulties can be caused by injuries to several parts of the brain and are often the chief disabilities in stroke or traumatic brain injury victims. There are several different types of attention[12] and our VR kitchen offers the opportunity for a therapist to monitor several of these. The patient must focus on the kettle boiling and must be aware when it automatically switches off, thus enabling the water to be poured into the cup. If there is a long delay before the patient reacts then there may be difficulties with focussed attention. Rizzo et al suggest applications to test different types of attention[13].

4. User Interaction

In addition to mouse input we have developed a home-brew VR glove to enable the patient to pick and move objects in the VE. Variable resistive bend sensors are attached to each finger of an ordinary glove. Signals are sent from the bend sensor to the motion translation unit where they are translated into a digital signal range and sent to the VR application through the serial port. This glove is basic and suffers from "jittery" output and limited resolution. It is only accurate enough to pick and move large objects such as the kettle. although it can also be used to point to, and therefore turn on/off, objects such as the tap and socket. For greater performance and accuracy we will use commercial gloves which use optical fibre based sensors. Position and orientation tracking of the glove is achieved using a commercial electromagnetic tracking system.

5. A Preliminary Case Study

We have implemented a preliminary case study using our virtual kitchen involving a few patients from a nearby hospital. The objective of the study was to monitor the patients' ability to navigate and interact with the VE using a computer mouse and our home-brew VR glove. The system comprised a high-end PC which displayed our VR kitchen, and a seventeen inch monitor. A head-mounted display was not used although we plan to use one in future to study aftereffects. We examined 9 patients who had mild to moderate degrees of cognitive impairment and who were, in the opinion of the occupational therapists, good candidates. The patients were required to select objects requested by the therapists using both devices. Selection using the mouse presented few problems although some problems, were encountered with the glove. These were due to problems perceiving depth caused by a lack of immersion, and therefore depth-cues. The position tracking system performed adequately as long as the patient's hand was at least two feet away from the monitor. After some practice most, especially the younger patients, were able to adapt and use both devices satisfactorily. We have been encouraged by the results and plan to soon implement a more comprehensive study.

6. A Networked Virtual Reality Rehabilitation System

Several remote monitoring systems are being developed which take advantage of improved communications technologies. The current condition of asthma patients can be tested remotely using a laptop PC, a spirometer and wireless communication to a remote server[14]. Our proposed system enables a remotely located specialist to monitor and interact with 1 or more patients as they perform cognitive rehabilitative tasks in a VE.

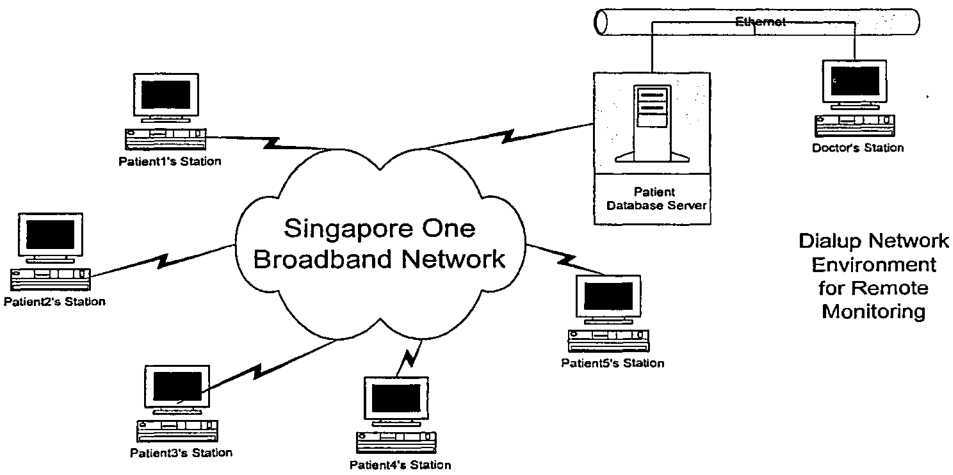

Fig. 3 Networked system using Singapore ONE

We plan to make use of a high speed network such as Singapore ONE[15], the broadband network that links all offices, homes and institutions in the country. The large bandwidth is over 100 times faster than a normal 28.8 kbps analogue modem and this high speed should ensure almost real time interaction between multiple users within a VE (fig 3). Our VR kitchen will be run over this network. A remotely located doctor can interact within the VE and can illustrate the task to be performed by the patient. A mistake by the patient can be played back by the doctor and paused at the critical point. Teleconferencing or internet telephony will be used for communication between patient and doctor.

A database will store all movements and interactions performed by each patient and this will enable a complete reconstruction of any session. The doctor can analyze past performance and results, and can play back previously recorded sessions which were not viewed in real time. The database will summarise data for the patient, creating tables and graphs, and detailing common mistakes perhaps suggesting possible methods of improvement. The rate of progress will be evaluated and the doctor informed by a computer generated email.

Additionally multi-user VEs can be developed. These would be especially beneficial to housebound patients who may feel isolated. For example 4 or 5 patients could meet together in a virtual pub. Each person would be represented as a realistic 3D human with a facial representation taken from a photograph.

7. Future Work

This involves demonstrating measurable benefits of our networked virtual reality system as against traditional methods of rehabilitation and assessment. We are currently working closely with occupational therapists from a major hospital. Several carefully selected patients will undergo rehabilitation from their homes, with therapists monitoring and interacting from the hospital. We will also study the effects of different methods of user interaction and any side effects of VE exposure. The results will be compared with a control group who will undergo traditional therapy.

8. Conclusion

Home health care will be a very important cost saving method of treatment in the new millennium. There will be a huge strain on medical resources such as personnel and hospital beds due to the growing number of elderly people who are by a long way the largest users of healthcare services. Our networked system, in conjunction with virtual reality, is a practical solution to this problem by enabling health care to be performed at home.

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