Assessing stroke patients' ability to remember to perform actions in the future using virtual reality

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ABSTRACT

Difficulties in assessing prospective memory (remembering to perform actions in the future) have contributed to a dearth of empirical evidence as to whether stroke patients are impaired at prospective memory tasks. A virtual environment was used to assess stroke patients' and age-matched control participants' performance of realistic event-based, time-based and activity-based prospective memory tasks. Stroke patients were impaired compared to controls at all the prospective memory tasks, but less impaired at the time-based task. Their prospective memory was more impaired than their retrospective memory, assessed by a free recall test. These results will be useful in directing future stroke rehabilitation strategies to focus on specific memory impairments.

1. INTRODUCTION

Impaired memory is one of the most disabling consequences of stroke (Sohlberg, et al, 1994) and a major target of cognitive rehabilitation. One of the most disabling forms of memory impairment is the inability to remember to perform actions in the future (prospective memory failure). Kvavilashvili & Ellis (1996) suggest that all prospective memory retrieval occasions may be classified as either event-based, time-based or activity-based. In event-based tasks, an action is required to be performed at a cue (e.g. relaying a message when you see a friend); in time-based tasks, an action is required at a previously specified future time (e.g. keeping an appointment at 3 p.m.); in activity-based tasks, an action is required before or after performing an activity oneself (e.g. switching off the stove after cooking).

It is assumed that many stroke patients have problems with their prospective memory, but there is a dearth of empirical evidence to support this assumption (Titov & Knight, 2000). No known study has compared the performance of stroke patients and age-matched controls to investigate whether stroke patients show significant deficits in performing different types of prospective memory task. A possible reason for this lack of empirical research is that it is difficult to perform a realistic and controlled assessment of stroke patients' prospective memory ability in a rehabilitation setting. This problem may be overcome by assessing prospective memory ability using virtual reality (VR).

VR is an interactive computer technology that can create the illusion of being in an artificial world. It provides a detailed three-dimensional computer-generated representation of the world that can be manipulated, and within which one can move around. A form of VR may be presented on a computer monitor and can be explored and manipulated using a joystick or other control device. Virtual environments using this technology can be designed to represent any real-life situation and programmed to record accurate measurements of performance within them. They are able to combine aspects of the realism of "naturalistic" studies with the control of laboratory-based studies.

There is considerable potential for using these virtual environments in the assessment and rehabilitation of people with brain damage which is only just beginning to be realised (see Rose & Foreman, 1999, for a review). For example, they have been used in the assessment and rehabilitation of people with traumatic brain injury (Christiansen, et al. 1998; Davies, et al., 1998), executive function disorders (Mendozzi, et al. 1998), contralateral neglect (Wann, et al., 1997), and temporal lobectomy (Morris, et al., 2000). Pertinent to the proposed investigation, they have been used to study memory processes in vascular brain injury patients (e.g. Rose, et al., 1999), and in memory rehabilitation of a vascular brain injury patient with amnesia (Brooks, et al., 1999). A virtual environment using this technology would appear to be an ideal medium for assessing the prospective memory ability of stroke patients.

This study therefore used a virtual environment to assess the ability of stroke patients and age-matched control participants to perform event-based, time-based and activity-based prospective memory tasks.

2. METHOD

1.1 Participants

Thirty-six stroke patients from the Stroke Rehabilitation Unit at the Kent and Canterbury Hospital, Canterbury, and 22 age-matched adults (mainly relatives of the stroke patients) participated in the study. The criterion for selection of the stroke patients was that, in the opinion of the physiotherapist, they were cognitively able to perform the task.

1.2 Equipment and Materials

The virtual environment was a four-room bungalow. It was constructed using Superscape VRT software, run on a desktop computer, explored using a joystick, and manipulated using a mouse. In the bungalow were 30 items with “to go” labels attached to them. Five of these items had glass components (computer, wine rack, television, grandfather clock and microwave). In the hall was a digital clock with a red button to its left.

A set of 12 photographs of common objects, e.g. a pen, a bus, were used in a free recall test.

A ten item questionnaire about typical prospective memory tasks, e.g. “How often do you set off to do something then can’t remember what?”, “How often do you forget to take medication?”, each item followed by seven rating boxes ranging from “Never” to “Always”, was used in a subjective prospective memory assessment.

1.3 Procedure

Participants were initially asked their age and the number of years they had spent in full-time education. They were also asked if they would lend the experimenter a personal item, e.g. a watch, which they should remember to ask to be returned at the end of the study.

They were then given a free recall test in which they were shown 12 photographs of common objects, one photograph at a time for three seconds each. As soon as they had seen all 12 photographs, they were asked to recall any objects they could remember and were given as long as they required for this task.

In the prospective memory task, participants were first informed that the owner of the virtual bungalow was moving to a larger house with a hall and seven rooms (lounge, dining room, nursery, kitchen, study, music room and bedroom) and that he had put “to go” labels on the furniture and objects to be moved. Their task was to organise these items for the removal men by asking the experimenter to move any items that they considered should go in each of the rooms of the new house in turn beginning with the new hall. (They were given a list of the rooms in the new house to refer to during this task).

They were also given the following three instructions concerning activities that they were required to perform during the removal task:

> *Ask the experimenter to put “Fragile” notices on the items with glass components (computer, wine rack, television, grandfather clock and microwave) before you move them*
>
> *Allow the removal men access to the bungalow by asking the experimenter to click on the red button beside the clock in the hall at exactly five-minute intervals. You may ask the experimenter to check the time on the clock in the hall whenever you like, but you should not use your watch to check the time.*
>
> *Ask the experimenter to close the door every time you leave the kitchen to keep the cat in.*

Before beginning the task, participants were informed that they should remember to ask the experimenter for a written explanation of the study when they had finished performing the task.

The experimenter first entered the bungalow using the keyboard direction keys. At the clock in the hall, each participant was asked to recall the three additional activities they were required to perform during the removal task (the prospective memory tasks). When the experimenter was confident that each participant could recall the three tasks, and the time on the clock in the hall registered an exact multiple of five, e.g. 10.05, 12.30, the furniture removal task began. The task continued until all the items with "to go" labels had been moved. Participants were then asked to recall the three prospective memory tasks.

Finally, participants were given the prospective memory questionnaire to complete. Where necessary, the experimenter completed the questionnaire in accordance with the participant's responses.

If participants failed to ask for the return of their belongings or for the written explanation of the study, these items were given to them as they left the study room.

3. RESULTS

According to Kvavilashvili and Ellis, 1996, there is a retrospective memory component of remembering to perform actions in the future, that of actually remembering what the action is. Unfortunately, 14 stroke patients and two control participants failed to recall all three of the prospective memory tasks when they were questioned immediately the removal task had finished. Indeed, four stroke patients and one control failed to recall any of these tasks. Since participants who failed to recall *what* actions they were required to perform would obviously forget *when* to perform them, these 16 participants were not included in the following analyses.

In all the statistical analyses the probability level was set at 0.05. There was no significant difference between the remaining 22 stroke patients and 20 controls in terms of age, [Patients' mean 72.95 years, Controls' mean 68.85 years, $t(40) = 1.58$, $p = 0.12$], or years in full-time education, [Patients' mean 10.95 years, Controls' mean 10.9 years, $t(40) = 0.66$, $p = 0.94$].

3.1 VR-based prospective memory tasks

Each VR-based prospective memory task produced 3-6 retrieval occasions. Figure 1 shows the mean probability of stroke patients and controls correctly performing the three VR-based prospective memory tasks.

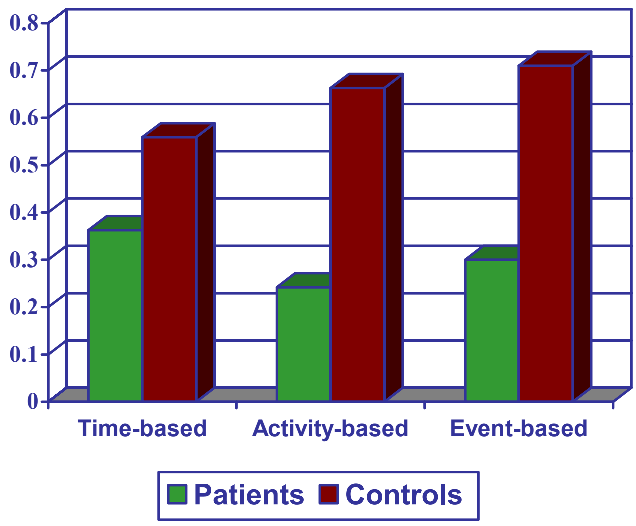

Figure 1. *Mean probability of correct performance in the three VR- based prospective memory tasks.*

Figure 1 indicates that the performance of the controls was higher than the patients in all three prospective memory tasks. However, there appears to be less difference between patients and controls in the time-based task than in the activity and event-based tasks.

Statistical analyses of the probability of correct completion of each of the VR prospective memory tasks used a 2 x 3 analysis of variance (ANOVA) with one between-participants' factor (patients vs. controls) and one within-participants' factor (time vs. activity vs. event-based prospective memory task). There was no significant difference between the three prospective memory tasks, [$F(2,40) = 0.49$, $p = 0.61$], but there was a highly significant difference between the patients and controls, [$F(1,40) = 19.43$, $p < 0.001$]. There was also a marginally significant interaction between the prospective memory tasks and patients vs. controls [$F(2,40) = 2.51$, $p = 0.088$].

A simple effects investigation of this marginally significant interaction showed a highly significant difference between patients and controls in the activity-based prospective memory task [$F(1,40) = 21.63$, $p < 0.001$], and in the event-based task, [$F(1,40) = 12.72$, $p = 0.001$], but only a marginally significant difference in the time-based task, [$F(1,40) = 4.00$, $p = 0.052$].

3.2 Real-life prospective memory measures

Seventeen of the 22 patients and 16 of the 20 controls remembered to ask for the return of their belonging at the end of the study. Conversely, only three patients and ten controls remembered to ask for a written explanation of the study. Chi-square tests revealed that there was no significant difference between patients and controls remembering to ask for their belongings [$\chi^2 < 0.001$, $p = 0.57$], but there was a significant difference between patients and controls remembering to ask for a written explanation of the study [$\chi^2 < 4.89$, $p = 0.01$].

3.3 Prospective memory questionnaire

Results of the prospective memory questionnaire indicated that patients rated their own prospective memory abilities as highly as controls [patients' mean = 55.59, controls' mean = 54.37]. An independent t-test confirmed that there was no statistical difference between the patients' and controls' ratings, [$t(39) = 0.61$, $p = 0.54$]. Interestingly, there was no significant correlation between participants' overall performance in the VR prospective memory test and their scores in the prospective memory questionnaire [Pearsons correlation 0.21, $p = 0.179$].

3.4 A comparison of performance across the three different prospective memory measures

Figure 1 highlights the differences between patients' and controls' overall performance in the VR-based prospective memory test (collapsed across the three VR-based prospective memory tasks), their performance in the real prospective memory tasks and their subjective ratings in the prospective memory questionnaire.

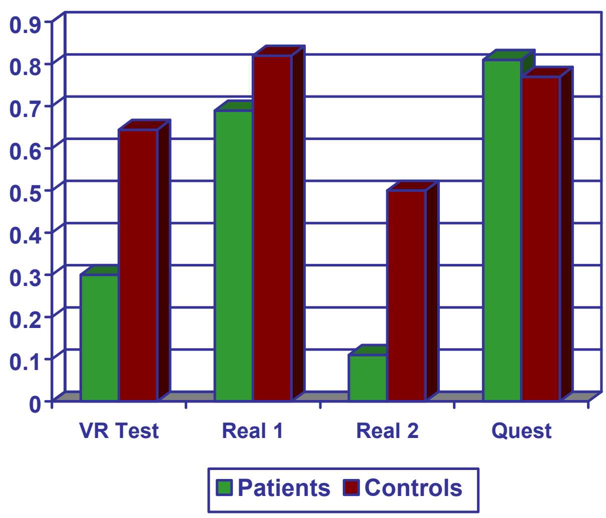

Figure 2. *Performance probabilities in the different prospective memory measures (VR Test = Overall performance in the VR-based prospective memory test; Real 1 = Remembering to request the return of belonging; Real 2 = Remembering to request a written explanation; Quest = Performance in the subjective prospective memory questionnaire).*

As can be seen from Figure 2, patients were impaired at the VR-based prospective memory test and one real prospective memory task, requesting a written explanation of the study. However, they were not impaired at

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the other real task, requesting the return of their belonging. Neither did they subjectively rate their prospective memory as being worse than the controls.

3.5 Free recall (ability to recall events in the past)

Mean performance of patients in the free recall test was 6.5 compared to the mean performance of controls which was 7.3. However, an independent t-test found no significant difference between patients and controls in the free recall test, [$t(40) = 1.42$, $p = 0.16$].

Figure 3 compares overall performance probabilities in the VR-based prospective memory test with performance probabilities in the free recall test.

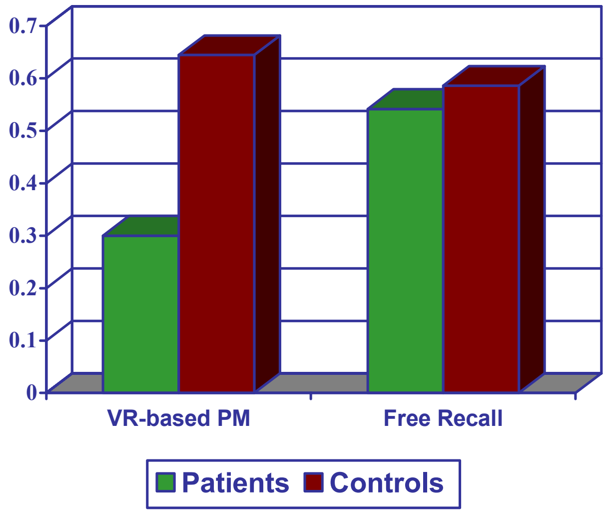

Figure 3. *Performance probabilities in the VR-based prospective memory test and the free recall test.*

As can be seen from Figure 3, patients were more impaired at the prospective memory test than the free recall test whereas the performance of the controls was similar in the two tests. It would therefore appear that stroke patients' prospective memory is more impaired than their retrospective memory, as measured by a free recall test.

4. DISCUSSION

In this study, a virtual environment was used to realistically compare the performance of stroke patients and age-matched control participants on event-based, activity-based, and time-based prospective memory retrieval tasks whilst they were performing a furniture removal task. Also included in the study were two measures of real-life prospective memory, a questionnaire relating to participants' subjective ratings of their own prospective memory abilities, and a free recall test.

An important finding that emerged from the study was that 14 of the 36 stroke patients and 2 of the 22 control participants were unable to recall all three of the prospective memory task instructions immediately they had finished the furniture removal task, even though they had been able to recall them immediately prior to beginning the task. If a stroke patient is unable to remember *what* is required, it is highly unlikely that he or she will remember *when* to do it. This is obviously a very real problem and should be borne in mind by therapists during rehabilitation.

The main result from this study was that the remaining stroke patients were impaired at all three prospective memory tasks, but less impaired at the time-based task. This result is counter to Maylor's (1996) prediction regarding the effects of age on prospective memory ability "...that age-related impairments should be more apparent in time-based tasks than in event-based tasks (which contain environmental support in the form of some external cue event)" p.178. This prediction is based on Craik's (1986) theory of age-related decrements in memory which proposes that self-initiated processing becomes more difficult for the elderly. If self-initiated retrieval is not more difficult for stroke patients, their inability to remember to perform tasks in the future must be attributable to a different impairment, perhaps an inability to multi-task. Alternatively, it is possible that the time-based task (instructing the experimenter to press a button by the clock in the hall at exactly 5-minute intervals) did not represent a realistic time-based task because the interval between each retrieval occasion was too short and stroke patients continually kept the task in consciousness. However, it is unlikely that the control participants adopted this behaviour as their performance in the time-based task was worse than their performance in the two other tasks (See Figure 1). Further research, utilising different time intervals in the time-based task, is required to investigate this effect.

The finding that the stroke patients were not impaired compared to the controls at the real prospective memory task of asking for the return of their property, but they were impaired at asking for a written explanation of the study, indicates how important motivation is in prospective memory performance. If rehabilitation strategies can encourage stroke patients to be more motivated to remember, it follows that their prospective memory abilities would improve.

Another aim of rehabilitation should be to explain to stroke patients that they may be likely to experience difficulties in remembering to perform tasks in the future, particularly as the results of the questionnaire which assessed patients' and controls' subjective knowledge of their own prospective memory abilities indicated that they are not aware of how impaired they are at prospective memory tasks. It is possible, however, that the stroke patients may have been referring back to their pre-stroke behaviour when completing the questionnaire, as some of the questions referred to situations which they would not encounter in a stroke rehabilitation ward.

It would appear from the finding that stroke patients were not significantly impaired at the immediate free recall task but they were impaired at the prospective memory tasks, that prospective memory ability is more affected by stroke than retrospective memory ability. However, the finding that 14 stroke patients failed to recall all three prospective memory instructions indicates that delayed free recall may be more affected by stroke than immediate free recall. Future research should compare stroke patients' immediate and delayed free recall to determine whether stroke patients do have particular problems retaining information during an intervening task.

5. CONCLUSIONS

In this study, virtual reality proved a useful medium to test stroke patients' prospective memory ability. The results of this exploratory study indicated that stroke patients have particular problems with both the content and retrieval of prospective memory tasks, i.e. *what* to remember and *when* to remember. However, when they were very motivated, they were able to overcome their impairments. Rehabilitation therapists should also note that stroke patients, may not be aware that they are susceptible to prospective memory problems.

Future studies would benefit from using this testing procedure to investigate whether there is any relationship between the area of the brain affected by stroke and prospective memory ability. If such a relationship were found, future stroke rehabilitation could be more effectively directed towards specific impairments of individual patients.

6. REFERENCES

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