Virtual Reality and Stroke Assessment: Therapists' Perspectives

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ABSTRACT

Involving users in the early stages of design has implications for the development, usability, acceptance and implementation of new computer systems. A project exploring the practical application of virtual reality to stroke assessment recently commenced at the University of Nottingham, with an emphasis on user centred design. A consortium of stroke therapists and researchers has guided the direction of the project through their involvement at the early planning stage. The consortium has provided broad guidelines for design, potential applications and identified barriers to this technology being routinely used in stroke assessment. This paper describes the process of introducing stroke therapists to virtual reality and presents their views on how it could be applied to stroke assessment.

1. INTRODUCTION

Stroke is a general term used to describe a condition in which the patient has suffered a sudden and usually debilitating traumatic brain injury, resulting in focal neurological deficit. Subsequent impairments which may be evident following a stroke include reduced cognitive functioning, memory loss, visual neglect, and disorders in self-awareness. A variety of assessment tests are available which are used to identify remaining functioning abilities and appropriate methods of rehabilitation. The most common assessment batteries used in the UK are the Rivermead Assessment Battery (RPAB) and the Chessington Occupational Therapy Neurological Assessment Battery (COTNAB). These contain a variety of drawing and picture-recognition tests which are used to determine what the patient can see in the visual field, how they interpret this information, their level of object recognition and memory functioning.

Although these tests are effective and have the benefit of standardised measures, it has been suggested that virtual environments might be useful for assessment and rehabilitation of cognitive functioning (Pugnetti et al, 1995; Rose et al., 1996; Rizzo and Buckwalter, 1997; Riva, 1998), improving spatial skills (Stanton et al., 1997) and learning and practice of everyday life skills (Christiansen et al., 1988; Brown et al., 1999). A project recently commenced at the University of Nottingham to explore the potential for using virtual environments (VEs) in stroke assessment. The project aim is to design and evaluate VEs that could support the goals of currently used assessment strategies, with a focus on practical implementation through user centred design. This work forms the basis of a part-time PhD begun in October 1999 by the first author.

The introduction of the virtual environment as a medium for the assessment of the stroke patient requires careful consideration of a wide range of complex user issues. In particular, implementing this technology within a programme of stroke rehabilitation as part of the routine assessment procedure has broad implications for both the patient and for the healthcare professional. The imposition of virtual reality technology might cause a negative response from healthcare workers who may feel threatened by any change to existing procedures, particularly if the current procedures are considered to be adequate to the task. Garside (1998) reports that some individuals within an organisation are frequently resistant to and resentful of imposed change. We were therefore interested to find out how occupational therapists (OTs) who work with stroke patients would regard virtual reality technology as a potential medium for conducting the tests which would be used as part of their routine assessment. The cutting edge of VR technology in assessment of brain injury contrasts sharply with the humanistic nature of occupational therapy. One of our concerns is that although academic research has demonstrated practical benefits of VR technology in assessment and rehabilitation following traumatic brain injury (Riva 1998; Rose et al 1997), the practical implementation of this technology might be resisted. Without the involvement of the users of this technology during the design phase, their needs and concerns might be overlooked; this could make our project impractical and its results unusable (Norman 1986).

A seminar was held at which occupational therapists were invited to experience virtual environments and to offer their perspectives on the application of VR to stroke assessment. Issues relating to the design and implementation of VEs for assessment were discussed. Encouragingly, there was a very positive response from the OTs who attended, despite most having no previous inexperience of virtual reality. Some concerns were raised which are discussed later. The outcome of the seminar, however, has been the formation of a consortium of occupational therapists who are interested in becoming involved with all aspects of design, evaluation and patient trials. The consortium has contributed to the initial planning and design of virtual environments through their discussion of user needs and will be consulted during redesign and evaluation throughout the project life-cycle.

2. THE SEMINAR

2.1 Overview

A seminar was held at Nottingham to which occupational therapists who work with stroke patients were invited. A list was obtained from Social Services of every community-based occupational therapist in the Nottinghamshire region who works with stroke patients. A list was also obtained of OTs in hospital-based stroke care throughout Nottinghamshire. The target sample was selected because it was a convenient and accessible population, although it is envisaged that future studies will draw from wider sources. A total of twenty-two individuals attended the seminar. Although invitations had initially been restricted to Occupational Therapists involved in care of the stroke patient, some OT departments had, because of workload, delegated colleagues to attend.

The aims of the seminar were:

- To inform healthcare professionals involved with stroke rehabilitation about the project.
- To explore currently used assessment strategies and identify areas which could be improved upon.
- To involve health professionals in discussions about user related issues.
- To discuss the potential of virtual reality technology to provide reliable and valid data.
- To identify an initial programme of VR development and evaluation.

In order for dialogue to commence it was essential that the OTs had some understanding of the nature of virtual reality, it’s limitations and potential. It was also felt that their understanding of patient’s needs as primary users of this technology would be improved by direct experience of a variety of virtual environments. The environments selected have all been used to support learning and/or training of real world activities, some of these have been applied in special needs education. Having gained this experience, it was envisaged that the OTs would be able to make informed decisions about user issues, barriers to implementation and the direction in which they felt the project should progress. This would be achieved by appraising assessment strategies currently used at the outset of and during rehabilitation and attempting to identify features which might be improved upon. It was hoped that a reasonable level of consensus would emerge and that a number of individual OTs would identify themselves as willing to contribute further to the project

2.2 Demonstrations

The seminar was timed to last for two hours. A short presentation was given during which some of the terminology and concepts used in virtual reality and virtual environments were explained. Delegates were then shown four virtual environments, all developed by VIRART, which they were encouraged to experience first hand. Although the virtual environments differed in their complexity and operation there was a planned progression through the demonstrations:

1. The Virtual Factory (Figure 1) is a realistic simulation of a manufacturing industrial environment. It has been designed to teach and assess health and safety issues in a manufacturing industry. The factory contains hazards that the user must identify and where appropriate rectify. The user navigates within an environment comprised of a large central factory area with a number of side rooms. This environment was selected because of its realism and focus on safety issues. Its simple, mouse-based navigational interface also makes it an ideal first encounter with VR (Cobb and Brown, 1997).
2. The Virtual City presents a wide variety of simulated activities, including acquiring items on a shopping list (Figure 2), using a bus and navigating around streets. It is a dynamic city with traffic moving, people

walking, shops into which one can walk and road crossings which must be operated correctly. It offers the opportunity for a wide range of different users needs issues to be addressed within one environment. The quality of visual information is approximately the same as the factory however the size and complexity of the environment and the sequences of tasks required to function within it are greatly increased (Brown et al., 1999).

3. Virtual Lego (Figure 3) comprised of a kit of pieces which must be put together in the correct order to build a three-dimensional model of an off-road vehicle. It was demonstrated to show how spatial manipulation and sequential processing can be practised and assessed in a virtual environment. The complexity of sequencing of tasks is approximately similar to those in the virtual city, however in this environment objects can be manipulated and rotated using the mouse or other standard input device (D'Cruz, 1999).
4. The Tangible Interface is a device that is placed on top of a standard keyboard (Figure 4). It comprises of physical objects with the same feel and appearance of their functional real world counterparts. These include a coffee jar lid, a kettle switch, a spoon, a kettle and a carton of milk. On the screen, a virtual environment simulating a kitchen with virtual objects is displayed. Interacting with the physical objects causes activation of the virtual equivalent. For example unscrewing the coffee jar lid causes the lid in the VE to unscrew. Interactions with physical objects in the real world are mirrored in a safe virtual counterpart (Starmer, 2000). This environment and interface was shown to demonstrate that input need not be limited to mouse and keyboard, but can comprise special-purpose devices tuned to individual environments and patients.

Figure 1. *The Virtual Factory (Cobb and Brown, 1997)*

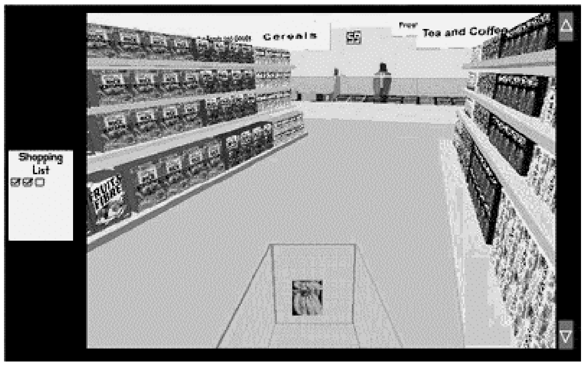


Figure 2. *The Virtual Supermarket (Brown et al., 1999)*

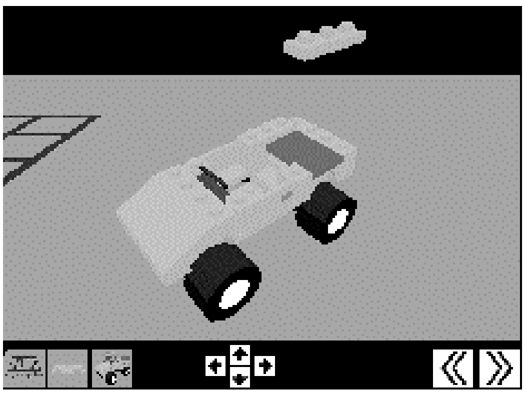


Figure 3. *Virtual Lego (D'Cruz, 1999)*

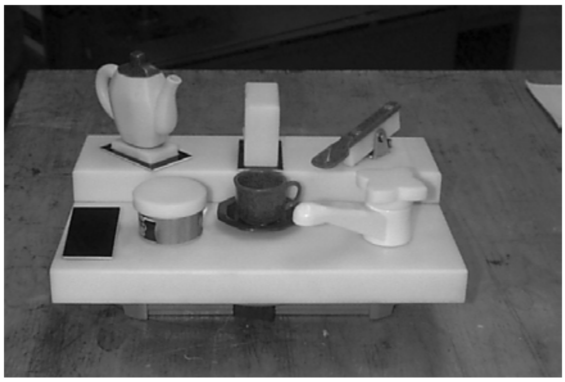


Figure 4. *Tangible interface to the Virtual Kitchen (Starmer, 2000)*

The delegates were divided into 4 groups, each of which spent roughly 10 minutes with each of the demonstrations outlined above. Each demonstration was supported by an individual, experienced demonstrator (two of the authors plus two other VIRART staff), who provided supporting information and explanations as required.

2.3 A Questionnaire

A questionnaire was devised to inform the project about current assessments used by the OTs during stroke rehabilitation and to ascertain therapists perspectives on the use of VR. Time to complete the questionnaire was provided during the seminar, immediately after the demonstrations. The questionnaire comprised five sections:

- *Your experiences with stroke patients* asked the therapists to indicate which aspects of stroke patient care they were involved and whether they were hospital or community based.
- *Your experience of virtual reality* asked if respondents had prior experience and what level.
- *Current Assessment Strategies* was designed to enquire about the tests used to assess the cognitive, perceptual and motor function following stroke.
- *The Patient and VR* listed twenty-five factors which might affect the design or use of a virtual environment system for stroke assessment and invited respondents to rate the importance of each on a five point scale, with the option to add comments.
- *Potential Applications of VR in Stroke Assessment and Rehabilitation* asked respondents to grade ten project ideas each based around a different aspect of assessment.

All of the delegates completed and returned the questionnaire.

2.4 Discussion Questions

The seminar closed with a discussion session, chaired by one of the authors and structured around three focus questions:

1. *What should influence the design of virtual reality systems for stroke assessment and rehabilitation?*
2. *At what stage in the rehabilitation process would virtual reality best be applied?*
3. *What are the barriers to this technology being used routinely in stroke assessment and rehabilitation?*

These questions were asked to initiate discussion and in the hope of eliciting a consensus of opinion on the route to best use of virtual reality technology in stroke assessment. Written notes were taken during the discussion session, which was also taped for future reference.

3. RESULTS

3.1 Demographics

The first two sections of the questionnaire show the context in which the main questions were asked. Half of those present were hospital-based occupational therapists, a further five were community-based OTs. Of those remaining, three were nurses/physiotherapists engaged in Health Care of the Elderly, while the final three were engaged in other duties within the hospital. Only two OTs claimed to have had any experience of VR prior to the seminars, one in the context of online shopping, the other in the context of 3D computer games.

3.2 Current Assessment Strategies

The questionnaire invited respondents to list and comment upon the techniques they currently use in the assessment of a variety of abilities and impairments, namely: a) recall of objects, b) recognition of objects, c) navigation around environments, d) spatial awareness, e) physical mobility, f) visual field defects, g) attention deficits, h) body image disturbance and i) sequencing tasks. Results are shown in Table 1, where numbers represent number of respondents using a particular method to assess a particular area.

Table 1.

Assessment Technique	Applied To								
	a	b	c	d	e	f	g	h	i
MEAMS	2	1							
Rivermead	2	1	1	3	1		1	2	
COTNAB	1	1		1		1		1	
Rey						2	2		
Practical	5	4	5	4	5	2	3	4	4

As one would expect, the Rivermead (Whiting et al 1985) and COTNAB tests are commonly used. Also employed is the Middlesex Elderly Assessment of Mental State (Thames Valley 1989), based upon a book of picture cards. Used with a similar frequency in our sample, the Rey Figure Perceptual Screen assesses the ability of a patient to reproduce a complex abstract line figure, testing the extent of disruption of the field of vision. The most striking feature of Table 1, however, is that under each assessment category at least half the respondents prefer practical tests based upon real physical objects over batteries of more abstract, standardised tests. This preference for real objects was also expressed in respondents' criticisms of currently available methods. Other comments expressed wishes for assessment tasks that consume less of the therapist's time, are more closely linked to treatment and can be modified to provide different levels of difficulty for different patients.

3.3 The Patient and VR

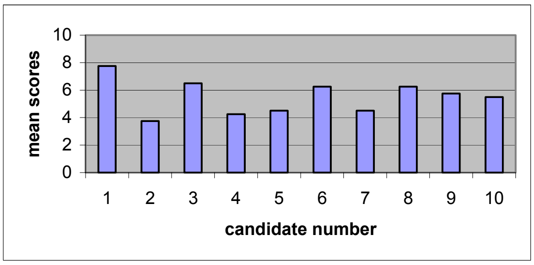
This section of the questionnaire was in two parts. In the first, respondents were presented with a list of eight patient features and asked to assess the weight they would give to each when deciding whether or not the use of a given VE-based assessment tool was appropriate. Space limitations preclude a detailed analysis of the data generated, suffice it to say that patients' age, motivation and severity of stroke were considered important features, as was any risk of side effects. Patient anxiety (due to stroke) was considered important, but somewhat less of an issue. Gender, physical mobility and prior experience of computer technology were generally considered not very important.

The second section sought opinion on factors that might affect the design and practical application of the technology. Ease of use by both therapist and patient was rated very highly, as was realism in the appearance and behaviour of virtual objects and the ability for therapists to set tasks at different levels of difficulty. The ability to manipulate virtual objects was also considered important, but secondary. This may be because of the potential for relearning sequences of operations provided by simpler, non-manipulative environments. The ability of the system to provide quantitative data was similarly rated important. Opinion was split on the question of simple vs. complex environments, perhaps because of a perceived trade-off between realism and usability. The most even response, however, was generated by the suggestion that virtual environments should only be used under supervision.

3.4 Potential Applications of VR in Stroke Assessment and Rehabilitation

Ten potential project areas were devised, based upon the aims and objectives of the currently used assessments. These were: 1) motor rehabilitation, 2) object recognition, 3) navigation, 4) assessing physical safety, 5) recall of object, 6) visual field deficits, 7) sequencing of tasks, 8) recognising body parts, 9) assessing neglected side and 10) ability to describe the function of objects. Respondents were asked to grade the suggested applications in order of preference. The mean ratings given are shown in Table 2, with lower scores indicating stronger preferences. Object recognition (3.75), safety (4.25), recalling objects (4.5) and performing sequences of operations (4.5), present themselves as the favoured applications of the sample of OTs questioned.

Table 2.



3.5 Therapists' Attitude to using VR

Finally, delegates were invited to express their personal response to the use of VR in clinical assessment. Six OTs reported positively that they would be interested in and/or would probably enjoy using VR. A further four expressed concerns over the level of staff training required and pointed out the need for evidence of effectiveness. Only two gave negative responses, preferring to use real world over virtual objects and tasks.

3.6 Discussion Questions

3.6.1 What should influence the design of virtual reality systems for stroke assessment and rehabilitation? As might be expected given the questionnaire responses, the general feeling was that the strength of VR technology lies in its ability to produce realistic, but safe and accessible, models of the physical world. The ability to create a realistic virtual environment in which the patient can perform purposeful tasks not possible in a real-world assessment/rehabilitation situation should therefore be a key design criterion. The assessment tasks should also be controllable. The provision of graded levels of difficulty was seen as highly desirable, both to suit the individual's ability and to respond to achieving targets. The task should also be able to be embedded in a wide range of scenarios to encourage transfer. It should be possible to monitor performance and progress. A good environment design would also allow the patient to work independently of the therapist, perhaps with support from other carers.

Controlling the environment raised some concern due to the differing physical abilities of these patients and it was suggested that a variety of input modes should be offered. These included touch screen, mouse, keyboard and other controls, their suitability would, however, depend upon the application and patient's physical ability. There was some feeling that the technology may not be appropriate during the acute initial phase.

3.6.2 *At what stage in the rehabilitation process would virtual reality best be applied?* There was a lower level of consensus in the group's response to this question than to either of the others. It was suggested that VE s could be used to support initial assessment in hospital, but might also find use during long term rehabilitation in both home and clinical environments. There are clearly a number of scenarios worth further investigation. Attention shifted during the discussion towards the interface between hospital and community. It was suggested that community-based OTs might take a laptop when visiting patients, supervising their actions in a VE tuned to their personal situation. Alternatively, patients might use VEs unsupervised, with the therapist reviewing progress during visits. The move towards more community-based care in the UK has prompted an interest in assessing independence; comments were frequently made about the difficulties of safety assessment and the potential of VR to provide a safe method of developing patients' ability to perform hazardous tasks. The need for realism was again raised several times.

3.6.3 *What are the barriers to this technology being used routinely in stroke assessment and rehabilitation?* Potential cost was identified early in the discussion, though the emphasis soon turned away from raw financial expense to the need to demonstrate clinical effectiveness. The current political climate stresses evidence-based practice, which requires outcome measures showing the benefit of a given treatment. That benefit may be indirect, improving the patient's self-esteem, for example. It was, however, suggested that other forms of computer-based rehabilitation have not been widely accepted because of a lack of evidence of transfer of training. Any successful system must also be quick to set up, easy to use and provide useful and usable feedback directly to the therapists.

4. DISCUSSION AND FUTURE WORK

The occupational therapists who attended the seminar were generally inexperienced in virtual reality prior to attending however their experiences with stroke patients have provided an insight into the issues and concerns which are important to them in the design and application of this technology. The attendance was not high but reasonable considering the source population invited. The actual numbers present meant that individuals were able to work in groups of five or six at each of the workstations. The trade-off was that for analysis purposes the questionnaires only provided a small sample size.

The use of VR to directly replace currently used assessments following a stroke was not pursued by the OTs. Emphasis was placed instead on the possibility of embedding assessment and rehabilitation strategies within realistic but controllable models of environments and (possibly hazardous) tasks which would be difficult to achieve in the real world. There would appear to be significant potential for the successful application of VR to stroke medicine in this way. Concerns were however raised that in order for this technology to be routinely used, in a climate of evidence-based practice, trials of virtual reality assessment tools would have to show a demonstrable improvement over current procedures. This will be the one of the challenges this project will have to meet.

As a follow-up to the initial seminar a meeting was held between the authors and a group of four consultants actively engaged in stroke research. Two of these have an occupational therapy background. The same virtual environments were demonstrated and the same discussion questions posed. The consultants were not, however, invited to fill in the questionnaire as a sample of four would be too small to yield any comparable results. It was interesting to find that the OT-based consultants independently focussed on safety assessment at the point of discharge between hospital/institutionalised care and community care as important. The consultant group also concentrated on the potential of VR to embed treatment strategies with realistic simulated environments rather than to simply mimic the currently available abstract test batteries. The consultant group stressed the individual differences expected between stroke patients even more strongly than the initial OT group. They suggested that initial research in this area might usefully take a case-based approach, working closely with a small number of patients rather than immediately attempting to identify generic techniques and solutions. The concept of enablement was introduced by one consultant and led to consideration of possibilities hitherto not discussed, such as increasing the quality of life by reducing frustrations such as communication problems and increasing patient participation in activities through collaborative interaction in a virtual environment. Language and speech difficulties were identified as a major source of anxiety and frustration amongst those patients who had made a good recovery. Further work in this direction is being initiated and will be the subject of a future report.

The results of the work described here have led us to the conclusion that ecological validity is among the most desirable attributes of stroke assessment and rehabilitation methods. Virtual reality may have the potential to address issues of object recognition, recall, navigation and sequencing tasks in simulated environments which can be controlled, to which levels of difficulty can be applied and from which objective data may be gathered. It is our intention to validate this statement through the development of stroke assessment and rehabilitation methods embedded in a virtual environment that encompasses these attributes. The current intention is to exploit the existing Virtual Supermarket (Figure 3), constructed as part of the Virtual City (Brown et al., 1999) and a faithful copy of a local store. This will provide the opportunities to make comparisons of patient assessment and attainment data between real and virtual environments and which will enable a range of assessments to be presented through recognisable and meaningful activity.

5. CONCLUSION

We have introduced virtual reality as a potential medium for delivering stroke assessment tools to the professionals who were previously unaware that this technology existed or that it could be used in this way. The interest generated has paved the way to the formation of a consortium of professionals who have expressed an interest in informing, guiding and evaluating all aspects of the project and this has also allowed us access to a potential patient base which will be used for future trials.

Possibly the most important issues concerning the use of VEs in stroke rehabilitation are the fidelity of the representation of the real world environment in a VE and the control interface used. This view is similar to that found in a study which examined occupational therapists' use and views of a virtual environment for making coffee (Davies et al., 1998). The therapists were able to complete the task in the virtual environment and it was concluded that VR could successfully be applied to patient training and rehabilitation although issues surrounding mental abstraction level, transfer of training and realistic interaction were identified. However, initial trials which required patients with traumatic brain injury to perform a meal preparation task within a virtual kitchen demonstrated adequate reliability in task performance with little or no evidence of adverse effects, despite the use of an HMD for viewing the virtual environment (Christiansen et al., 1998). This would suggest that it is feasible to apply virtual environment for life skills training in stroke patients.

Having invited healthcare professionals to offer their perspectives on virtual reality as a medium for stroke assessment, we feel that the next logical step in the user centred design process will be to identify patients themselves who are willing to participate in trials of VR technology. The immediate plans for this project are to commence a series of case-based trials, from which it is envisaged we will be able evaluate a variety of virtual environments and provide design guidelines which we hope will inform future projects of this nature.

Acknowledgements. The authors would like to thank all of the Occupational Therapists and Consultants who attended these seminars. Their willingness to participate in this event and enthusiasm to support our research is very much appreciated. We would also like to thank the various members of VIRART and the Mixed Reality Laboratory, University of Nottingham, who assisted in the organisation of the seminar.

7. REFERENCES

Brown, D. J., Neale, H. R., Cobb, S. V. G., & Reynolds, H. (1999). Development and evaluation of the virtual city. *International Journal of Virtual Reality, 4*(1), 28-41.

Christiansen, C., Abreu, B., Ottenbacher, K., Huffman, K., Masel, B. and Culpepper, R. (1998) Task Performance in Virtual Environments Used for Cognitive Rehabilitation after Traumatic Brain Injury, Arch Phys Med Rehabil, Vol 79, 888-892.

Cobb, S.V.G. and Brown, D.J. (1997) Promotion of Health and Safety at Work using a Virtual Factory. *Proceedings of Virtual Reality in Education and Training, VRET'97*.

D'Cruz, M.D. (1999) *Structured Evaluation of Training in Virtual Environments*. PhD Thesis, University of Nottingham.

Davies, R.C., Johansson, G., Boschian, K., Lindén, A., Minör, U. and Sonesson, B. (1998) A practical example using virtual reality in the assessment of brain injury. Paper presented at the *2nd European Conference on Disability, Virtual Reality and Associated Technologies*, Skovde, Sweden.

Garside (1998) Organisational context for quality: lessons from the fields of organisational development and change management *Quality in Health Care (supplement)* 1998: (7) S8-S15.

Norman D (1986) Cognitive Engineering in; Norman D and Draper S (eds*) User Centred System Design: New perspectives on Human-Computer Interaction.* Hillsdale New Jersey, Erlbaum Associates

Pugnetti, L., Mendozzi, L., Motta, A., Cattaneo, A., Barbieri, E. and Brancotti, A. (1995) Evaluation and retraining of adults'cognitive impairment: Which role for virtual reality technology. *Comput. Biol. Med.* Vol 25, 213-227.

Riva, G. (1998) Virtual Environments in Neuroscience, *IEEE Transactions on Information Technology in Biomedicine*, vol 2, No 4, 275-281.

Rizzo, A.A. and Buckwalter, J.G. (1997) Virtual reality and cognitive assessment and rehabilitation: The state of the art, In: G.Riva (Ed.) *Virtual Reality in Neuro-Psycho-Physiology*, Amsterdam: IOS Press, 123-146.

Rose, F.D., Attree, E.A. and Johnson, D.A. (1996) Virtual reality: An assistive technology in neurological rehabilitation, *Curr.Opin. Neurol*., vol 9, 461-467.

Rose, F. D., Attree, E. A., & Brooks, B. M. (1997). Virtual environments in neuropsychological assessment and rehabilitation. In G. Riva (Ed.), *Virtual Reality in neuro-psycho-physiology: Cognitive, clinical, and methodological issues in assessment and rehabilitation* (pp. 147-156). Amsterdam: IOS Press.

Stanton, D., Foreman, N and Wilson, T.N. 1998. Uses of vr in training: developing the spatial skills of children with mobility impairments. In G, Riva, bk weiderhold, and e. molinari. Ves in clinical psychology: scientific and technological challenges in advanced patient-therapist interaction, IOS press, 219-233.

Starmer, T. (2000) Development of an input device to control a virtual environment for students with disabilities. Undergraduate Thesis, University of Nottingham.

Thames Valley Test Company (1989) *The Middlesex Elderly Assessment of Mental State* Bury St Edmonds, TVTC.

Whiting, Lincoln, Bhavani and Cockburn (1985) *Rivermead Perceptual Assessment Battery* Windsor NFER-Nelson.