Virtual city for cognitive rehabilitation

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ABSTRACT

Virtual Reality technology offers opportunities to create new products, which could be applied to the cognitive rehabilitation of people with acquired brain injury or neurological/psychiatric disorders. The effects provided by Virtual Environments (VE) stimulate cerebral neuroplastic changes, enhancing the rehabilitation process. This article discusses issues related to this field and presents the main features of an Integrated Virtual Environment for Cognitive Rehabilitation development process. Finally, initial results of an experiment with a group of schizophrenic patients are presented.

1. INTRODUCTION

Nowadays the medical practices allow an increase rate of survivors from traumatic brain injuries and diseases affecting the CNS (Moline,1997). New medications for neuropsychiatric patients are also diminishing the percentage of hospitalization and are promoting the permanence of these people at their home. These changes stimulate the development of new therapeutic approaches that integrate basic elements of social life and contribute to enhance the life quality of these people. Nevertheless, in all these cases, the therapy takes a long time, the support material is expensive and the construction and maintenance of the real environments is complex. The combination of all these factors creates a barrier that makes it difficult to access and diffuse therapeutic practices to a greater number of people (Costa,2000).

These questions are stimulating the researchers of variable fields to search new options for rehabilitation of people with disabilities. In this context, the computer has been explored by different kinds of software that reproduce, basically, the neuropsychological tests or traditional rehabilitation procedures (Digit,1996), (Shapes,1996), (Pipeline,1998). However, we observe that specific results of the experiments are not published, creating problems in order to make a more accurate assessment to these products.

Recently, Virtual Reality (VR) based software are thought to be potentially more representative of every-day life situations than paper-and-pencil treatment procedures or limited software (Pugnetti,1998). VR provides opportunities to enlarge the actual limits of mental health applications providing valuable scenarios, with common elements for the patients, putting them in contact to daily life activities.

Although Virtual Reality immaturity and high costs of equipment, some results points this technology as a new possibility to rehabilitate cognitive and motor functions, stressing its characteristics as a motivator factor.

So, VR can amplify the therapeutic possibilities by virtual environments with exercises that stimulate a variable kind of abilities, proposing similar tasks, alike real life. Another positive factor of this technology is that Virtual Reality integrated in the WWW could disseminate virtual therapeutic environment to small villages far from urban centers or where economic problems do not allow the construction of real scenes.

Starting from several technical and theoretical factors involved in the conception of a product for treatment of brain disorders, this article will describe a virtual environment (Ambiente Virtual Integrado para Reabilitação Cognitiva - AVIRC) that explores therapeutic strategies and can act, in an integrated way, in different types of cognitive disorders, offering significant opportunities to the patients to face common day-to-day situations.

In the next sections we will present the basic characteristics of virtual reality technology discussing the brain plasticity theory that supports ability recover, illustrate the discussion with some cognitive rehabilitation experiments and propose AVIRC. Finally, we will describe the initial results of an experiment with a group of schizophrenic patients.

2. VIRTUAL ENVIRONMENTS

Virtual Reality includes advanced technologies of interface, immersing the user in environments that can be actively interacted with and explored. The user can also, accomplish navigation and interaction in a three-dimensional synthetic environment generated by computer, using multi-sensory channels (Pinho,1999). In this case, diverse kinds of stimuli can be transmitted by specific devices and perceived by one or more user's senses.

There are three fundamental ideas involved in VR: immersion, interaction and presence. Immersion can be achieved by the use of HMD (head mounted display), trackers, electronic gloves, that support user navigation and interaction, supporting the exploration of the environment and the manipulation of objects in an easy manner. Interaction means communication between the user and the virtual world. Presence is a very subjective sense that the user is physically inside of the virtual environment, participating in it.

So, a Virtual Environment is considered to be a three-dimensional, real-time graphical environment synthesized by a computer, in which the viewpoint or the orientation of displayed objects are controlled by the user via body position sensors or user-input devices (Lewis,1997).

3. COGNITIVE REHABILITATION BY VIRTUAL REALITY TECHNOLOGY

Virtual Reality applications have some interesting results based on environments that work with specific disabilities related to mental problems or motor problems, as can be observed in: Treatment of phobias (North,1998); Manipulation of wheel chairs for children (Inman,1997); Body image disturbances (Riva,1998); Head injury (Christiansen,1998); Parkinson disease (Riess,1995), and Autism (Stricland,1997), among others. As a psychological approach, there have been experiments to help cancer patients accept their disease (Oyama,1997). For attentional retraining and perceptuo-motor skills reacquisition, there has been work by Wann et al. (Wann,1997).

These pilot studies sought to discuss and experiment with the possibilities offered by VR technology. In these contexts, VR is allowing therapeutic practitioners to help their patients in a number of innovative ways, offering new approaches to old questions and increasing the effectiveness of consolidated methodologies.

Therapeutic change may occur either through the reacquisition of cognitive abilities via repetitive, systematic, hierarchical restorative cognitive stimulation or by teaching alternative compensatory strategies that target actual task performance (Rizzo,1997). Another fundamental issue, which has important implications regarding the feasibility of a VR approach applied to cognitive rehabilitation, concerns the concepts of transfer or generalization of functions. In this case, the environment would stimulate transfer from the training environment to day-to-day functioning. The principal objective of every rehabilitation program is generalization that promotes autonomy and independence. In this work, generalization is related with pedagogical issues and associated strategies to keep learning process more effective.

3.1 Plasticity in Rehabilitation

Brain plasticity can be taken as any behavioral modification that results from environmental stimulus change. The central nervous system is able to learn new behaviors, adapt to changing environmental situations, acquire memories and mature with the organism (Schwartzkroin,1989). In this sense, neural plasticity ability supports the cognitive rehabilitation procedures and VR provides resources to augment interactive experiences.

From the results of experiments in this field we perceive that among different functions that emerge from neurons interaction, the ability of learning and exploit memory can be influenced by external factors. So, the possibility of brain plasticity from environmental stimuli is essential to therapeutic strategies development to many cerebral disorders.

3.2 Schizophrenia

Schizophrenia is a serious psychiatric illness that can involve massive disruptions of thinking, perception and behavior, and is not yet cleared up by science. Its prevalence rate is about 1% of world population. This disease is characterized by pervasive impairment in social, cognitive, affective, and daily functioning. The more common deficits are associated to attention, information processing, memory, learning and executive functions (Cassidy,1996).

In the related literature we can find studies about psychiatric disorders and associated experiments with computer software. Not always the results indicate that the psychiatric patients can work productively with computers (Field,1997), but there are some that confirm the positive computer influence to enhance the cognitive performance of these people (Burda,1994). In all these cases, they worked with simple software on a flat-screen. We haven't found cognitive rehabilitation experiments using VR equipments to work with schizophrenic patients.

So that, two main aspects have supported this work: first of all, we searched a virtual environment that could be used to stimulate the fundamental cognitive functions that compose the elaborated activities for different nature of disabilities. Second, we verified if schizophrenic patients could use this environment to learn and train lost abilities, individualizing this process to meet the needs of each patient.

4. AVIRC: INTEGRATED VIRTUAL ENVIRONMENT FOR COGNITIVE REHABILITATION

AVIRC presents an unified workspace: a city. It focuses on cognitive processes training such as attention and concentration, and functional skill training such as executive functioning in everyday life. AVIRC is composed of a square surrounded by streets and several types of constructions: houses, stores, a library, a church, small buildings and a supermarket that can be freely visited by patients. Some characteristics of AVIRC development are discussed in the following subsections:

4.1 Motivation

Usually, VR experiences in cognitive rehabilitation are restricted to a specific disabilities set. In general, we observed that examples work with punctual functions related to each disability, acting mainly in attention, memory, motor abilities and using challenging strategies, common to educational games. In respect to the integration of transfer and generalization concepts, it is verified that in many experiments this aspect remains to be solved.

The above considerations have guided this research towards a proposal that embodies different integrated cognitive function stimuli, respecting interdependence between them and information processing.

Based on these observations, we have searched for an environment that could be used in the treatment of different brain disorders.

4.2 Objective

The main aim of this research led to the design of an interactive tool to support cognitive ability recover for people with different cerebral disabilities, exploring learning strategies and offering opportunities for expressive experiences with day-to-day situations.

4.3 General requirements definition

This environment is based on neuropsychology, psychology and neurology, and considers the recuperation of cognitive functions and executive functions. In this case, cerebral plasticity, therapeutic strategies for cognitive rehabilitation, technical aspects and experimental results of similar works are considered in the construction of this environment. We also consider, pedagogical aspects of recognized theories: some tasks support a restorative approach, with a behavioral emphasis; other tasks involve the integration of cognitive functions, under a more constructivist functional approach (Costa,1999).

In Table 1 we define virtual environment based on a framework that detail its fundamentals components and main characteristics.

4.4 Specific requirements definition

In this environment the patient can accomplish different tasks, carefully associated to the therapeutic procedures used for the rehabilitation of specific functions, and aiming to offer transfer and generalization opportunities. In Table 2 some tasks and the appearance of the associated physical environments are briefly described.

4.5 Prototyping

The prototype was built using VRML (Virtual Reality Modeling Language) that provides three-dimensional worlds with integrated hyperlinks that can be put on the Web. The programming is supported by Internet Space Builder and Internet Scene Assembler software (Parallelgraphics®), and the interaction was programmed in JavaScript.

The scenes can be visualized on a web navigator (ex:Netscape® or Explorer®) with a plug-in (ex:Cortona®). In figures 1, 2 and 3 some scenes of version 1.1 are presented.

Table 1: *AVIRC description framework (Costa,2000b)*

Characteristics	AVIRC
Therapeutic approach	Restorative and functional
Disorders	Psychological, Psychiatric and Neurological
To make possible	Transfer and generalization
Cognitive Functions	Alertness, attention, concentration, perception, memory and executive functions
Equipment	PC Pentium III 450 with a graphical accelerator device, I-Glasses and a head position tracker
Interaction model	1st moment: subjective immersion 2nd moment: spatial immersion
Interaction degree	1st moment: low 2nd moment: medium/high
Interaction equipment	1st moment: flat-screen 2nd moment: I-glasses with a head motion tracker

Table 2. *AVIRC's description of tasks*

Cognitive Function	Physical Environment Description	Task Description
Alertness	A house room with many decorative elements: clock, photos, pictures, calendar, background music	Answer the date, hour, turn on/off the radio and the lamp
Concentration	Clean music room without ornamentation contains a piano with colored keys	Hear and repeat a sequence of musical notes associated to colored keys
Attention	Game room contains books and games.	Solve different puzzles and choose books, guided by some clues
Perception	In the street several people are walking	Look at cards with people's photos and identify those that have already been seen
Memory	Street contains a public telephone and several traffic signals	Reach the telephone and dial a number starting from oral and written requests

4.6 Experiment

Some initial experiments are being carried out with a group of schizophrenic patients to test AVIRC acceptance. These patients participate in a treatment program of a public day-hospital, where they spend all day and at night they go home. They develop a lot of activities as arts, games, sports, music and recently, computer classes. To make this research we had to submit a project to an ethical committee, according to Brazilian Health National Council.

In this study, we are interested in observing if the patients accept the VR technology and respond to virtual environment tasks in a meaningful way. The initial experiments consider three stages:

1 - Integration of the patients with the computer;

2 - Flat-screen virtual environment acceptance;

3 - Immersion equipment acceptance.

We have a group composed by 5 patients and we are at the end of the first stage. All group members are accepting computer sessions and show a growing enthusiasm. The initial results indicated that patients were self-adapting to technology, which allowed us to proceed to second phase.

On the first attempt, they were a little surprised with the colors and objects composing the scenes. They are very motivated and no absence was observed on the two first sessions. They are very curious about the I-glasses. We will only verify cognitive gains during the fourth stage.

Figure 1: *Music Room.*

Figure 2: *Partial view of the city.*

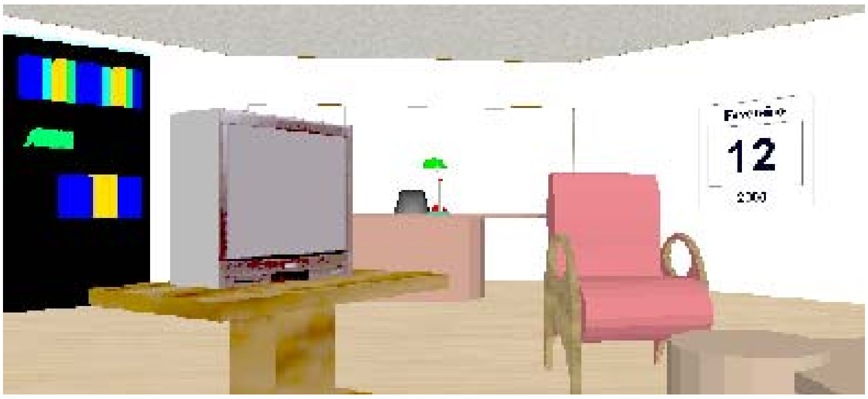

Figure 3. *Alertness room view.*

5. CONCLUSION

This paper presented an Integrated Virtual Environment for Cognitive rehabilitation (AVIRC), stressing possibilities for using in cognitive rehabilitation of people with different cerebral problems.

The main characteristics presented here were defined starting from the study of neuropsychological procedures for treatment of different types of brain disorders. Unlike the commercial products available today, this environment explores some traditional tasks under a more constructivist focus, following the current pedagogic tendencies and integrating rehabilitation strategies for different cognitive functions. The use of VR technology, with an interface close to reality, could reduce the gap between patients and daily life tasks, decreasing fear of errors.

The research described in this work as well as numerous studies going around the world indicate that virtual environments may be of great value in helping individuals principally when training them to live better in the real world.

The initial results with a group of schizophrenic patients indicate that they accept the VR technology and they are very enthusiastic to work with computers. However, the use of this technology in cognitive rehabilitation of schizophrenia merits further research to determine functional relationships between the virtual environments and cognitive gains.

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6. REFERENCES

Burda, Philip; Starkey, Timothy; Dominguez, Florentino; Vera, Vivian; (1994), Computer-Assisted Cognitive Rehabilitation of Chronic Psychiatric Impatients; *Computers in Human Behavior*, Vol 10(3), pp 359-368.

Cassidy, James; Easton, Margareth; Cappelli, Carol; (1996), Cognitive Remediation on people with Severe and Persistent Mental Ilness; *Psychiatric Quartely*, Vol 67, winter.

Christiansen, Charles; Abreu; Beatriz; Ottenbacher, Kenneth; Huffman, Kenneth; Masel Brent; Culpepper, Robert; (1998), Task Performance in Virtual Environments used for Cognitive Rehabilitation after Traumatic Brain Injury; *Archives Phys. Med. Rehabilitation*, vol 79, pp. 888-892, August.

Costa, Rosa Maria E.M..; Carvalho, Luís Alfredo; Aragon, Doris; (1999), Ambientes Virtuais Na Reabilitação Cognitiva, *II Workshop Brasileiro de Realidade Virtual*, Marília, Brasil, pp. 115-126. (in Portuguese)

Costa, Rosa M.; Carvalho, Luis; Aragon, Doris; (2000), Virtual Reality In Cognitive Retraining, International Workshop on Advanced Learning Technologies, Palmerston-North, New Zeeland. (to be presented)

Costa, Rosa Maria E. M.; (2000b), Ambientes Virtuais na Reabilitação Cognitiva de Pacientes Neurológicos e Psiquiátricos, *D.Sc. Thesis*, Coppe- Universidade Federal do Rio de Janeiro, August. (in Portuguese)

Field, Colin; Galletly, Cherrie; Anderson, Deborah, Walker, Pieter, (1997), Computer-aided Cognitive Rehabilitation: possible aplication to the attentional deficit of schizophrenia, a report of negative results, *Perceptual and Motor Skills*, 8(5), pp 995-1002

.Inman, Dean; Loge, Ken; Leavens, John; (1997), VR Education and Rehabilitation, *Communications of the ACM*, 40(8), pp 53-58.

Lewis, Christopher; Griffin, Michael; (1997), Human Factors Consideration in Clinical Applications of Virtual Reality, *Virtual Reality in Neuro-Psycho-Physiology*; Ed. Giuseppe Riva, IOS Press.

North, Max; North, Sara; Coble, Joseph; (1998), Virtual Reality Therapy: An Effective Treatment for Phobias, *Virtual Environments in Clinical Psychology and Neuroscience*; Ed. Riva, Wiederhold, Molinari, IOS Press.

Pugnetti, L.; Mendozzi, L.; Attree, E.; Barbieri, E.; Brooks, B.; Cazzullo, C.; Motta, A.; Rose, D.; (1998), Probing Memory And Executive Functions with Virtual Reality: Past and Present Studies; *CyberPsychology & Behavior*, Vol 1(2), pp 151-161.

Oyama, Hiroshi; (1997), Virtual Reality for the Palliative Care for Cancer, *Virtual Reality in Neuro-Psycho-Physiology*; Ed. G.Riva, IOS Press, Holanda,.

Riess, Torn; Weghorst, Suzanne; (1995), Augmented Reality in the Treatment of Parkinson's Disease, *Interactive Technology and the New Paradigm for Health Care*, Eds K. Morgan, R. Savata, H. Sieburg, R. Mattheus, J. Christensen, IOS Press.

Pinho, Márcio; Kirner, Cláudio; (1999), *Uma Introdução à Realidade Virtual*, in http://www.inf.pucrs.br/~pinho/RV/tutrv.htm. (in portuguese)

Riva, Giuseppe; Bacchetta, Monica; Baruffi, Margherita; Rinaldi, Silvia; Molinari, Enrico; (1998) Experiential Cognitive Therapy: a VR based Approach for the Assessment and Treatment of Eating Disorders; *Virtual Environments in Clinical Psychology and Neuroscience*, Eds. Riva, Wiederhold, Molinari; IOS Press.

Rizzo, Albert; Buckwalter, Galen; Neumann, Ulrich; (1997), Virtual Reality and Cognitive Rehabilitation: A Brief Review of the Future, *Journal of Head Trauma Rehabilitation*, 12(6), pp 1-15.

Schwartzkroin, Phillip, Fuchs, Albert; (1989), Physiological Bases of Learning, Memory, and Adaptation; *Textbook of Physiology*, Eds Patton, Fochs, Hille, Scher e Steiner, WB Saunders Company, Vol 1, pp 718-735.

Strickland, Dorothy, (1997), Virtual Reality for the Tratment of Autism; *Virtual Reality in Neuro-Psycho-Psysiology*; Ed. Giuseppe Riva, IOS Press.

Wann, John; Rushton, Simon; Smyth, Martin; Jones, David; (1997), Virtual Reality for the Disorders of Attention and Movement, *Virtual Reality in Neuro-Psycho-Physiology*; Ed. Giuseppe Riva, IOS Press.