Developments of a collaborative research on VR applications for mental health

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ABSTRACT

The collaboration between or two scientific institutions is giving significant contributions to VR research into several fields of clinical application. Concerning the important issue of side-effects, future studies will clarify whether the encouraging results obtained in the recent past on patients with neurological diseases can be confirmed, and whether specific recommendations for the use of immersive VR in selected clinical populations can be made. Recent collaborative studies on the application of non-immersive VR to improve clinical testing of spatial memory provided evidence of good replicability of results in both healthy and neurologically affected groups. The development of retraining applications for spatial memory impairments and future studies aimed at assessing the impact of ambulatory disability on spatial cognitive abilities will be based on these findings. Finally, a newly approved transnational project will lead our groups into the field of the assistive technology to improve working skills and opportunities for employment of subjects with mental disabilities who seek a job.

1. INTRODUCTION

Though it has been promoted as a revolutionary tool, VR has not yet entered the practice and changed the methods of cognitive testing and rehabilitation. In the last years, our two groups in Milan (FDG) and London (UEL) have been developing the rationale to propose VR as a clinical tool (Rose et al., 1996), along with software programs and testing protocols to assess whether this technology can be safely used to produce meaningful results in both research and clinical contexts. This report deals with some the most recent developments of our collaborative projects.

The ARCANA system has been originally developed by the FDG group on a proprietary platform as a research prototype for testing so-called "strategy application disorders" (Pugnetti et al., 1995). An improved version is now being developed in collaboration with UEL which has an open configuration and runs on a standard fast PC workstation in both immersive and non-immersive modes. The paradigm has been conceived as an analog of the Wisconsin Card Sorting test (WCST) and, as such, has a well developed rationale and a known field of application. The psychometric characteristics of the preceiding immersive system have been recently published (Pugnetti et al., 1998). It has also proved useful to expand our investigations into aspects of VR-induced exploratory behavior and their psychophysiological correlates (Alpini et al., 1996; Pugnetti et al., 1996b; see also Alpini et al., this volume).

While the results of studies with the new versions are not yet available, here we discuss unpublished findings concerning side-effects reported by subjects performing with a previous version of the ARCANA system. Data are pertinent to an immersive VR system equipped as described in a previous publication (Pugnetti et al., 1995).

2. METHODS

A group of 36 outpatients with neurological impairments as a result of multiple sclerosis (MS; n.25), cerebrovascular disease (n.4), traumatic brain injuries (n. 5) and normal-pressure hydrocephalus (n.2), as well as 32 healthy subjects matched for age and level of education gave informed consent to participate in VR test sessions of 30 min. (max 45 min.) duration. Patients were recruited among those with stable neurological conditions, good bilateral visual acuity, preserved dominant hand dexterity, no history of epilepsy, psychiatric, and vestibular disorders, and no severe cognitive impairments. Before any test session patients and healthy subjects were carefully explained the aims of the research, the potential risks of immersive VR and the way they could interact with the virtual environment (VE). They were also interviewed about previous experiences with immersive VR, their susceptibility to common kinetosis and were given the opportunity to wear the headset (HMD) and practice with a VE for up to 15 min. while instructions were repeated to assure full comprehension. All practice and test sessions were carried out with the subjects seated comfortably on a revolving chair; this was necessary to equate controls' posture to that of some of the patients who could not stand easily because of their illness. They were instructed to rotate smoothly and slowly, and to avoid the combination of forward movements in the VE and real head rotations that produces a visuo-vestibular sensorial conflict. Subjects who reported any side-effect during or after the practice trial were reassured about the benign nature of the symptoms and let reexamine their decision to participate. Both training and test sessions were carried out in a small but quiet facility in the hospital. Test sessions were run usually the day after practice. The recording of side-effects was done according to the methodology reported by Regan and Price (1993, 1994). The Motion Sickness History Questionnaire was used to rate each individual's susceptibility to common kinetoses. A Malaise Questionnaire (MQ) was used to rate every 5 min. the presence of physical discomfort of the cybersickness type. A Simulator Sickness Questionnaire (SSQ, 26 items version) was compiled by the subjects prior and immediately after the VR session to rate the presence and severity of symptoms other than malaise. In addition, structured interviews based on the Equipment and Display Questionnaire (E&DQ) and a 6 items Immersion Questionnaire were carried out at the end of each test session to investigate ergonomic factors and subjective feelings. The reader is referred to the original papers by Regan and Price (1993, 1994) for details on the rating instruments.

3. RESULTS

No instance of severe malaise was observed during the practice sessions. Five subjects (7%) - 3 healthy controls and 2 MS patients - asked to discontinue the test because of severe nausea which always occurred between 10 and 20 min. from the start. Their condition did not require any treatment besides removal of the HMD and a brief rest. Their data were not included in the other statistics.

The prevalence of VR-induced side-effects of any type was measured by the pre- vs post-VR change on the total sickness score of the SSQ, and was around 7.5 points for both patients and healthy controls who completed 30 min. of testing. This figure was neither related to the severity of neurological condition (in the patients) nor to an unspecific sensitivity to kinetoses (for both groups). The maximum change was observed on Kennedy's (Kennedy et al., 1992) disorientation factor (mean of 12 points), followed by the oculomotion and nausea factors (< 6 points each). Patients' change scores did not differ from those of healthy controls, but patients reported more symptoms than controls on the pre-immersion questionnaire (Fig. 1). The time course of the malaise ratings (any symptom) followed the pattern already described by Regan and Price; it increased to reach a maximum of 40% of the subjects reporting at least one symptom after 25 min. of exposure, decreasing thereafter to return at baseline levels 10 min. after the end of the session (Fig. 2). According to the Malaise Questionnaire the mean prevalence of VR-induced symptoms across a 30 min. session was 16% in the total sample. Again, patients did not report more symptomatology than healthy controls. No clinically significant aftereffects were noticed on standard clinical balancing tests performed only on healthy subjects after the session. Since it was felt that clinical measurements could not pick up subtle changes, a pilot study using a computerized stabilometric platform was carried out on a subsample of 8 healthy subjects and 6 MS patients who performed on ARCANA1 and were matched to 10 controls and 7 MS patients who did not (Pugnetti et al., 1996). Results showed that immersive VR did not worsen static balance of either healthy controls or neurological patients, though the latter showed significant absolute impairments due to their illness. On average, 38% percent of the total sample (n.63) reported some negative rating concerning ergonomic factors of the HMD (8 items on the E&DQ) ; over 60% rated it as uncomfortable for a prolonged use, while 48% found it too heavy. On average, the efficiency of the display was rated somewhat negatively by 25% of the subjects, mainly due to the difficulty to adjust the focus and

the interpupillary distance or to keep regulations steady, so that the images were felt to be unstable. The response of the tracker was also criticized by 25% of the users; they felt it too slow or imprecise for an optimal interaction with the VE. Fourty-five percent of the users were not satisfied with the pointer we have adopted (a hand-made light-weight woodden key incorporating the tracker). Only 21%, however, reported that the above ergonomic factors may have interfered with their performance. Interestingly, patients tended to complain less than healthy controls. From the analysis of the Immersion Questionnaire it emerged that 34% of the subjects did not felt "immersed" in the virtual environment (VE) during the session, whereas 43% did; in the remaining 22% the effect was modest. Only 14% felt that the virtual experience had changed their affective state toward excitation; 58% reported no change, whereas 27% reported only slight changes. Again, no significant differences between patients and controls were noticed.

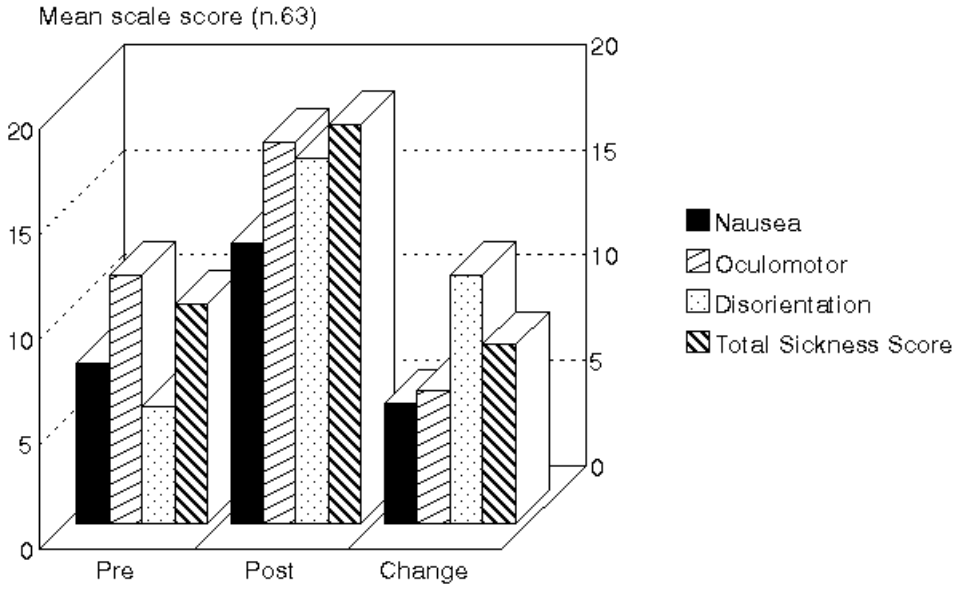

Figure 1. *Pre-immersion, post-immersion and change profiles on the SSQ for all subjects*

4. DISCUSSION

These findings are consistent with those reporting that immersive VR causes symptoms incompatible with the continuation of the experience in 5 to 30% of the users (Stanney et al., 1998). Since hardware factors are important determinants of the type and prevalence of VR-induced side-effects, our data should be compared only to those obtained with comparable systems and methodologies. Regan and Price's data (1993) seem to fit that criterion. These authors reported higher overall ratings of nausea both on the MQ and on the SSQ which were aministered to a larger sample (n.150) of healthy volunteers. Eight (5%) of their subjects withdrew from the experiment because of severe side-effects. The differences may be explained by a number of concurrent factors such as the weight and technical characteristics of the HMDs, but perhaps the most notable differences were that our subjects, unlike those in the largest Regan's study, were seated on a revolving chair during the experiment and that they were instructed to avoid movements that could exacerbate symptoms. In a further experiment comparing 44 subjects who sat while using VR with 24 subjects who stood, the same authors did not find significant differences in malaise ratings (results reported by Kolasinsky, 1995). Further studies are needed to clarify this issue.

The time-course of malaise ratings was also different; in Regan's study symptoms were reported to last longer after reaching their maximum at the end of the VR period (20 min.). In our study, symptom reports tended to decrease after 25 min., when subjects were still interacting with the VE, and returned to baseline levels at the 10 min. post-VR rating point. Therefore, our findings do not totally support the conclusion that malaise ratings increase steadily as a function of immersion time. The occurrence of a within-session adaptation may also be considered. Our hypothesis is that adaptation may be associated to the changing pattern of interaction that we have shown to occur with our VR task; i.e. the permanence in each successive

virtual room decreased as subjects routinized their strategy and reduced exploratory movements (head and body rotations) in the second half of the session (Pugnetti et al., paper presented at MMVR6, S. Diego, CA, January 21, 1998).

Perhaps the most relevant finding of our study is that neurological patients - who may be considered at greater risk to develop side-effects from immersive VR - are, in fact, no more susceptible than matched healthy subjects. It should be noticed, however, that this conclusion is based mostly on subjective reports, and that they do not necessarily imply that immersive VR can be already safely introduced in a clinical setting. Our findings on the maintenence of static balance after VR exposure confirm Regan and Price's results (1993, 1994), but appear at variance with other studies (Di Zio and Lackner, 1997) reporting significant - albeit transient - impairments of static balance after immersive VR. Admittedly, our data need confirmation on larger patient samples. It seems, however, that comparisons across studies employing such diverse hardware, software, time of exposure, postures during exposures, measurement devices and criteria must be considered very cautiously. Replication studies are needed in this important area of VR research. The development of the new immersive and non-immersive versions of the ARCANA paradigm in collaboration with the UEL group will allow the planning of studies aimed at revisiting the main questions raised by our former experiences: whether immersive VR can really be safely proposed for clinical use, and whether immersive and non-immersive versions differ in terms of psychometric yield.

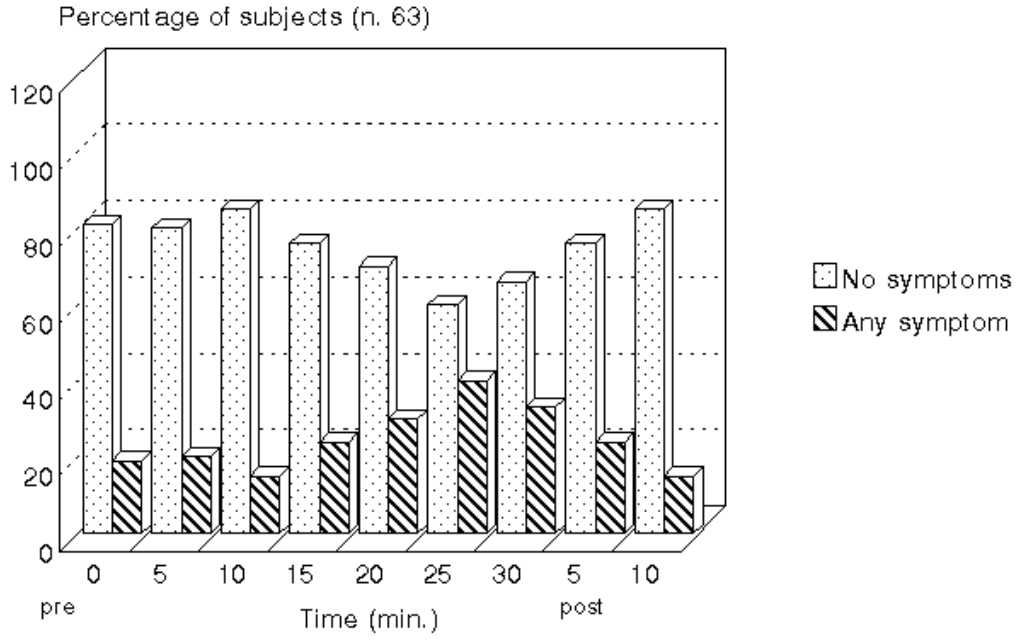

Figure 2. *Percent of subjects reporting at least one symptom on the MQ as a function of time*

5. VR FOR MEMORY RESEARCH

The demonstration that VR is an efficient tool for diagnosing memory deficits and their retraining is also actively pursued by our groups. Most, if not all, the evidence concerning visuospatial memory deficits in neurological patients has been collected using two-dimensional, non-interactive stimuli (e.g. pictures) in typical "paper-and-pencil" tests. These studies have generally found impairments on tests of egocentric spatial orientation and on tests of anterograde memory for visuospatial (topographical) information, all of which exclude locomotion and/or extensive exploration of large-scale spaces. This is unfortunate, because the integration of sensorimotor information has been shown to be important in the development of a cognitive representation of space and, specifically, of the external environment (Kirasic, 1991). The most essential use of spatial knowledge is that of assisting the interaction between an individual and his/her surrounding space. For example, memory for a layout should facilitate route finding whereas memory for

objects should serve other purposes. In fact, there is growing neurobiological evidence that cortical areas and pathways involved in processing spatial coordinates (*where?*) are rather distinct from those processing shapes or patterns that mediate objects recognition (*what?*) (Epstein and Kanwisher, 1998). VR lends itself to devise experiments employing true 3D visual stimulation and exploration of large-scale spaces while assessing the differential effect of being an active or passive participant on different memory systems. Such studies have been pioneered by the UEL group in London, and have recently been replicated - for the first time - in Milan using the original yoked-control methodology described by Andrews et al. (1995) and Attree et al. (1996) in a non-immersive VR setup. The replication study investigated whether exploration of computer-generated environments can selectively enhance spatial memory in patients with MS (Pugnetti et al., 1998b). The hypothesis was that active subjects would show a better recall of the spatial layout of the environments they explored, whereas passive subjects would show a better recall of the contents of the VEs. Consistent with the hypothesis and results of the previous studies, 15 patients and 15 healthy subjects who controlled their movements in a virtual house using a joystick recalled the spatial layout of the environments better than 15 patients and 15 controls who merely watched the active participants' progress (Fig. 3). Among passive subjects, only healthy controls did significantly better than active participants in the recall of virtual objects. There were no significant differences between active and passive participants' recall of correct object locations in the virtual environments. MS patients' recall of the spatial layout and of the virtual objects was significantly worse than that of healthy subjects, but patients' data did not correlate with traditional neuropsychological measures of spatial memory on which MS patients have been shown to be impaired (Beatty et al., 1988). We concluded that VR can be used to test aspects of spatial memory that are not measured by traditional tests. We have also reported an enhanced effect of being an observer in a second experiment in which a different group of 26 MS patients were asked to recognize pictures of the objects they had incidentally memorized while exploring the same VE (Pugnetti et al., 1998). In that study we found the time dedicated to VE exploration to be directly related to recognition memory in patients but not in healthy controls, whereas the ability to handle the joystick to navigate the VE was slightly impaired in some of the patients and may have selectively influenced their ability to freely recall the objects they have seen. These results have implications also for the design of future clinical VR applications based on standard PC platforms.

Though the precise reasons why an enhanced spatial memory occurs after active exploration are uncertain (see Brooks et al.,1998 and Pugnetti et al., 1998b for discussions on this issue), it appears that the use of VR-based simulations can help at least the identification of the conditions and factors - other than known disease-related variables - that favor or mitigate the expression of memory deficits in neurological disorders such as MS and stroke, as recently reported by Rose et al. (1997). This appears to be a genuine instance of added value of a VR application to a clinical diagnostic problem. We have shown that a form of spatial memory which has not been tested so far in MS patients because of the lack of adequate means is defective, but can be modulated by direct interaction with the environments, whereas object memory does not seem to benefit by not being involved in an active exploration. Future research could investigate whether there is any transfer to the real world of spatial knowledge trained with VR in selected MS patients, and whether memory for objects would be improved by active interaction with them. VR applications could also contribute to understand if severe motor disability *per se* can be a factor in the development of visuospatial deficits due to the restriction imposed on self-controlled exploratory activity.

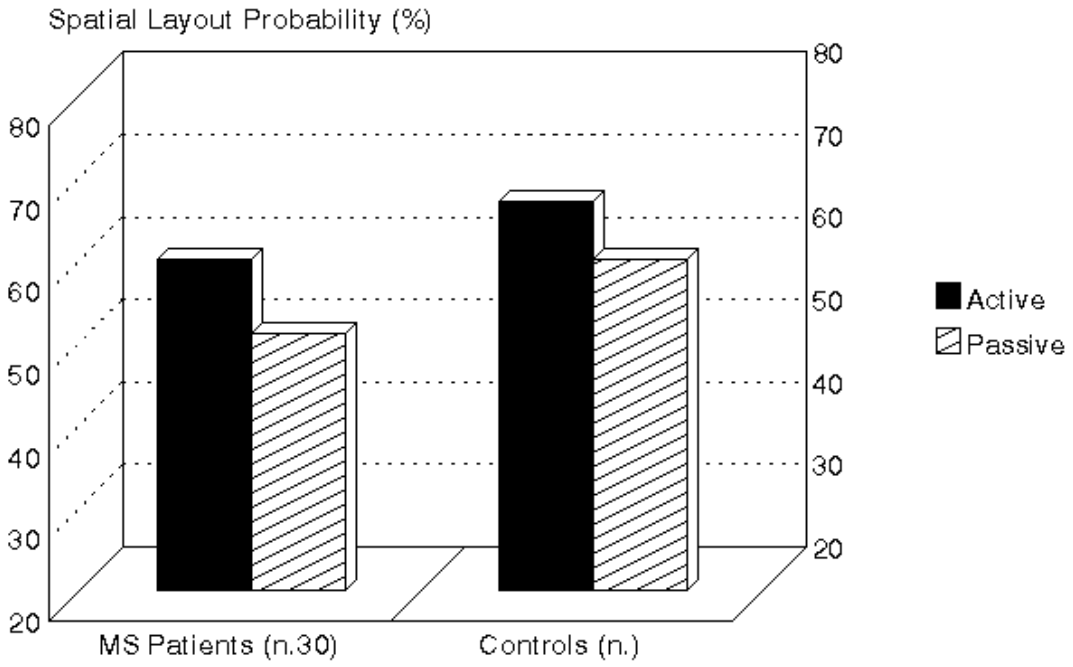

Figure 3. *Mean probability for recall of spatial layout in MS patients and healthy controls.*

6. THE VIRT PROJECT

On winter 1997 a project aimed at the development of a training tool based on VR to assist subjects with mental disabilities who are seeking employment, has been approved by the Italian Ministry of Labour and Social Affairs. The project, named VIRT (for Virtual Reality Training), is led by CIRAH, a non-profit association based in Milan that supports initiatives for the disabled who are eligible for a job application. Our two institutes - Fondazione Don Gnocchi and University of East London - participate in the VIRT consortium as partners along with national cooperatives (IL MELOGRANO and CSLS) and national associations from Spain (FEPROAMI) and France (UNAPEI and QUARTZ) that promote education, training, social and work integration of people with disabilities. The project is supported by the Horizon - Employment Initiative european funding program and has links with other projects, such as TIME, that also offer training opportunities to disables using new information technologies.

The main aim of the VIRT project is to assess whether low-cost VR technology is suitable to develop models that will supplement and improve current training procedures for subjects whose mental impairments do not totally preclude their integration in a productive activity. All too frequently subjects with a mental disability have limited access to new and more effective training tools based on latest technologies. As the latter becomes more and more available to non-disabled in most educational, training and work places, it will inevitably create more and more discrimination if educators, trainers and employers of the disabled are denied the opportunity to participate in the development of specific applications for their clients. This is a critical issue as far as equal access to resources for both disables and their tutors are concerned. The project will make educators, trainers and sensible employers aware of the potential of VR and will also make them responsible for a number of critical choices concerning the development and the use of the new training tool. In particular, their advice and decision will be important in the planning and refining phases of the development of the VR applications, while they will have major responsibility for the testing phase. We started from an analysis of the training curriculum and work experiences that are currently offered to employable mental disables in the participating countries. It emerged that the offer is far less than what is needed to cope with the number of potential trainees and the variety of working experiences that are necessary to make them aware of their role in a productive process and, more broadly, in a working

organization. A flexible tool to simulate a wider range of working tasks than those available at the actual place will have a precise role in the training curriculum of disables. In general, it will serve to broaden their working experience, to foster their decisional autonomy, and to be more aware of their skills. More specifically, it will serve as an additional way to interact with tutors and workmates, to share experiences with them, to get reliable feedbacks, to apprehend difficult attitudes such as self-monitoring and self-correction trough exercise by trial-and-error, free of personal and material risks. The applications will combine VR scenarios and multimedial presentations in order to maximize the access to the different contents (e.g. instructions in different formats, examples of real tasks sequences, testing of transfer between a virtual and a real representation, etc.) and their flexible use. Tasks will be organized in coherent "modules" according to a topological specificity, which is currently maintained in every work training organization participating to the project. Accordingly, a variety of warehouse, workshop and office tasks are planned to be simulated, each with its own variants and difficulty levels. The trainers' role will be to configure each application and select the appropriate training schedule and methodology of approaching the VR system for each subject. A special effort will be made to provide the system with the wider possible capability to personalize the training in order to mimick what is currently done with real job training and insure that the psychological peculiarity of the relationship between the trainer and the trainee be maintained. As many as 60 disabled will be trained by the participant cooperatives during the two and a half years duration of the VIRT project. Data concerning feasibility, acceptance, side effects, impact on psychological and work organization factors, ways of interaction, transfer of learning, perception of utility and efficacy, data analysis and definition of performance will be obtained.

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