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Emerging trends in Cybertherapy

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Emerging Trends in CyberTherapy
Introduction to the Special Issue

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ABSTRACT

According to the recent reports presented by IST Advisory Group (ISTAG) the evolutionary technology scenarios in support of the Knowledge Society of the 2010s will be rooted within three dominant trends: (a) Ambient Intelligence, the pervasive diffusion of intelligence in the space around us; (b) B3G, "Beyond 3rd Generation" mobile communication system; (c) Shared Virtual Reality, with the increase of the range, accessibility and comprehensiveness of communications.

The convergence of these trends manifests itself as the next frontier of Information and Communication Technologies. This convergence *stimulates a change in the way health care is carried out, making it an embodied experiential process in* which communication and collaboration of geographically dispersed users may also play a key role.

In this special issue we will try to outline this process and its potential for the future of cybertherapy. We suggest that a key role will be played by the attainment of "*Immersive Virtual Telepresence"* (IVT). In IVT tools, *distributed virtual reality systems are combined with wireless multimedia facilities* - real-time video – *and innovative input devices* – tracking sensors, biosensors, brain-computer interfaces

Keywords: *Cybertherapy, Ambient Intelligence, Virtual Reality, Mobile Communication, Biosensors*

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1. Introduction

According to the recent reports presented by IST Advisory Group (ISTAG) - the Unit within the European Union providing an independent advice concerning the strategy,

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content and direction of research work to be carried out in the domain of Information and Communication Technologies (ICT) (http://cordis.europa.eu/ist/istag-reports.htm) - the evolutionary technology scenarios in support of the Knowledge Society of the 2010s will be rooted within three dominant trends (ISTAG, 2002):

- Pervasive diffusion of intelligence in the space around us, through the development of network technologies and intelligent sensors towards the objective of the so-called “*Ambient Intelligence*” (AmI);
- increasingly relevant role of mobility, through the development of mobile communications, moving from the Universal Mobile Telecommunications System (UMTS) "Beyond 3rd Generation" (B3G);
- increase of the range, accessibility and comprehensiveness of communications, through the development of multi-*channel multimedia technologies*.

The convergence of AmI, 4G and multi channel multimedia technologies manifests itself as the next frontier of ICT, *making it an embodied experiential process in* which communication and collaboration of geographically dispersed users may also play a key role. Specifically, we suggest that in reaching this goal a key role will be played by the attainment of "*Immersive Virtual Telepresence"* (IVT). In IVT tools, *distributed virtual reality (VR) systems are combined with wireless multimedia facilities* - real-time video – *and innovative input devices* – tracking sensors, biosensors, brain-computer interfaces (Riva, Vatalaro, Davide, & Alcañiz, 2004).

In the following paragraph we will try to outline this process and its potential for the future of cybertherapy

2. Embodiment: From cognition to virtual reality technology

For a long time cognitive science considered action, perception, and interpretation as separate activities. A recent trend in cognitive science is instead seeing cognition as *embodied* (Prinz, 2006). This is a rethinking of the idea that cognition is primarily a matter of performing formal operations on abstract symbols and has little or nothing to do with the sensorimotor activity and environment in which it occurs (Freeman & Núñez, 1999).

The *Embodied Cognition* paradigm takes as its starting point the idea that cognition occurs in specific environments, and for specific ends (Clark, 1997, 2001; Haugeland, 1998). Moreover, the *Embodied Cognition* approach underlines the central role of body in shaping the mind (Clark, 2001, 2003; Gallagher, 2005; Gallese & Lakoff, 2005; Garbarini & Adenzato, 2004; Lakoff & Johnson, 1980; Ziemke, 2003). Specifically, the mind has to be understood in the context of its relationship to a physical body that interacts with the world. Hence human cognition, rather than being centralized, abstract, and sharply distinct from peripheral input and output modules, has instead deep roots in sensorimotor processing.

In this picture, what is the role of "Virtual Reality" (VR)? The basis for the VR idea is that a computer can synthesize a three-dimensional (3D) graphical environment from numerical data. Using visual, aural or haptic devices, the human operator can experience the environment as if it were a part of the world. For these features, VR is described as a "*simulation technology*" with, and within which, people can interact. In summary, VR provides a new human-computer interaction paradigm in which users are no longer simply external observers of images on a computer screen but are active participants within a computer-generated three-dimensional virtual world (Riva, 2005; Wiederhold & Wiederhold, 2003).

If concepts are embodied simulations, and VR is a simulation technology, apparently should be possible to use VR simulations both for teaching concepts and for modifying them. In particular, as suggested by Tart (1990) more than 15 years ago VR offers "intriguing possibilities for developing diagnostic, inductive, psychotherapeutic, and training techniques that can extend and supplement current ones" (p. 222). Within this framework, VR can be considered an embodied technology whose potential is wider than the simple reproduction of real worlds (Riva, 2003). By designing meaningful embodied activities, VR may be used to facilitate cognitive modelling and change.

3. Immersive Virtual Telepresence: simulation meets embodiment and communication

However, VR is only a first generation IVT tool. As we have seen in the Introduction, in IVT tools *distributed virtual reality (VR) systems are combined with wireless* *multimedia facilities* - real-time video – *and innovative input devices* – tracking sensors, biosensors, brain-computer interfaces (Riva *et al.*, 2004).

In general, the IVT perspective extends the potential of virtual reality by:

- *the widening of the input channel* (Wiederhold & Rizzo, 2005) through the use of biosensors (brain-computer interface, psycho-physiological measurements, etc.) and advanced tracking systems (wide body tracking, gaze analysis, etc.);

- *the induction of a broader sense of "presence" or "telepresence" through multimodal human/machine communication in the dimensions of sound, vision, touch-and-feel (haptics).* Typically, *the sense of presence is achieved through multisensorial stimula such that actual reality is either hidden or substituted via a synthetic scenario*, i.e. made virtual through audio and 3-D video analysis and modelling procedures (Renò, 2005; Spagnolli & Gamberini, 2005). In high end IVT systems, multimedia data-streams, such as live stereo-video and audio, are transmitted and integrated into the virtual space of another participant at a remote system, allowing geographically separated groups to meet in a common virtual space, while maintaining eye-contact, gaze awareness and body language. Presence with other people who may be at distant sites is achieved through avatar representations with data about body movement streamed over a high-speed network (Rettie, 2005).

Since distance learning and e-health are principally involved with the handling and transmission of medical information, *IVT has the potential to enhance their user experience through the expansion of human input and output* channels (Wiederhold & Wiederhold, 2004). The two principle ways in which IVT can be applied are:

a) *as an interface, which enables a more intuitive manner of interacting with information* (Rose, Brooks, & Rizzo, 2005), and
b) *as an extended communicative environment that enhances the feeling of presence during the interaction* (Riva, Castelnuovo, & Mantovani, 2006).

Within this framework, IVT can be considered an "embodied technology" whose potential is wider than the simple reproduction of real worlds (Riva et al., 2006). By designing meaningful embodied activities, IVT may be used to facilitate cognitive modeling and change. Introducing IVT in cybertherapy will provide significant advantages:

- The IVT-based treatment differs from traditional therapy in that computer graphics and various display and input/output technologies are integrated *to provide the patient with a sense of presence or immersion*. More in detail, IVT provide a new human-computer interaction paradigm in which users are no longer simply external observers of images on a computer screen but are active participants within a computer-generated three-dimensional synthetic world. In this world the patient has the possibility of learning to manage a problematic situation (Standen & Brown, 2005).

- Moreover, IVT offers a high level of control of the experience without the constraints usually found in computer systems. IVT environments are highly flexible and programmable. They enable the therapist to present a wide variety of controlled stimuli, such as a fearful situation, and to measure and monitor a wide variety of responses made by the user. This flexibility can be used to provide systematic restorative training that optimize the degree of transfer of training or generalization of learning to the person's real world environment (Rizzo, Schultheis Kerns, & Mateer, 2004).

- Finally, IVT systems open the input channel to the full range of human expressions: in rehabilitation it is possible to monitor movements or actions from any body part or many body parts at the same time. On the other side, with disabled patients feedbacks and prompts can be translated into alternate and/or multiple senses (Morganti, 2004).

4. The contents of this Special Issue

It is interesting to note that this issue of the PsychNology Journal well reflects this trend. Both biosensors, adaptive displays and new interfaces are widening the typical bunch of cybertherapy tools as shown by the following papers. The critical challenge, however, is moving from preliminary studies to real world application. In this context it is critical that the pioneers in this field will both share information about their experience and examine the results of the preliminary trials so that suitable development work will spread up. This is the critical goal of this special issue.

The first paper, by Botella and colleagues, discusses the use of the “Emma’s world”: a virtual environment where a series of tools are available and they can be selected based on the therapist’s instructions. The specific use of the different scenarios will depend on the specific objectives of the therapeutic session and can be selected by the therapist in real time. Initially, the environments have been designed to be related to different emotions. Specifically, the paper presents a case study in which the adaptive display is used in the treatment of a 70 year-old woman with storm phobia.

The second paper, by Jung and colleagues, discusses the possible use of a tangible interaction system based on a virtual reality platform to provide sensory integration therapy to autistic children. The outcome of a preliminary study on 12 autistic children is presented in the paper.

The third paper, by Galimberti and colleagues provides a theoretical model for the ergonomics of advanced cybertherapy applications based on virtual reality. Through the analysis of the pros and cons of the approaches used by two different projects dedicated to the development of clinical virtual reality environments, the paper comments on the concepts of ecology and context of use.

The final paper is a presentation of an ongoing project by Morganti and colleagues, who investigate the technical and clinical feasibility of using an enactive interface in the rehabilitation of reaching and grasping movements of upper-limb hemiparesis. Such interface supports the perception-action interactions with an environment allowing users to learn on how to perform a useful action in a particular context.

In summary, the goal of this Special Issue is to provide a forum for presenting and discussing the emerging processes and tools. The critical goal of the papers presented is to stimulate more clinicians and technical professionals to design and test these tools to improve the overall outcome of cybertherapy interventions.

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Using a Flexible Virtual Environment for Treating a Storm Phobia

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ABSTRACT

Most of the Virtual Environments (VE) currently available in the field of psychological treatments are designed to solve a specific problem (acrophobia, flying phobia, claustrophobia, etc.). Our research group has developed a versatile Virtual Reality (VR) system (an adaptive display) that could be useful for different problems. In previous studies, a VR application called "EMMA's world" was developed for the treatment of PTSD and pathological grief. The aim of the present work is to show the utility of this system for the treatment of a storm phobia. The patient was a 70 year-old woman, who was not familiar at all with computer technologies. As the patient was not able to confront even a virtual storm, the treatment was applied in two phases: *In vivo* exposure (exploding balloons), and exposure to VE simulating storms, rain, thunders and lightings. Results showed changes in the expected direction and were maintained at 6-month follow-up.

Keywords: *virtual reality exposure, adaptive display, psychological treatment, specific phobia.*

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1. Introduction

The first virtual reality (VR) application in Clinical Psychology was focused on the treatment of acrophobia. Rothbaum, Hodges, Kooper, Opdyke, Williford, & North (1995) published the first case study in which the patient overcame his fear of heights after being exposed to a virtual scenario which simulated acrophobic situations. Since then, numerous case studies with efficacy data about the use of VR for this or other specific phobias have been published: acrophobia (Choi, Jang, Ku, Shin, & Kim, 2001; North, North, & Coble, 1996); claustrophobia (Botella, Baños, Perpiña, Villa, Alcañiz, & Rey, 1998; Botella, Villa, Baños, Perpiñá, & García-Palacios, 1999); spiders phobia (Carlin, Hoffman, & Weghorst, 1997); flying phobia (Baños, Botella, Perpiñá, & Quero, 2001; Klein, 1999; North, North, & Coble, 1997; Rothbaum, Hodges, Watson, Kessler, & Opdyke, 1996; Wiederhold, Gervitz, & Wiederhold, 1998); driving phobia (Wald & Taylor, 2000), etc. Later controlled studies which demonstrate the efficacy of this new way of applying the exposure technique have been carried out: acrophobia (Emmelkamp, Bruynzeel, Drost, & Van der Mast, 2001; Emmelkamp, Krijn, Hulsbocsh, de Vries, Schummie & Van der Mast, 2002; Krijn, Emmelkamp, Olafsson & Biemond, 2004); claustrophobia (Botella, Baños, Villa, Perpiñá, & García-Palacios, 2000); spiders phobia (García-Palacios, Hoffman, Carlin, Furness, & Botella, 2002; Hoffman, García-Palacios, Carlin, & Botella, 2003); flying phobia (Botella, Osma, García-Palacios, Quero, & Baños, 2004; Maltby, Kirsch, Mayers, & Allen, 2002; Mühlberger, Wiedemann, & Pauli, 2003; Rothbaum, Hodges, Smith, Lee, & Price, 2000; Rothbaum, Hodges, Anderson, Price, & Smith, 2002; Wiederhold, 1999); driving phobia (Wald & Taylor, 2003; Walshe, Lewis, Kim, O'Sullivan, & Wiederhold, 2003). In short, in a decade the use of VR as a tool for the application of exposure in phobias has been notably developed and its use has been extended to other anxiety disorders and other psychological disorders (for a revision see: Anderson, Jacobs, & Rothbaum, 2004; Krijn et al., 2004; Pull, 2005; Rothbaum, 2006; Wierdehold & Wierderhold, 2004)

However, the point is that each research group has developed specific and different virtual environments to confront only one of these problems. A paradigmatic example in the matter would be the way in which the VR systems for the treatment of Post-traumatic Stress Disorder (PTSD) have been developed: the Vietnam VR world (Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001), the September 11th victims one (Difede & Hoffman, 2002), the Iraq war one (Rizzo et al, 2004), the one designed for motor vehicles victims (Walshe et al., 2003), and so on. However, this rationale can be problematic due to the high cost to apply these treatments in the daily clinical practice since many virtual environments are needed to treat diverse problems. Furthermore, it could be difficult for clinicians to use many of these systems since most of them are not compatible between them and most of the times they require different software and hardware. So far if a patient suffering from different disorders (for instance, panic disorder, PTSD and eating disorder with important body image problems) comes to our consulting room it is necessary to appeal to diverse VR systems designed to treat each one of these problems.

What is stated in this work is to follow a somehow different rationale, instead of taking the patient to different specific virtual worlds, would it be possible to go and back from the “real world” to the “virtual world”? That is, as it occurs in the real world, would it be possible that in that complex virtual world the participant could go to many different places and could experience many diverse events and situations?. Would it also be possible that this virtual environment could protect users in every moment and allow them to experience every situation without risk as current VR systems do now? Finally, and giving a step beyond the traditional VR systems, it would be possible that that virtual world were designed in order to be adapted to the *user’s needs*. That is, to work in the line defended by Schmeisser (2004) regarding an *adaptive display*: “Dream of a display that pays attention to the viewer”, a system that was able to automatically adjust its contents to the constantly changing state of the observer.

Trying to progress in this line of work our group has developed a VR system initially designed for the treatment of PTSD (the EMMA’s World developed within the European Project EMMA IST-2001-39192). This system is able to adapt in a dynamic way to every user’s needs, regardless of the type of trauma suffered by the person. Results obtained so far indicate that the system is efficacious for this type of problem (Botella, et al., 2005). Furthermore it can be perfectly adapted for the treatment of other type of problems. By now we have already used it successfully for the treatment of pathological grief (Baños, et al., 2005; Botella, et al., 2005), adjustment disorders and phobia of darkness in children. The aim of this work is to show the utility of this adaptive display for the treatment of a very severe and interfering storm phobia with many years of history in an old woman who was not familiar at all with computer technologies.

2. Participant's description

R.A is a 70 year-old woman suffering from a storm specific phobia according to DSM-IV criteria (APA, 2004). The problem began when she was a child; she always avoided storms and constantly asked her mother about how the weather was going to be like. At home she was protected and she did not go to school when it was raining. The problem continued during adolescence. The patient reports that this phobia has interfered in different areas of her life: family, work, partner relationships, social life and leisure time. Since always the distress and fear has been very high. At a work level, if there was bad weather she did not go to work and, if the storm started during work she went to the bathroom until the storm ended. With her boyfriends, they could not go out when there was bad weather. If she decided to travel she had to check previously and constantly the weather and temperature in order to avoid summer storms. If she was with her friends and started to rain, they had to take her home in a hurry and she closed her eyes and presented physical symptoms (heart beatings, sweating, trembling, suffocation, mouth dryness and fear dying). In the assessment moment, to solve her problem and every time that it rained or storms were announced, the patient entered inside a wardrobe she had at home wearing earphones with a very loud music and a mobile phone and she waited until any of her friend ring her when the storm was finished. In those moments the patient had panic attacks and prayed for the storm to stop.

R.A had previously received psychiatric and psychological treatments (Gestalt and Psychodynamic approaches) for this problem; however, her problem did not improve.

3. Assessment

The assessment was carried out in 2 sessions. In session 1 the Anxiety Disorders Interview Schedule (ADIS-IV) (DiNardo, Brown & Barlow, 1994) was applied. During session 2 the participant answered the following measures: *Anxiety Sensitivity Index* (ASI), (Peterson & Reiss, 1987); *Cardiac Anxiety Questionnaire* (Eifert et al., 2000); Degree of fear, avoidance and belief in the negative thought using 0-10 scales and *Maladjustment Scale* (Adapted from Echeburúa, Corral, & Fernández-Montalvo, 2000). Furthermore, during VR exposure sessions the patient was asked to inform periodically her level of anxiety, the sense of presence she felt in the virtual environment and the reality judgement she attributed to the virtual experience. These questions were answered in a 0-10 scale. Finally, 6 months after treatment the patient was asked again to inform the degree of fear, avoidance and belief in the negative thought regarding her target-behaviours.

4. Hardware description

The configuration used different devices: two PCs, a big screen where the environment was projected, two projectors, a wireless pad (Logitech Wingman) and a system of speakers (Logitech x-530).

The PC1 has the graphical outputs from its graphic card connected to two projectors, which are used to project the environment in a metacrilate screen (4 x 1.5 m). The projectors have a resolution of 1024x768 pixels, and a power of 2000 lumens. However, they have been regulated for a power of 1000 lumens in order to be comfortable for the user. Specifically, the main characteristics of this PC1are the following:

- Processor: AMD XP-3000+
- Hard disk: 120 GB
- Graphic card: Nvidia 6600 AGP 128 MB.
- RAM: 512 MB.
- A network card for connecting to the other PC.
- Operating system: Windows 2000.

The PC2 is the host of the therapist’s application and controls the features of the virtual environment that is shown to the patient. The characteristics of this PC2 are the following:

- Processor: PIII 800.
- Hard disk: 40 GB.
- Graphic card: Nvidia GeForce II MX.
- RAM: 256 MB.
- A network card for connecting to the other PC.
- Operating system: Windows 2000.

Both PCs have installed the software Brainstorm eStudio, which has been used for developing the application.

5. EMMA's world description

In the "EMMA's world", the patient visualizes a virtual environment where a series of tools are available and they can be selected based on the therapist's instructions. In this work we are going to focus exclusively on the tools related to the virtual environments (for a more detailed description see Rey, Montesa, Alcañiz, Baños, & Botella, 2005). There are five different pre-defined scenarios or 'landscapes' available: a desert, an island, a threatening forest, a snow-covered town and a meadow (see Figure 1). The specific use of these scenarios will depend on the specific objectives of the therapeutic session and can be selected by the therapist in real time. Initially, the environments have been designed to be related to different emotions. For example, the desert can be related to rage, the island can be used to induce relaxation, the threatening forest can be related to anxiety, the snow-covered town can be used to reflect a sad mood, and the meadow can be used to induce happiness.

Figure 1: The different aspects of the virtual environment: the meadow, the desert, the island, the snow-covered town and the threatening forest.

Apart from this large-scale control (changing the entire aspect of the outer part of the virtual environment) the therapist can also make modifications in the scenario and graduate their intensity. Different effects can be applied to the environment: a rainbow can appear; it can start to rain or to snow; an earthquake can be generated; the hour of the day (and the corresponding illumination) can change. All these effects can be launched from the same interface, and the therapist can control both the appearance and disappearance of the effect, as well as the intensity with which the effect is shown.

In the present work we use different scenarios in which we included a storm with lightings, thunders of different intensity, and we varied the time of the day (with more o less illumination, being at day or at night). Specifically, the patient was exposed to the meadow and the therapist provoked the effects (e.g., thunders, day or night, etc.) depending on the patient's exposure hierarchy using the control panel of the PC2. Figure 2 shows different moments of the treatment sessions.

Figure 2: Some pictures of the treatment sessions,
showing differences in the effects included in environments.

6. Treatment

The treatment consisted of a total of 7 sessions: 2 psychoeducation sessions (1 hour), 3 in vivo exposure sessions which consisted of exploding balloons (1 hour and a half) and 2 intensive VR exposure sessions with a duration of one hour and one hour and a half respectively. Next the specific agenda of each session is presented:

Session 1: *Educational component:* What is anxiety? Differences between fear, anxiety and phobia. Adaptive anxiety versus disturbing anxiety. Anxiety manifestation. Triple response system: physical, cognitive and behavioural.

Session 2: *Educational component:* What is a storm? How storms are formed? What are thunders and lightings? Why they occur? The importance of these atmospheric phenomena.

Session 3: What is exposure? Advantages and disadvantages. Constructing the hierarchy. Exposure to items 3 and 4 of the hierarchy. Homework assignments: exploding balloons with the same size used in therapy and not entering her wardrobe when it rained. In Table 1 the hierarchy used for in vivo exposure is presented.

ITEM	SITUATION	SUDs
1	To talk with a deflated balloon during the therapy session	1
2	To have a small inflated balloon in therapy	2
3	The patient has to prick a small balloon with a pin.	3
4	The patient has to prick a medium size balloon with a pin.	4
5	The therapist prick a medium size balloon at any time without warning	5
6	The therapist explodes a small firecracker in the park 10 meters away form the patient.	6
7	The therapist explodes a small firecracker in the park 1 meter away from the patient.	7
8	The patient explodes the small firecracker	8
9	The patient has to prick a big balloon with a pin.	9
10	The therapist pricks a big balloon at any time without warning.	10

Table 1: Hierarchy for in vivo exposure

Session 4: Homework review. Continuing with the exposure to the hierarchy: items 5, 6 and 7. Homework assignments.

Session 5: Homework review. Continuing with the exposure to the hierarchy: items 8, 9 and 10. Homework assignments.

Session 6: Homework review. Virtual exposure (two 90 minutes intervals with a 30 minutes break)

Session 7: Homework review. Virtual exposure

7. Results

Table 2 shows an important decrease in the scores obtained by the participant for all questionnaires from pre- to post-treatment: anxiety sensitivity, cardiac anxiety, and in the interference caused by the problem in different life areas and in general.

Questionnaire		Pre-treatment	Post-treatment
Anxiety Sensitivity Index		23	8
Cardiac Anxiety Questionnaire		25	16
Maladjustment Scale:	Work	5 (a lot)	0 (nothing)
	Social life	5 (a lot)	2 (something)
	Leisure time	5 (a lot)	2 (something)
	Partner relationship	5 (a lot)	0 (nothing)
	Family life:	5 (a lot)	2 (something)
	Global scale:	5 (a lot)	2 (something)

Table 2: Scores obtained in the Questionnaires before and after treatment.

On the other hand, Tables 3, 4 and 5 show the scores obtained by the participant during the three VR exposure sessions regarding the level of subjective anxiety (SUDs), the sense of presence and the attribution of reality to the virtual experience.

Time	Anxious element	Presence	Reality judgement	SUDs
10.00	Walking without rain	6	6	4
10.05	Drizzling	7	6	6
10.10	Moderate rain	7	7	7
10.20	One lightning	7	7	8
10.30	Moderate rain	7	9	7
10.40	Moderate rain	7	9	6
10.50	Gets dark	10	10	10
11.00	Strong rain	10	10	9
11.10	Strong storm	10	10	10
11.20	Strong storm	10	10	8
11.30	Strong storm	10	10	6

Table 3: Recording of 1st VR exposure session (1st interval).

Time	Anxious element	Presence	Reality judgement	SUDs
12.00	Walking	10	10	0
12.05	Rain and	10	10	5
12.10	Moderate rain	10	10	6
12.20	Moderate rain	10	10	7
12.30	Moderate rain	10	10	8
12.40	Strong rain	10	10	7
12.50	Strong storm	10	10	6
13.00	Maximum storm &	10	10	9
13.10	Maximum storm &	10	10	9
13.15	Maximum storm &	10	10	8
13.20	Maximum storm &	10	10	6
13.30	Strong storm	10	10	4

Table 4: Recording of 2nd VR exposure session (2nd interval after 30 minutes break).

Time	Anxious element	Presence	Reality judgement	SUDs
16.00	Walking	4	4	0
16.05	Rain and a thunder	5	10	5
16.10	Moderate rain	7	10	6
16.20	Moderate rain	10	10	6
16.30	Moderate rain	10	10	5
16.40	Beach with rain	10	9	7
16.50	Beach with rain	10	10	6
17.00	Maximum storm &	10	10	7
17.10	Maximum storm &	10	10	5
17.15	Maximum storm &	10	10	3
17.20	Maximum storm &	10	10	1
17.30	Strong storm	10	10	1

Table 5: Recording of 3rd VR exposure session.

Lastly, results obtained for the level of fear, avoidance and the degree of belief in the negative thought ("I am going to die because of the physical sensations experienced during a storm") related with each of the three target-behaviours are presented in Figures 3, 4 and 5. As can be observed, a notable decrease of all these clinical variables is produced at post-treatment, and this change is maintained at 6-moth follow-up.

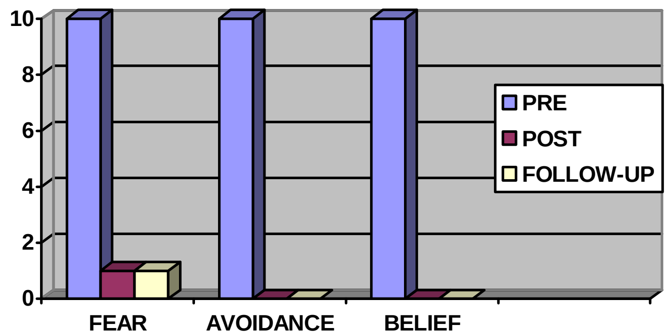

Figure 3: Target-behaviour 1- Confronting a storm at home without entering inside her wardrobe and without wearing earphones.

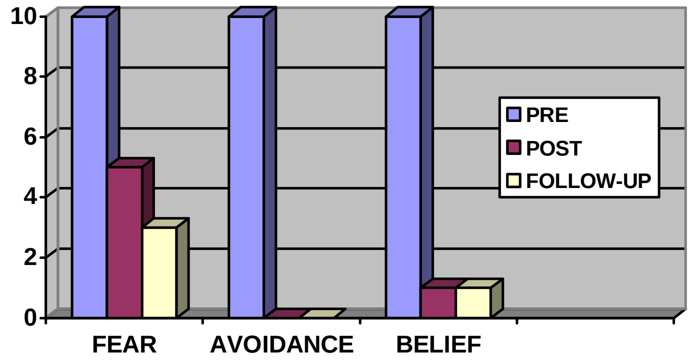

Figure 4: Target-behaviour 2- Confronting a storm at a friend’s house without entering the bathroom and without wearing earphones.

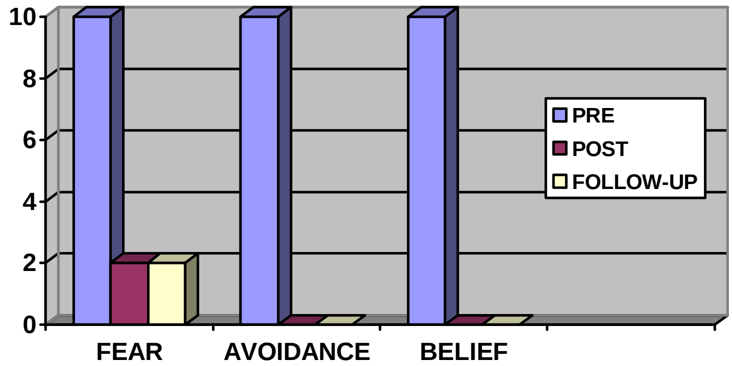

Figure 5: Target-behaviour 3- Confronting a strong rain in a journey without entering inside a bathroom and without wearing earphones, being able to go for a walk in the street.

8. Discussion

Firstly, the positive results obtained in this case report suggest a high potential of VR for the treatment of storm phobia. At the end of the treatment the patient was able to confront the situations related to storms feared at pre-treatment and this improvement was maintained at 6-month follow-up, that is, she continued confronting her target-behaviours, coping with storms in different contexts with very low levels of anxiety. On the other hand, and regarding effectiveness or the Axis II of the Guidelines for Empirically Validated Treatments (APA, 1995), the participant not only overcame her problem but she was very satisfied with the received treatment. At all time the patient reported that she liked the system and that she found the virtual reality procedure very useful. During therapy she even stated that after so many years suffering this problem for her this treatment had been an excellent solution. In this study we only used self-report measures and we did not included physiological data. This could be a limitation of the study but results available for this case indicated a significant improvement.

Another interesting result in this study is the presence and reality judgment scores reported by the participant. The patient reported a high sense of presence and reality attribution along all VR treatment sessions. All these results are showing that these computer technologies have been useful for an old participant. In this point, it must be pointed out that the patient did not use a HMD, but she visualized the environment on a big screen. No negative side effects or problems with the use of the VR system were reported by the participant. Ten years ago one of the problems with the use of VR was its possible negative side effects, mainly cybersickness. However, after ten years of experience acquired by other researchers and also from our own experience it can be pointed out that these symptoms have not been a big problem. Patients do not experience this syndrome as often as it was predicted. The number of persons who have not been able to get immersed for a while in a virtual scenario due to this problem is minimal.

Finally, this treatment has used an adaptive display. As it has been mentioned before, most of the virtual environments currently available in the field of psychological treatments have been designed and developed to solve a specific problem. The EMMA’s world is demonstrating that can be useful to treat different problems, like PTSD (Botella et al, 2005) pathological grief (Baños et al., 2005; Botella et al., 2005), and now storm-phobia. But even more, we have observed that the use of an adaptive display like EMMA’s world gives rise to a dynamic of generation of new ideas and possibilities of use on the part of the clinicians as they have been working with the system. As it has been already pointed out, in the future it might be possible that “a complex and versatile virtual world” could be available and that each researcher and clinician could add richer elements and working possibilities and utilities. This would allow us to work with our patients alternatively in the “real world” or the “virtual world” in a way that facilitates the progress in overcoming problems. This virtual world might also be dynamically adjusted to every user’s needs. Even more, it might be that in a near future the limitation that presents the adaptive display used in this work could be overcome, and the “adaptation” of the system could not be “mediated by the clinician”, but adjusted in each case and in each moment according to the user’s needs.

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The Application of a Sensory Integration Treatment Based on Virtual Reality-Tangible Interaction for Children with Autistic Spectrum Disorder

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ABSTRACT

Children with autistic spectrum disorders have difficulties integrating motor and sensory experiences. It is important to address therapeutic interventions for these children. However, there are some limitations of the sensory integration therapy and the application of virtual reality for autistic children. SIT based on VR-TIS (VR-SIT) has three components: measurement of coordination ability, social skills training, sensory integration therapy. These components all originated from sensory integration therapy. A total of 12 autistic children and 20 healthy controls, all aged between five and six years, participated in this study. There are significant differences in autistic children and healthy controls for coordination ability measurement and social skill training. We found that it is possible to apply our system to the assessment of, and the therapy for, autistic children.

Keywords: *Autism, Virtual reality, Sensory integration, Virtual reality tangible interaction.*

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1. Introduction

Children with autistic spectrum disorders have difficulties integrating motor and sensory experiences (Baranek, 2002). These abnormalities of sensory processing affect all aspects of adaptive, cognitive, social, and academic functioning, and correlate with higher levels of stereotypic, rigid, and repetitive behaviors in autism (Baranek, Foster, & Berkson, 1997a ; Reynolds, Newsom, & Lovaas, 1974). It may therefore be important to address in therapeutic interventions for children with autistic spectrum disorders (Piek & Murray, 2004).

Sensory integration therapy (SIT) is based on a theory developed by Ayres, which emphasizes the relationship between sensory experiences, and motor and behavioral performance (Ayres, 1972). SIT is intended to focus directly on the neurological processing of sensory information as a foundation for learning of higher-level (motor or academic) skills (Baranek, 2002). There are some advantages of SIT. It is possible that unstructured therapy using role-play situations can provide social skills training by practicing intimacy with friends. However, most sensory integration therapies involve a therapist treating a child. In such instances the limitations of sensory integration therapy for autistic children are the length and cost of treatment. In addition, there are limitations on the number and variety of place that can be used for children in therapy to experience. So the therapy may become repetitive. Moreover SIT could be perceived be subjective and individual conclusion about evaluation of treatment's outcome.

Several studies have reported the clinical use of virtual reality (VR) technology for autistic children. Children with autism performed as well as controls on a computerized version of the WCST, but significantly worse than controls on the standard, non-computerized version. Pascualvaca and colleagues (Pascualvaca, Fantie, Papageorgiou, & Mirsky 1998) suggested that social/motivational factors could be responsible for the effect that is children with autism might prefer to receive feedback about their performance from a computer rather than from an examiner. Virtual environments for social skills training would best be used in collaboration with other people (Murray, 1997). Virtual reality technology is an exciting tool for allowing children with autism to practice behaviors in role-play situations, while providing a safe environment for rule learning and repetition of tasks (Pascualvaca et al.,1998).

However, some ethical and technical concerns surround the use of fully immersive virtual reality technology. For example the use of head-mounted displays (HMDs) can elicit ‘cyber sickness’ in some people (Cobb, Nichols, Ramsey, & Wilson, 1999).

Moreover, because HMDs place some limitations on the child's interaction with another person, the mixed and augmented reality is more useful for group interactions and sensory experiences.

The known limitations of pre-existing therapeutic intervention methods for autistic children may be reduced by sensory integration therapy based on the virtual reality – tangible interaction system (VR-TIS). VR-TIS is a system that connects the human body, the physical environment and a computer. It measures human behaviors accurately and makes sense of their behavior through visual feedback (Hornecker, 2004). Therefore this high-tech equipment can be useful for the detection and measurement of human responses, especially sensory integration. In addition tangible features are designed to make artificial barrier less apparent and more intuitive by mixing the synthetic virtual environment with the natural physical environment (Ko, Park, & Lee, 2002).

The purpose of this study was to develop a program of sensory integration therapy based on VR-TIS for the assessment and treatment of autistic children. We also aimed to verify that the program is an efficacious assessment and treatment for autistic children.

2. Methods

2.1 Participants

A total of 12 autistic children and 20 healthy controls, all aged between five and six years, participated in this study. All children in the autism group met the DSM-IV criteria for autism and were recruited from the outpatient unit at the Children's Hospital in Seoul. Unrelated healthy children were recruited from the kindergarten belonging to C University in Seoul, Korea.

The mean IQ of the 12 autistic children (two girls, ten boys) was 64. The mean social maturity scale (SMS) index was 73, and all were six years old. Of the 12 autistic children, one dropped out of the study. He would not enter the room in which was carried out treatment program after second session.

Healthy controls were recruited via questionnaire. For the teacher questionnaire, revised and interpreted IOWA (Iowa Social Competence Scales: Preschool form) teachers questions were used. The test for children was performed simply, using the symbol test from the intelligence quotient test (WISC). Children who were regarded as having normal social ability in both tests were recruited as healthy controls.

2.2 Instruments

SIT, based on VR-TIS (VR-SIT), has three components: coordination ability measurement; social skill training; and sensory integration therapy. Coordination ability, social skill, and sensory integration, which are fundamental to each component, are the deficient ability of autistic children. Therefore, application of our program attempted to measure each child's ability. These components are all derived from sensory integration therapy.

Our VR–TIS consisted of a Pentium IV PC, a projector, a screen (200 × 150 cm), an infrared reflector, a digital camera, and tangible devices (e.g., a stick, rotation board, trampoline). Participants can see the result of their actions on the screen as they perform the tasks.

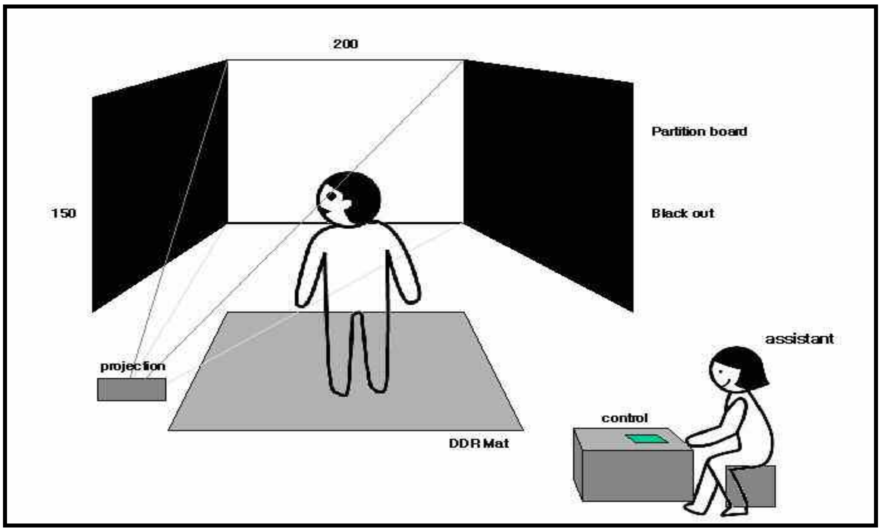

Figure 1: An example of the system construction

1) Visuomotor Coordination Ability Assessment

The Visuomotor Coordination Ability Assessment is a measuring program for visuomotor coordination ability, which does not require whole scenario, and only measures a specific phase. Levels can be controlled by the therapist. The program involves breaking virtual balloons with a real stick, and reinforcements are provided for success. And the number of balloons, the type of reinforcement became different by level. Reinforcement types were selected based on the therapist’s experiences and outcomes of parent survey. These were then classified into auditory and visual substances (Dawson & Watling, 2000): participants received one of eight visual and ten auditory reinforcements as a reward for breaking each balloon. Participants completed 10 sessions.

	Visual reinforcements	Auditory reinforcements
1	Falling, like powder	Laughing
2	Falling, like water drop	Crying
3	Disappearing, like shining star	Angry or irritating sound
4	Exploding, like fireworks	Horror sound
5	Light rotation	Buzzing
6	Balloon changes into father's face	Chatting
7	Balloon changes into mother's face	Firing laser beam
8	Balloon changes into baby's face	Aircraft flying
9		Firecracker explosion
10		Water dropping

Table 1: Type of reinforcements

2) Social Skills Training

Social skills training contents were designed to minimize sound effect and background to allow conversation between participants and the therapist, and to allow the participants to concentrate on the graphic factors. It was designed to look like a game, and each of the five phases could be progressed through gradually. And Participants completed 10 sessions.

3) Sensory Integration Therapy

To measure the functions of sensory integration treatment effectively, images were developed from various rides in an amusement park. It was expected that exposing the client to such a range of vivid stimuli, which would be impractical or unsafe in the real world, would be beneficial. Conditions such as swaying from side to side, and backward and forward, stairs, screen rotation, user rotary motion (such as turning four sides or turning the screen), running, and trampoline, were used.

Step	Title	Contents
1	Spot-eyes-face looking training	To see light of the screen without interaction. If it is boring, one can skip it easily.
2	Real face and graphic expression selection training	Matching the expression on a graphic face to the expression on a real face.
3	Increasing the facial expression training	This is an interaction that can be controlled by a stick. The child selects a face from a number of facial expressions. If it is the face that the therapist wanted, the rewarding balloon is big and sound effect is big (such as smiling sound), and the balloon follows the child (Robert, & Helen,2004).
4	Looking the spot without sight	In the middle of the screen, a face is shown and the eyes are moving with a little spot. The eyes move to each of the four sides for three minutes.
5	Pointing the sight	There are four foods in each of four corners, and the question 'what does the child want?" is shown. If he/she gives the answer, there is a reward of the food being eaten on the screen (Robert, & Helen,2004).

Table 2: Composition of social skill training contents.

The intensity of each condition can be controlled. Among the 10 sessions, this program was progressed by 4 to 8, except 1 to 3 and 9 to 10.

2.3 Procedure

Demographic data were collected before the test was begun, by examining the records of the children and their degree of adaptation to the therapist. We also tested the children's sociability (SMS) and sensory integration and researched their preferred visual and auditory reinforcements. We then tested the sensory integration training, social skill training, and visuomotor coordination ability in 10 sessions. Although we had planned to test sociability and sensory integration again, we decided that administering the test after 10 treatment sessions would be affected by the repetition of the tests. It was also difficult to test the children because of their treatments in other fields. After the 10 times of the test, we discussed the usefulness of our system with the therapist and assistants.

2.4 Data analysis

We measured the reaction time of children in the tasks of stopping the balloon, moving the balloon, and reading the mind, to find the changes in reaction time and the adaptation of children to each task. We also measured the accuracy, the distance the stick was moved, and mean reaction time of coordination ability, to find the adaptation and improvement in the adaptation ability exercise in each session. Data were analyzed by a repeated-measure Analysis of Variance (ANOVA).

3. Results

3.1 Visuomotor Coordination Ability Assessment

We tested the Visuomotor Coordination Ability measurements of reaction accuracy, movement of the stick, and average reaction time by repeated measure ANOVA analysis. As repetition increased, the accuracy of the reaction increased, and the movement of the stick decreased. However, the mean reaction time changed greatly (a = 0.031, R^2 = 0.011). Measuring a variable of mean reaction time had no effect ($F(1,3)$ = 0.038, p = n.s.) the slope of the movement of the stick was high (a = -1.792, R^2 = 0.5961), however, there was no meaningful result because of higher varied amount for each session and children. This was same result as the report of the therapist that the children's interest was decreased by the repetition.

1) Movement of the Stick

Movement of the stick was efficient in later sessions. Although the movement was not great, accuracy improves and more space was used as the sessions progressed. Namely, there was difference of the sight.

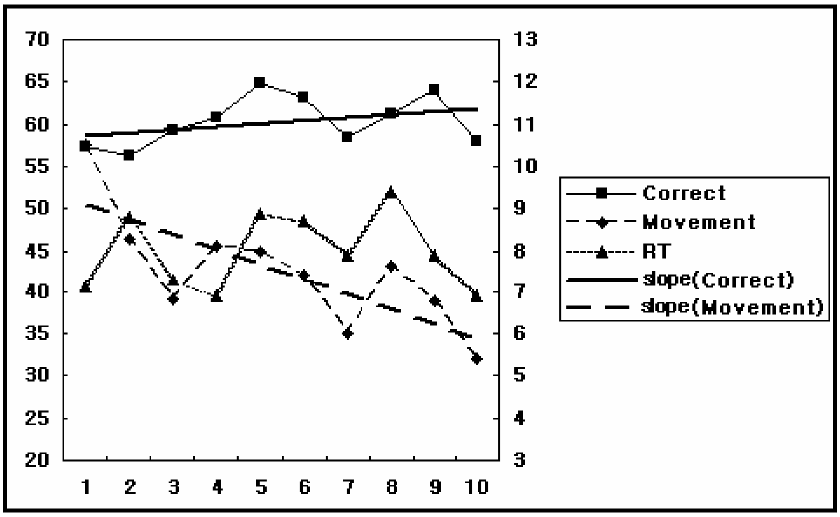

Figure 2: Variation of reaction accuracy, stick movement, and reaction time for coordination ability measurement program.

2) Comparison of the Visual and Auditory Reinforcements

Reaction accuracy was highest when reinforcement was a firecracker explosion sound with water dropping at the same time (60.2%), and then mother's smiling sound (59.7%). As we expected, the lowest accuracy was when reinforcement was the smiling sound with the laser sound of the star, which children with social disability abhor (53.3%, 51.9%).

3) Comparison to Healthy Control Children

Autistic children became more accurate due to their practice. However, there was no significant difference between autistic and healthy control children because the variance of the autistic children was so dramatic (t = 1.803, p = n.s.). Healthy control children showed more movement of the stick (t = 4.962, p < .01) But, it was better for the movement of the stick (t = 4.962, p < .01) and faster reaction times (t = 3.931, p < .01), indicating that they performed more efficiently than the autistic children.

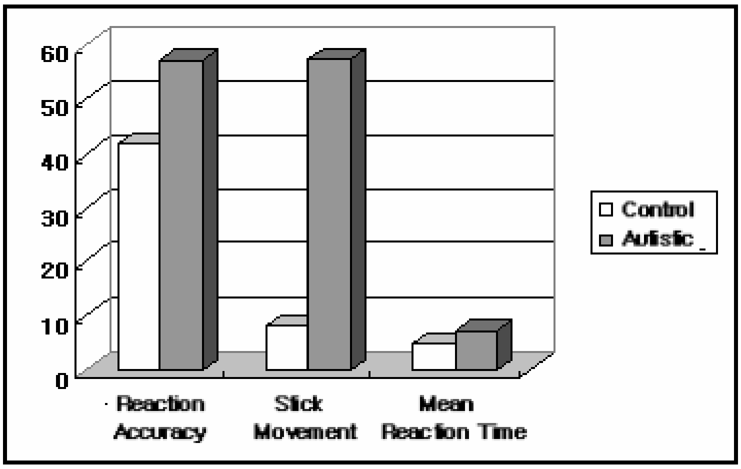

Figure 3: Comparison between groups for coordination ability

The following formula was used for principal component analysis of coordination abilities.

CA index = 0.797 X reaction accuracy – 0.799 X movement of stick
– 0.687 X mean reaction time

This formula was adapted to healthy control and autistic children. There was a significant difference between the autistic and healthy control children ($p < .01$), which implies that the autistic children had performed the tasks inefficiently.

3.2 Social Skills Training

We tested the reaction time of each child to the social skills training such as the stopping balloon, moving the balloon, and reading the mind. Repeated measure ANOVA for the 10 sessions was used.

As the number of sessions increased, the mean reaction time gradually decreased, but the variance was very high. Reading the mind (F (1,2) = 0.663, p = n.s.) and moving the balloon (F (2,3) = 10.401, p = 0.08) did not show any significant results: however on the stopping the balloon task, the reaction time (F (1,2) = 21.339, $p < .05$) and slope (a = -0.403, R^2 = 0.335) decreased as the sessions progressed.

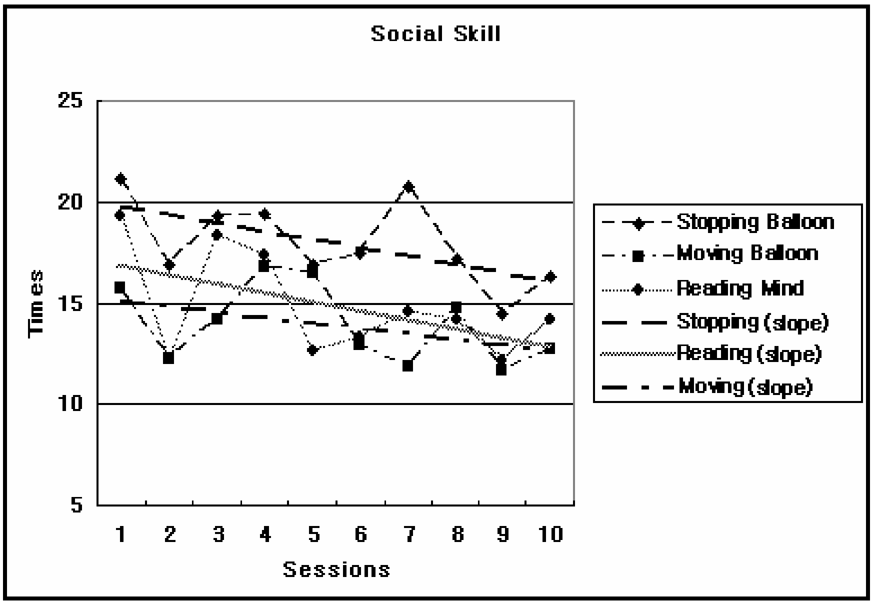

Figure 4: Variation of reaction time for the social skills training program.

1) Comparison to Healthy Control Children

We compared the autistic children with normal kindergarten children. It was difficult compare directly, because autistic children had practiced and adapted the system. However, it can be used to compare the difference of the two.

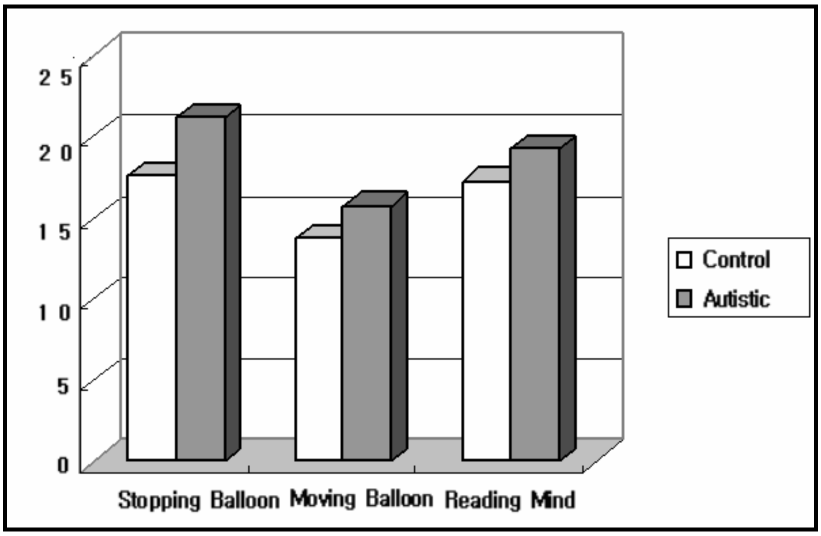

Figure 5: Comparison between groups for social skill program.

	Autistic	Control	t	P
Stopping Balloon	21.1±10.9	17.6±3.1	1.034	n.s.
Moving Balloon	15.8±5.1	13.8±3.1	1.105	n.s.
Reading Mind	19.3±9.7	17.3±4.8	0.601	n.s.

Table 3: Comparison between groups for social skill program.

As Table 3 shows, there was no significant difference between autistic children and healthy control children because autistic children had had practice time, but autistic children showed longer response times and higher standard deviations in each task.

3.3 Sensory Integration Therapy

Fewer sessions (3 to 8) and the limitation of the stimuli used for sensory integration training (primarily focused on vestibular organs) made the effects of SIT difficult to measure, which used the same measurement of sensory profile. Moreover, there are no variables that can be measured in research differ from the social skills training and coordination ability measurement. It is possible that to judge the effect of the sensory integration therapy, the overall impression of the effect of the sensory integration test immediately after those of sociability and coordination ability, and indirect observation of the interest of the children who engaged the sensory integration therapy program, could be used.

As in other forms of therapy, boredom had a large effect. The children had time to adapt but became bored easily. For example, a taste for foothold was decreased because repeated contents. On the other hand, preference for unrepeated stimuli such as running, increased as the sessions progressed. Thus, we can assume that the preference for tangible interaction had effect.

It did not affect the statistics of the sensory integration therapy about influence on social skill program and coordination ability that operated after the sensory integration therapy.

4. Discussion

Until now, there has been no research on autistic children using VR-TIS. From our research, however, we can see its possibilities. It may be difficult because autistic children have mental disabilities that affect their ability to participate (Luke & Tsai, 2003; Dahlgren & Trillingsgaard, 1996). However, all except one of our original participants were able to complete the tasks. There was s significant difference between healthy controls and autistic children. This implies that this program can be used to classify the normal and autistic children. But specifically we found that it is possible to apply our system of and therapy for, autistic children.

There are two main limitations of traditional SIT for autistic children: the number of places or situations that can be experienced by the therapy is limited, and repetition results from the use of the same tools repeatedly. However the SIT programs based on VR–TIS provides a good composition of various places, and we can easily change the places according to our needs. Real places in this research contain a variety of stimuli from unusual places, which addresses the original limitation of SIT.

Even though presence plays a significant role in virtual reality, it is not easy to generate and maintain presence in virtual space (Banos, Botella, Guerrero, Liano, Rey, & Alcaniz, 2005). Research results about efficient and meaningful therapeutic studies using virtual reality for children with autism and developmental disorders have been presented (Moore, McGrat, & Thorpe, 2000; Parsons & Mitchell, 2002; Trepagnier, 2002; North, 1996), but there have been difficulties in those virtual reality therapies in terms of presence and immersion According to our results, VR-TIS suggested the possibility of the new interaction. Children who participated in this research applying VR-TIS performed tasks using tangible devices without any particular difficulties. Moreover, children showed the great interest about the program with virtual reality while they were performing tasks. This can be interpreted as our program applying both virtual reality and tangible interaction system to embody presence adequately.

In this research, social skills training and coordination ability measurement had better effects than sensory integration or trampoline by giving the reality. This was caused by individual differences in the case of the sensory integration therapy (Baranek, Foster, & Berkson, 1997b). In addition, the contents of the problem solving and recognition of social training and coordination ability tasks were more interesting to the children than any other tasks. And, social skills training program produced more interaction by conversation with therapist than sensory integration therapy that represented reality.

Social skills training module can elicit various conversation, so it was useful in both before and after treatment, while measuring the coordination ability was more training module. By recognizing these special features of the modules, we can develop the applicability to other therapy programs. The sociable module could be made more interesting by including the transcripts or voices of these conversations.

However, some limitations of our study have to be considered. Firstly, there are differences in the preferences and adaptation levels of participants, even though they have the same symptoms (Parsons & Mitchell, 2002), so the therapy should be individualized but our program was not. Thus, in future trials, the therapy should be individualized to be more effective. The level of contents should also be individualized.

During the 10 sessions of the test, many children became bored even though we had tried to vary the contents. Also, during the adaptation test, in which the children were able to practice 2~4 times before the real test, some children tended to concentrate more and later became bored by the repetition. In future studies, we suggest that the adaptation tests e excluded and that new and more varied materials be developed.

Tangible interactions, such as the stick, trampoline, and interactive stepping floor, were used in many fields. The interactive stepping floor was used user rotary motion, swaying from side to side, and screen rotation (such as turning four sides or turning the screen). However, it was hard to offer a proper interaction because of the repetition that bored the children. Therefore, for tangible interaction, it would be more useful to use various tools rather than simple, multiprocess tools.

To allow a larger screen projection, we used a wide and dark room. This led to the room being too dark for face–to–face interaction. It is very important to consider the mental aspects for autistic children (Greenspan & Wieder, 1997). The layout of the therapy room was designed to be parallel with therapist and children, but it was sometimes difficult to see the children. It would be helpful to offer several pieces of furniture so that participants can be comfortable and can product their exercises without any inconvenience. We should also be careful with the lighting for face–to–face interactions.

Some limitations in this study are apparently due to the use of VR–TIS for assessment of autistic children for the first time. However, we believe that our findings have potential for the clinical field. We will address the identified limitations in future studies. Subsequently, VR–TIS might be a useful tool for assessing and treating those children with autistic and pervasive development disorders.

Acknowledgements

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The development of an integrated psychosocial approach to effective usability of 3D Virtual Environments for Cybertherapy

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ABSTRACT

The aim of the paper is to describe a possible direction of development and theoretical model for ergonomic research in the Virtual Reality (VR) field dedicated to psychotherapy applications. Through considerations on the strong points and limitations encountered during two different projects dedicated to the creation of virtual reality environments (VRE) for use in psychotherapy, it comments on the concepts of ecology and context of use. The theoretical perspective proposed intends to highlight the evolution from an *ecology of state* to an *ecology of process*. Given the considerable obstacles connected primarily to the lack of accepted standards for the ergonomic evaluation of 3D environments and the specific nature of the applications and user type in question, ergonomic research will represent an increasingly highly strategic aspect of clinical protocol design and upgrades: a number of closing considerations are dedicated to the operative aspects of ergonomic research and the role of the researcher.

Keywords: *VR Ergonomics, VR usability, Virtual Reality Exposure Therapy.*

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1. Introduction

This contribution illustrates the development of a psychosocial model for analysing the usability and ergonomics of virtual environments used as a support in cognitive behavioural psychotherapy. The evolution of the methodological perspective will be examined through a critical appraisal of the experience conducted within the context of two projects dedicated to VR-supported cognitive behavioural psychotherapy, focussing on the problem statement and the theoretical and research development/maturation process. The theoretical background refers to the ethnometodological approach, a perspective that gives evidence of how people, in specific social situations, are able to solve complex tasks producing shared meanings and achieving their goals during the interactions, in order to make their actions understandable and successful (Galimberti et al., 2004).

VR is now considered a therapeutic tool offering tangible improvements to the efficacy of conventional treatment of specific psychological disorders. Its consequential cost-benefit impact means that fewer resources are required to obtain the same or even better results than those traditionally possible. (Riva, 2005) Computer-generated virtual environment-based psychotherapy, also known as VRET (Virtual Reality Exposure Therapy) consists in enabling the patient to interact with a feared stimulus, seen within a virtual environment containing anxiogenic elements. It goes without say that the adoption of new immersion techniques must offer advantages in order to replace or provide back-up to the tried and tested therapeutic techniques used to treat anxiety-related disorders and phobia. Several authors (Vincelli et al., 2003; Riva, 2005; Krijn, Emmelkamp, Olafsson, & Biemond, 2004; Krijn, 2005), have dealt with cognitive-experiential therapy (CET) as this new methodology is known, which aims to de-condition fear reactions, modify the representation of reality and distorted convictions regarding panic symptoms and reduce anxiety-related symptoms. The innovative aspect of this therapy is the integration of cognitive behavioural techniques with the experiences offered by VR: the wealth of studies that have been conducted on the subject allows us to identify for which pathologies, especially those related to phobia-type disorders, VR-based cognitive therapy is most effective (Krijn, 2005).

2. Problem statement

To date, despite intense, widespread research on both usability and VR, there is no evidence that improvements in the former field could be applied to VR evaluation. To our knowledge, new VR technology has not yet been adequately closely connected with the important characteristic of usability. All too often, methods designed for the evaluation of the usability of interactive computer applications, and their well-known limitations, are used to evaluate VR. For this reason, we believe it necessary to develop *VR specific* usability evaluation methods and criteria. Sutcliffe and Gault (2004) observed that few evaluation methods have been proposed for assessing the usability of VEs, although field studies by VR designers have demonstrated the need for HCI knowledge and methods. The point has been discussed by several authors: Gabbard and Hix (1997), for instance, attempted to highlight usability problems associated with the use of VR, while Bowman and Hodges (1999), among others, pointed out, among others, that VR system designers cannot rely on the methods developed for standard graphical user interfaces (GUIs) alone, as VR interaction is totally different from that of the latter devices; Kalawsky (1999) adapted checklist evaluation methods, based on Nielsen's heuristics (Nielsen & Mack,1994), to VR. Generally speaking, most studies reviewed by Sutcliffe and Gault (2004) have followed observation and expert interpretation of users' errors or experimental studies reporting performance data and problems in a range of VR technology. Nevertheless, we believe that Gabbard's (Gabbard, Swartz, Richey, & Hix, 1999) statement that researchers interested in VR usability are left to perform ad-hoc assessment or in-house evaluations with little or no scientific basis for their approach, is no longer suited to the current situation. Recent developments in the ergonomics field have provided us with practically all the tools necessary to develop a method for guiding VE usability evaluation.

3. Reference projects

The two projects considered are:

- VEPSY Updated "Telemedicine and Portable Environments in Clinical Psychology" (European Project – IST 2000 – 25323)
- NeuroTIV "Immersive Virtual Telepresence Managed Care for the Assessment and Rehabilitation in Neuropsychology and Clinical Psychology" (Italian National Research Project 2004-2007, funded by the Italian Ministry of University and Research –FIRB MIUR 2001)

4. VEPSY Updated Project: a first step towards an 'ecological context of use

As exhaustively reported by Galimberti and colleagues (Galimberti et al., 2004), on the basis of tasks assigned in the framework of the VEPSY Updated Project conducted at our research unit (Licent – Laboratory of Communicative Interaction Studies and New Technologies, Catholic University of Milan), we did not orient usability analysis on telepresence evaluation. This task was accomplished by clinical units, whereas we focus on the functional features of VEs (Virtual Environments). Our main goal was to obtain usability evaluation of processes of VR use as performed by 'real' users in 'real contexts of use'. For this reason, having completed a *functional analysis* of VEs, we performed a sort of '*fine tuning'* of VR scenarios.

As the VEPSY environments are designed for clinical use, in order to fulfil our goals, further steps were necessary after basic functional evaluation:

- To establish a minimum threshold of ergonomic acceptability to be used for every VEPSY VR module, on the basis of specific indicators identified and reported in the Guidelines prepared at the beginning of the project.
- To develop a new method of ergonomic and usability evaluation taking into account the requirements needed by the specific typologies of end users:
  - Psychotherapists
  - Patients affected by specific psychopathologies
- To integrate the results on the basis of the observations that emerged after *Large Clinical Trials*: this implied a direct comparison and interaction with the clinical group.

The possibility to arrange a research setting taking into account the cultural context of use, the bargaining nature of interaction and its intrinsic 'opaqueness', represented the main methodological objective of this first study. In particular, an ethnomethodological perspective was adopted.

As stated by Zucchermaglio (2002),

> Ethnography is one of the most suitable methods for entering communities by interpreting the meanings that are relevant for members in building up and interpreting the social world, looking for them in the discursive interactions and in public inter-subjectively accessible behaviour. The validity of ethnographic research does not lie in the objectivity of the description, but rather in the level of authenticity, plausibility and reliability provided by the descriptions also to the subjects observed (...). For the understanding of social situations, we must stress

the importance of the categories of meaning performatively used by people involved in those specific situations.

Licent research unit carried out ergonomic evaluation of two of the four VEPSY modules in 3 Phases:

- **Panic Disorder and Agoraphobia modules**: in ***Phase 1,*** *guidelines on heuristic basis* were prepared in order to have an effective evaluation tool. Afterwards, usability tests (observations) were carried out on generic users.
- **Eating Disorder modules**: in ***Phase 2*****,** *basic functional requirements were verified*, referring to the results obtained in *Phase 1*. Usability tests (observations) were subsequently carried out on a different sample for comparison with *Phase 1*, considering psychologists and non-psychologists.
- **Eating Disorder modules**: in ***Phase 3***, *semi-structured interviews* were carried out on psychotherapists involved in the clinical trials of the modules considered.

Phase	Specific goals	Specific objects	S Samples	Results	Analysis context
1	**Functional Characteristics analysis**	**Panic Disorders Modules**	**AGeneric users n=33**	**Non-specific Ethnomethods**	**Generic contextualisation**
2	**Fine tuning**	**Eating Disorders Modules**	**BPsychologists /generic users n= 16**	**Specific Ethnomethods**	**Finalised contextualisation**
3	**Integration**	**Panic Disorders Eating Disorders Modules**	**CPsychologists involved in clinical trials n=4**	**Professional Ethnomethods**	**Lived experience**

Table 1: Summary of the VEPSY Updated research framework

To fulfil our goal we had to shift our attention from VEs themselves to the relationships between users and VEs, focusing on how these relationships take shape in their real context of use. To approach the most ecological context of use, we used the LPP (Legitimate Peripheral Participation) model: “This model considers the knowledge acquisition in progression terms – from the periphery to the centre - in the participation activities of the *communities of practice”* (Zucchermaglio, 2002).

The study was therefore broken down into three phases, each one characterised by:

- specific aims;
- specific objects (i.e. two VEs typologies for different psychological disorders);
- samples reflecting non-specific, specific and professional ethnomethods;
- generic, finalised and lived experience analysis contexts.

Specific tools

Classic usability evaluation methods such as functional analysis aided by expert heuristic evaluation supported by ad hoc guidelines and user-based tests were supported by two specific ethnomethodological tools: *micro-narration* and *interviews*, used in phase 2 and in phase 3, respectively. Within the framework of the paradigmatic change under consideration, a relevant role is played by the narrative concept of knowledge and culture.

Narration can be considered both an adequate tool for recovering shared practices, in particular, through recollection, and also a useful tool for creating a group culture, i.e. suggesting a repertory of meanings establishing what it is important to observe in connection with consolidated habits. In the different phases of the analysis, micro-narration and interviews were presented to subjects in order to recover information related to the co-interaction with the artefact and with the co-construction of meanings in a specific professional community.

Micro-narration: users were supplied with specific information helping them to interact *“as if”* they were in the real context. For example: basic information about the specific VR protocol and about the therapeutic setting was given to the psychologists tested. They were informed that “the purpose of the environments is not the creation of a perfect reproduction of the real world: patients and therapists involved are aware of the fact that the effectiveness of the tool for the patient does not depend on the perfect accuracy of certain specific elements but rather on the feeling of presence perceived that could be very different from that of a person without pathologies”. Non-psychologist users were asked not to consider VEs as videogames and the potential applications of the environments considered were explained to them.

*Semi-structured interviews***:** in-depth interviews with the clinical group (psychotherapists involved in the clinical trials) were carried out in order to move towards an ecological context of use. In the specific case, the investigation focused on 4 main areas with reference to ergonomic aspects:

- In context use of the VEs for psychotherapy sessions.
- Expectations of the therapeutic protocol.
- Usability (local interaction with the artefact, interpretation of the situation and context definition).
- Towards a culture of use (possible future application of the VEPSY modules; critical aspects for training activities etc.).

5. NeuroTIV Project: reasons for a clinical-ergonomic analysis

From the ergonomic point of view, the VEPSY Updated project allowed us to conceive the experience of artefacts' use as immersed in a social and goal-driven context and to stress the component of ambiguity inherent to everyday situations. At the same time, the need for a more context-situated analysis strongly emerged in order to better understand possible discrepancies between standard clinical protocol application and the real use of the VR scenarios by therapists and patients during therapy sessions. For example, some of the IT systems' drawbacks and errors proved to be a 'plus' within the context of the therapeutic framework, such as the case of the graphic appeal, which did not seem to influence the effectiveness of VR therapy at all (Galimberti et al. 2004).

VR scenarios serve to speed up access to the personal experience of patients affected by specific psychopathologies and the representation of the stimuli functional to the activation of this process does not need to fulfil requirements connected with the realism of the experience intended the physical characteristics of VEs: in this sense, emphasis shifts from quality of image to freedom of movement, from the graphic perfection of the system to the actions of actors in the environment (Gabbard & Hix, 1997). Through a correct interaction between the therapist and the patient it is possible to anticipate and avoid orientation and navigation problems. The use of devices is simplified and the system is accessible.

It can be claimed that the criteria adopted to analyse VEPSY modules allowed us to achieve the following:

- Recognize the mediated character of every experience of presence
- Conceive the experience of artefacts' use as immersed in a social and goal-driven context
- Stress the ambiguity component inherent to everyday situations
- Demonstrate how cultural dimensions affect the effective use of VEs

On the other hand, for both ethical reasons and with reference to specific goals and roles assigned to the partners in the VEPSY Updated project, the ergonomic research unit did not participate in clinical trials, and the need for a detailed exploration of therapist – patient interaction was therefore felt very strongly. This is - in our opinion - the key to a new and more effective approach to the ergonomic analysis in real context.

Design and clinical practice were kept separate to a certain extent and therefore in the NeuroTIV project great efforts were made to overcome this limit by keeping the design phases and the fine-tuning of the environments strictly connected to the clinical applications and requirements.

The ergonomic evaluation was included in the design process from the very beginning of the project in a preventive ergonomics perspective. This because we think that the attempt to meet clinical and technological requirements are two aspects of the same design process that cannot be considered separately.One fundamental aspect of the NeuroTIV research is the possibility to use outpatients as subjects for user-tests rather than for video-recorded interaction analysis alone.

The opportunity of improving the realism of VR environments, to give a concrete example, will therefore be suitably verified with the panel of therapists, who are, in turn, expert "users" and reference targets. In the interest of a more efficacious use of virtual reality in a therapeutic context, the planning of in-depth training on the use and technological operation of VR artefacts would also appear essential. Each individual element and input emerging from a qualitative analysis of this kind will therefore be verified and tested with the ultimate aim of making it possible to improve both the environments and the clinical protocols currently used (Vincelli, Choi, Molinari, Wiederhold, & Riva, 2000).

5.1 Ecology of State and Ecology of Process

As highlighted by Cantamesse and Menti (2002), ergonomics has a somewhat vast field of application: from the design of everyday items to user-computer and user-computer-user interaction. Psychology and especially Social Psychology has played an important role in the evolution of the ergonomics towards a *preventive* rather than a *corrective* function. The adoption of the concept of *preventative ergonomics* also led to the introduction of the principle whereby human or machine error in any case takes place within a relational context, in which attention is centred on the relationship between people, environment and instrument used. From this point on, ‘IT artefacts’ are considered “as experience transformers”: the task becomes part of a broader scenario. The achievement of an ecology, that we can define “ecology of state”, in the ergonomics research field, becomes a priority.

Having established that the ecology level reached in the first study was the highest possible in that specific situation, for the second it was decided to ‘force’ the limits encountered previously by applying an analysis model that privileges the possibility of coming closer to the situation of use, partly through a theoretical context flexible enough to allow the application of more specific analysis instruments and procedures.

From an *ecology of state*-oriented perspective we attempted to shift the focus to the concept of *ecology of process*. We believe this to be a key step towards truly grasping the specific nature of the context and at the same time, in order to have a satisfactory research base on which to ‘graft’ and through which to interpret the data produced.

Ecology of state in turn includes ecology of context, which has been exhaustively defined and conceptualised by different research streams such as the Situated Action Theory, Activity Theory, Distributed Cognition and Scenario-based design (Spagnolli Gamberini, Cottone, & Mantovani, 2004) and an *ecology of situation* characterised by the consideration of the interaction in which the term refers to both the set of interactions as a whole and in their specific nature. In this sense, we can say with certainty that the *ecology of state* was respected in the first study.

The *ecology of process* concept represents a further step towards an improved ecological framework by introducing the value of the *dialogical perspective.* The dialogical importance promoted at each level of the phases of analysis becomes the key to a deeper and more fluid understanding of the assumptions and meaning that guide, first and foremost, actions and interactions *between* therapists and patients. On a higher analysis level, the dialogical perspective allows a new, more flexible way of producing and interpreting data originating separately from therapists, patients and expert researchers/evaluators. Lastly, by considering a third level, we can conclude that the entire system design process is inspired by a dialogical persspective in that it aims to effectively and non-rigidly integrate the stages of design, analysis in context of use, ergonomic evaluation, creation of the VR system and final work on the clinical protocol in use.

As regards the type of data produced, the reference to the *ecology of process* may be broken down as follows:

Focus of attention	Type of data produced		Interaction level
	Interactional non-mediated data (video recordings)	***Reported mediated data (questionnaires, interviews, focus groups)***	
Therapists	Observation of therapists' use of VEs Data concerning therapist-patient interactions during VE experience	Data reported by therapists	Personal experience of VE use Situated interaction between users (therapist-patient)
Patients	Observation of the patients' use of VEs Data concerning patient-therapist interaction during VE experience	Data reported by patients	Personal experience of VE use Situated interaction between users (therapist-patient)

Table 2: Typology of data produced within an *ecology of process* perspective

The focus of attention shifts from therapist to patient from time to time, but does so within a concept of ongoing comparison and data integration, results of analysis and, lastly, results of the product, meaning the proposed modifications to the environments that may lead to a substantial change in the therapeutic experience.

In order to give a concrete example, one aspect that the researchers faced in the first project was the cultural background of the same therapists involved in the research. A simple 'functional requirements collection' (a basic step in all ergonomic studies) proved to be unsatisfactory for several reasons.

Firstly, the therapist's theoretical background and 'therapy style' can strongly influence his/her evaluation of VR environments in both a positive and negative way. For example, there is a significant difference between when therapists consider the VR environment as a simple stimulus to help patients remember their personal experience without intending to fully exploit the characteristics of the immersion experience and when they intend to guide patient navigation by proposing a sort of narrative-path and co-discovering possible difficulties together with their patients. This aspect cannot be solved by referring to the clinical protocol as it of course leaves therapists free as far as their personal relational style is concerned. However, in this case, there is a high risk of designing VREs tailored to suit the 'vision' of a specific therapist. Secondly, therapists often have to deal with the considerable problem posed by the technical faults of pilot versions of VR environments. This can seriously affect therapy, so strategies to maintain the patient's attention focused on general therapy aims by using different techniques to increase the sense of presence in the feared situation are of course applied by therapists when necessary. Thirdly, the level of confidence in the potential of technology and the different opinions that therapists, patients, researchers and IT designers have on technology and VR, can play an important role in every phase of the project and great attention must be paid to this issue.

These are just some examples of problems that the adoption of an ecology of process perspective can help to overcome through a continuous integration of patients' and therapists' experiences (both considered as expert users) and their reciprocal representations. In particular, a flexible approach to the research allowed by a continuous and controlled shift of attention from therapists to patients, from outcomes of mediated and non-mediated data produced and from an individual representation of the level of interaction to a situated perspective could help us to build a more functional model.

5.2 The VR design process

Starting from the evaluation of the critical level with reference to the usability indicators usually applied, such as, for example, heuristic evaluation adapted to 3D environments (Sutcliffe et al., 2004), the investigation of the real context of use is the fundamental step that can effectively contribute to the optimisation of the whole designing processes together with the effective integration of existing methods and the improvement of usability evaluation tools that are still too vague for VR applications.

One of the aims of the NeuroTIV research project is the development and production of highly complex multi-media interactive software.

This requires a formal approach to the development process that correctly integrates the following activities:

- requirement management;
- analysis;
- design;
- codification;
- testing.

The structuring of an iterative process in this sense is guided not by a rigid sequence of predefined phases, but by systematic management of project risks, in order to achieve a progressive reduction. This choice allowed the group to deal with the technological evolution of resources, characterised by exponential speed, but above all to manage dynamic requisites in their definition phase, thus offering a guideline and method for keeping track of the changes.

With specific reference to the second phase of the design cycle (see figure below), the ergonomic analysis should reach its highest level of ecology of process: the evaluation will be based on the analysis of therapist-patient interactions (8 sessions for each of the 9 patients, for a total 72 sessions) and outpatient tests (12 subjects). Focus groups and separate in-depth interviews will be carried out with independent therapists involved in the project.

The first level analysis, conducted with the support of the Atlas.The first level of analysis, will be conducted with the support of the Atlas Ti 4.2 software for quali-quantitative analysis, is aimed at investigating pratice habits for the use of VR in the framework of the therapeutic protocol, with special focus on VR scenarios and their ergonomic aspects.Ti 4.2 software for qualitative and quantitative analysis and is aimed at investigating practice habits for VR use within the framework of the therapeutic protocol, with special focus on VR scenarios and their ergonomic aspects. On the other hand, in the user-based tests, outpatients are considered as ‘expert users’:Conversely, in the user-based tests outpatients are considered as ‘expert users’: their contribution is relevant in order to evaluate and improve the structure and the navigability of VR scenarios.their contribution helps in evaluating and improving the structure and navigability of VR scenarios.

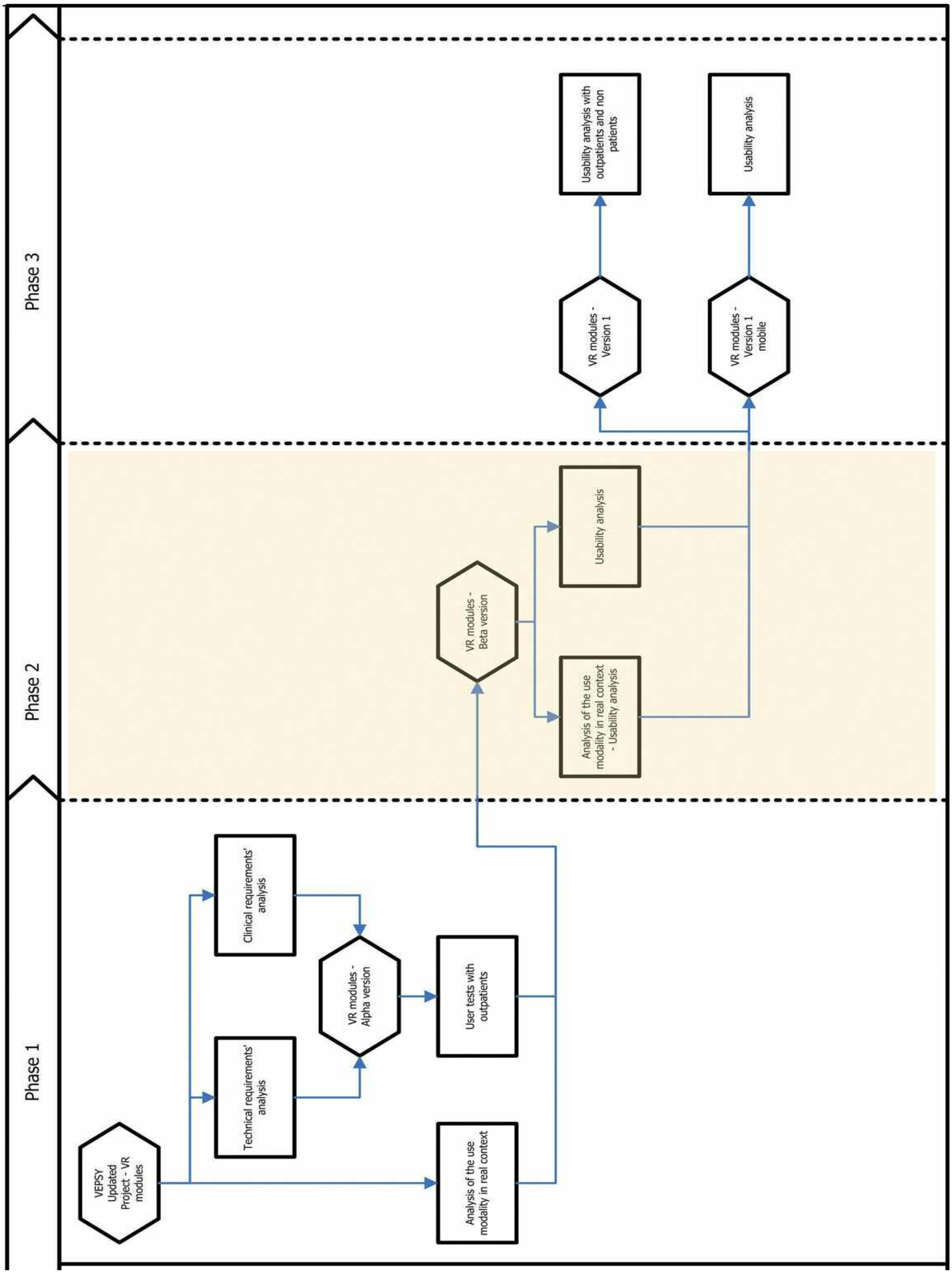

Figure1: NeuroTIV: VR modules' design process

A preliminary analysis required the definition of 14 macro-categories (for a total of 56 codes), obtained from literature and the texts themselves, based on the inter-subjective evaluation of 5 independent judges. These categories relate to:

- characteristics of environments used for the specific pathology;
- actions possible within the VE;
- interacting players;
- representations and descriptions;
- reference to technical and therapeutic aspects;
- comparison with the real environment and past experiences;
- navigation instructions;
- states of mind;
- locus of control.

As regards VE implementation, the efficacy of certain specific functions related to the following areas will be studied:

<u>Area 1: Usability of the environments</u>

This area concerns the identification of usability basic defects in a classic sense. The main methods applied were the *functional analysis aided by expert heuristic evaluation* and *user-based tests*. This aspect was particularly challenging because, at present, there are very few guidelines specific to VR user interfaces. To overcome this problem *Guidelines on heuristic basis* were prepared in order to have an effective evaluation tool (Galimberti et al., 2004) The heuristics used in this study are derived from Nielsen (Nielsen et al.,1994; Nielsen 2000). Usability tests on generic users were also carried out.

<u>Area 2: Interaction within the VR environment</u>

A separate area is dedicated to aspects connected to interaction in the VR environments, as the aim was not only to verify the correct technical operation of functions already or about to be implemented (which would strictly speaking belong to the usability area), but above all to understand what level of environment interactions may be judged necessary and satisfactory for therapeutic purposes, and for what reasons (characteristics of avatars: 2D vs. 3D, use of the emotive facial expression channel, verbal interaction with avatars, sound realism)

Area 3: Narration

It was decided to investigate the usefulness of including introductory pre-sequences or narrative sequences inside the environments, based for example on the formulation of tasks to be performed or compulsory routes, in order to complement the conventional therapist-guided exploration method with the aim of supporting the patient during the imagination/recollection process. Again, verbal interaction with avatars could represent a crucial issue.

Area 4: Information on VR-based therapy

This area contains all the information provided by the subject relating to experiences, representations and expectations regarding VR therapy.

6. Discussion

Since the very beginning of the NeuroTIV project significant elements have been introduced in the VR environments to allow a more effective interaction from the therapeutic point of view. These modifications follow two directions: the *improvement of the interaction*, from one side, and the improvement of the *perceived correspondence between the real and the virtual world.* With specific reference to this second aspect, we agree with the O'Neill (2005) position which stresses out the importance of 'agency' in order "for a virtual space to become an inhabitable place": in this sense great efforts are necessary to design VR environments allowing a good balance between the need of the patient to explore and act autonomously and the primary role played by the therapist who guides and supports the patient in the navigation, co-discovering and co-constructing with him/her possible representations and meanings. Another crucial aspect is represented by the opportunity offered by the technology to mix the material and non material dimensions recognizing that "the mediated Place is simultaneously physical, cognitive and cultural" (Spagnolli & Gamberini, 2005). The identification of the right elements, narrative paths and, more in detail, of meaningful cues for the specific purposes of the VR environments under preparation is a really interesting challenge both for therapists and designers.

The specific type of object and, above all, the specific nature of the users (therapists and patients) pose considerable problems regarding the ecological validity of the research. Following an evolutional-type path conducted within the scope of two research projects, of which one is still in progress, we aimed to highlight certain theoretical and methodological key points, including the need for an approach that is increasingly close to the actual context of use within an ecology of process perspective, faced with an ecology of context that would appear to be no longer sufficient to support and opportunely motivate subsequent design choices. The research needs to be validated on a larger scale - even if qualitative methods are applied in this case - and the development of assessment tools deriving from different disciplines can be of great help.

In NeuroTIV, the functions regarding ergonomic research and the technical creation of VR environments, which were previously separate, were definitively integrated into the work group. The design and VR environments implementation unit is composed of expert programmers and electronic engineers coordinated by a psychologist with expertise in new technologies and computer design. In turn, the researchers assumed a more constructive role towards therapists: it is not a case of gathering requisites and evaluating functions from a primarily technical standpoint, but of suggesting and testing together what can be substantial changes (3D avatars, addition of the expressive emotive channel, introduction of narrative paths inside the environments) that could also significantly influence the clinical protocol.

7. Conclusions

With this paper we attempted to trace a possible path of intervention regarding difficulties that ergonomic research in the VR field, and in particular that referring to clinical psychotherapeutic applications, still encounters due to the lack of accepted standards for evaluation tools.

From an operative research standpoint, it is unfortunately true that, to date, no standard VR systems have been developed for the various pathologies and even officially acknowledged standard clinical protocols are few and far between (Riva, 2005). In order to attempt to take a step forward in this direction, it would appear essential to involve therapists in studies. As we have seen, the possibility of analysing the methods of use and the interactions created by clinicians with different theoretical backgrounds, expectations and representations is extremely important.

Another aspect that emerged is the change in perspective towards the subjects involved: patients and therapists are now considered as equally expert users – each one in his/her own field of competence. The possibility of conducting user-based tests not only on users with disorders, but also on outpatients, and having planned various points at which researchers can come into direct contact with patients (for example by assisting the therapist in the technical arrangement of the setting at the beginning and end of the session, or by being on hand at all times to gather patients' comments or observations) considerably extended the boundaries of interaction within the work team. A good researcher, especially when dealing with qualitative analysis, must take full advantage of these moments of active participation.

Lastly, we believe it important to include a consideration on the specific role of the ergonomic researcher: this expertise is all too frequently relegated to a merely 'technical and technological' context, or restricted to design cycle phases, which is likely to considerably reduce the efficacy and quality of the entire project. This provides the stimulus to seek a role that becomes increasingly context-specific and that fosters exchange and dialogue: in the case in question, with the decision to better define the clinical – ergonomic value of the research, we attempted to highlight the impossibility of separating the competences of expert users (clinicians, first and foremost) from those of ergonomic researchers and lastly the IT experts and programmers, in a constructive, albeit not obstacle-free, commitment to the creation of a design culture 'expanded' to all levels of activity.

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WORK-IN-PROGRESS

Grasping Virtual Objects: a Feasibility Study for an Enactive Interface Application in Stroke

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ABSTRACT

Recent studies show that 30% to 66% of patients who suffered a stroke are unable to recover the upper limb functionality and that most patients present motor disability five years after the acute event. Despite a general motor recovery the incapability to reach and grasp objects in the usual environment remains one of the most common disabilities after stroke. At the present time treatments for such impairments have been based on movement repetition of targeted tasks as part of training activities. Clinicians, however, are still looking for the possibility to provide a rehabilitation procedure that could match the natural and intuitive mode of interaction with objects that humans generally have in reaching and grasping in the daily contexts. In the last years the evolution of technologies appears to meet this request, notably with the growing of enactive interfaces. Such interfaces support the perception-action interactions with an environment allowing users to learn how to perform a useful action in a particular context. The expertise gained through the interaction with this multimodal interfaces results, in fact, in the acquisition of intuitive movements that is essentially based on subjective experience and on the perceptual consequences of their motor acts.

The main aim of this work is to investigate the technical and clinical feasibility of using an enactive interface in the rehabilitation of reaching and grasping movements of upper-limb hemiparesis that occurred after stroke. In this study ischemic stroke patients will be requested to perform technology-enhanced grasping task at our rehabilitation center, in addition to usual physical therapy.

Key words: Motor skill – Rehabilitation – Enactive interfaces - Stroke – Reaching and grasping functions

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1. Introduction

Recent studies show that upper limb impairment affects 85% of stroke patients, and that most of stroke patients with initial upper limb impairment still have significant functional problems five years after the acute event (Broeks, Lankhorst, Rumping, & Prevo, 1999). Although intensive therapy for the upper limb after stroke is associated with small but statistically significant improvements in neuromuscular and functional outcomes, scientific results are unclear about the effectiveness of specific upper limb rehabilitation strategies. In the last decades a number of articles have been published on the effect of various rehabilitation methods to improve arm function after stroke are evaluated (Van der Lee, Snels, Beckerman, Lankhorst, Wagenaar & Bouter, 2001; Rodgers et al., 2003; Woldag, Waldman, Heuschkel, & Hummelsheim, 2003). These rehabilitation strategies include a) the increased intensity of physiotherapy, b) a 'forced use' of impaired arm, c) the introduction of electrical stimulation and/or electromyographic biofeedback, d) the proposition of repetitive tasks.

Two reviews concerning various types of treatment for the arm in stroke patients concluded that more intensive exercise therapy is beneficial (Duncan, 1997; Richards & Pohl, 1999) and a similar conclusion in favour of more intensive exercise therapy was drawn in two exhaustive meta-analyses, which were not limited to the arm (Langhorne, Wagenaar, & Partridge, 1996; Kwakkel, Wagenaar, Koelman, Lankhorst, & Koetsier, 1997).

Moreover, several studies have been conducted on the role of repeated motor practice for motor learning and recovery. In particular, in a multiple baseline study across individuals it has been shown that the repetitive performance of identical hand and finger movements resulted in a significant increase in hand function compared with conventional physiotherapy (Butefisch, Hummelsheim, Denzler, & Mauritz, 1995).

In spite of the proven effectiveness of physiotherapeutic treatment, functional recovery of the affected upper extremity remains unsatisfactory in most of the cases. A fully recovered arm of a hemiparetic patient will not improve substantially his quality of life if it is not accompanied by recovery in the manipulative abilities of the hand.

In particular, major barriers to arm motor recovery after stroke are coordination deficits and the use of maladaptive movement strategies for reaching and grasping.

2. How are we able to grasp?

Movement strategies, and grasping in particular, have been extensively investigated by several disciplines, including physiatry, kinesiology, neurophysiology and cognitive neuroscience. There is a consensus that grasping an object requires coding of the object's intrinsic properties (size and shape), and the transformation of these properties into a pattern of distal (finger and wrist) movements (Jeannerod, Arbib, Rizzolatti, & Sakatam, 1995). In order to grasp an object the human brain must have the possibility to identify the target object, to evaluate an approximation to it (reaching), and finally to execute the correct movement in order to grasp it. Roughly speaking, human brain must have the possibility to plan an action.

Research on movement has shown that in order to specify a plan of action, the human central nervous system (CNS) must first translate sensory inputs into motor goals - such as the direction, amplitude, and velocity of the intended movement. Then, to perform a movement, it has to convert these desired goals into signals that control the active muscles during the execution of limb trajectory. Specifically, to plan an arm trajectory toward an object, the CNS first has to locate the position of the object with respect to the body and represent the initial position of the arm. To specify the limb's trajectory toward a target, the CNS must locate not only the position of an object with respect to the body but also the initial position of the arm. Information about arm configuration to be used in the programming of the arm's trajectory is provided by the visual and proprioceptive system.

The planning of limbs' movements constitutes an early and separate stage of information processing, in which the formation of arm trajectories the CNS formulates the appropriate command for the desired trajectory on the basis of knowledge about the initial arm position and the target's location. During planning, the brain is mainly concerned with establishing movement kinematics, a sequence of positions that the hand is expected to occupy at different times within the extrapersonal space. Later on, in the execution phase, the dynamics of the musculoskeletal system are controlled in such a way as to enforce the plan of movement within different environmental conditions.

There is evidence that the planning of arm trajectories is specified by the CNS in extrinsic coordinates. The analysis of arm movements has revealed kinematics invariance, suggesting that CNS planning takes place according to the hand's motion in space (Flash & Hogan, 1985). Evidences derived from straight and curved movements indicate that the kinematics invariance could be derived from a single organizing principle based on optimizing endpoint smoothness (Flash & Hogan, 1985). If actions are planned in spatial or extrinsic coordinates, to execute a movement the CNS must convert the desired direction and velocity of the limb into signals that control muscles. The elastic properties of the muscles provide instantaneous correcting forces when a limb is moved away from the intended trajectory by some external perturbation.

Thus, although apparently simple, successful grasping requires to integrate information from various domains devoted to localizing the target in space, analyzing its dimensions, shape and orientation, and selecting the proper hand configuration. Moreover, this complex mechanism appears to be able to operate independently from object semantic identification (Daprati & Sirigu, 2006). Opposition of the thumb is a common feature in most hand-object interaction such grasping, yet placement of the fingers and amplitude of their aperture vary considerably according to the type of hand–object interaction. In particular grasping, characterized by changes in grip aperture, can be distinguished in precision grip - characterized by opposition of the thumb to one or more of the other fingers – and power grip - where the fingers are flexed to form a clamp against the palm (Castiello, 2005).

Two levels of awareness have been identified in representing actions in humans (Jeannerod, 2003). An automatic level relies on unconscious interaction with objects in external world. This level is characterized by a pragmatic processing of the external objects, in which agents are extracting from them those intrinsic and extrinsic properties that are relevant to action. At the failure of automatic level it is possible to substitute a conscious level of action, in which the representation of movements is voluntarily activated and a specific action is intentionally selected from several possible alternative.

Like most of movements directed towards objects, grasping is executed automatically. Once grasping is started, movements are accurately performed leaving only short time for regulations. However, as noted before, object-oriented movements are organized and represented in human mind prior to overt execution. In the action of grasping a cup, for example, the finger position during the reaching phase has to be appropriate for a stable grasp of the specific object. This is possible because of the interplay between the possibility to physically represent the external object and the internal motor planning of the appropriate action to be executed (Paulignan, Frak, Toni, & Jeannerod, 1996).

3. The introduction of technology in rehabilitation

The intrinsic interactive feature of virtual reality (VR) allows the development of effective training environments for the rehabilitation of motor functions (Rose, Attree & Johnson, 1996; Riva 1997; Rizzo & Buckwalter,1997; Morganti, 2004).

The main innovation of VR is the possibility of providing a new type of human-computer interaction. In fact, all body movements can be potentially used to interact with a virtual environment (VE). Furthermore, the changes of the VE determined by these movements offer new action opportunities. However, VEs should not be considered as equivalent to “natural” environments, but environments that allow the definition of experiences that suite the personal goals of the user.

The raising interest towards the use of interactive simulations, such as VR, in neurological rehabilitation, is justified by several advantages provided by this approach (see Figure 1). First, VR allows the creation of a completely multimodal stimulation, which provides patients with a great sense of involvement in action. Accordingly, VR interfaces developed for rehabilitation application were designed to support a sense of realism for the actions that patients are performing within the simulated worlds.

Furthermore, several studies have shown that knowledge acquired in VR can be transferred in a real environment (Wilson, Foreman, & Tlauka, 1997). These studies emphasize the potential effectiveness of using VR in the treatment of highly social-disabling cognitive dysfunctions, as they suggest that improvements reached in simulated settings may be transferred in patients’ everyday life.

VR training settings enable patients to successfully act within a safety environment. In addition to the reduced performance anxiety, this characteristic can enhance confidence in action execution and foster patient’s motivation, thereby improving his/her autonomy in everyday-like situation. Moreover, acting in a sheltered scenario increases patients awareness of the physical burdens determined by the disease, as well as of the risks associated to the exploration of an unknown environment.

Finally, rehabilitation protocols can take advantage of the patient’s playfulness with the VR experience, thus enhancing his/her motivation and compliance towards therapy.

VR Application	Benefits	Challenges
Neuro-muscular	○ Improved Compliance ○ Fine time resolution ○ Rehabilitation at home ○ On-line data gathering	○ Equipment cost ○ Technical expertise ○ Safety at home ○ Network bandwidth
Post-Stroke	○ Engaging/motivating ○ Repetitive intensive ○ Adaptable to patient condition ○ Usable in chronic phase ○ Activities of daily living	○ Clinical acceptance ○ Technical expertise ○ Abnormal limb configuration ○ Upper functional population applicability ○ Cognitive load

Figure 1: Benefits and challenge of interactive technologies use in rehabilitation (adapted from Morganti, 2004)

In spite of its benefits, the adoption of VR in the field of rehabilitation poses several challenges. First, there is lack of statistical data concerning the efficacy and safety of VR as a rehabilitation tool. Moreover, clinical research is needed to show the cost-effectiveness of using VR in rehabilitation with respect to traditional methods.

Studies on chronic post-stroke patients have shown that VR can improve the performance even long after any conventional therapy has been stopped (Holden & Todorov, 2002). For example, Wilson and colleagues (Wilson, Foreman, & Stanton, 1997) developed a VR tool in order to provide patients with action opportunities which compensated physical burdens determined by their disability. More specifically, the system allows patients to actively construct and execute actions within a simulated environment turning them able to interact with the environment by using sensory channels different from the impaired ones. This approach fostered patients' autonomy in their everyday environment, and increased their motivation in performing actions. Rose and colleagues (Rose, Attre, Brooks, & Johnson, 1998) have developed a VR system which allows substitution of natural environmental stimulations with artificial stimuli derived from VR simulation. The goal of the experiment was to monitor patient's reactions to specific categories of stimuli, and to assess patient's capability of discovering relations among the different kinds of preserved sensory stimulation. This use of VR revealed to be effective in evaluating residual abilities, particularly when clinical symptoms appear to be confused.

Finally, a controlled study assessed the importance of haptic feedback (Broeren, Bjorkdahl, Pascher, & Rydmark, 2002) in VR. A haptic device was used to assess motor coordination in the rehabilitation of upper limb following acute stroke. Patients were requested to perform a coordination task such as reaching, grasping, and moving a haptic device to different positions on the screen. Device coordinates were monitored as well as the target position, time, and trajectories distances. Results showed that, the VR system was able to establish an assessment method for discriminating functional motor skills of upper extremity between healthy individuals and stroke patients. According to the authors of this study, by increasing the complexity of the VR system will be able to lead in motor recovery.

The applications that we have reviewed here encourage the use of VR in rehabilitation. However, to further improve these applications, it is important to create a closer collaboration between technological development and clinical work

Indeed, whit the introduction in rehabilitation of advanced technologies such as immersive VR, the problem of acceptance by both clinicians and neurological patients should be taken into account. These users are often unfamiliar with VR devices such as head mounted display and virtual gloves. Thus, there is a need for developing flexible systems that are easy to install and use, either in an outpatient clinic, or at home.

Among the recent works on advanced technology for rehabilitation an interesting approach comes from the EU-funded project I-Learning (Gaggioli et al., 2004; Gaggioli, Meneghini, Morganti, Alcaniz, & Riva, 2006). The technological tool for upper limb rehabilitation in stroke patients provided in this project consists of a movement tracking system and a custom-designed interactive workbench that the authors define as a virtual reality (VR) mirror. In the I-Learning approach, the VR mirror displays a 3D electronic image of the movement performed by the patient’s healthy limb. This is viewed from an ego-centric perspective that facilitates the generation of kinaesthetic motor imagery by the patient. The treatment has been focused on different motor exercises, such as flexion-extension of the wrist, intra-extra rotation of the forearm and flexion-extension of the elbow. The patient was requested to perform the motor task with the unaffected arm, thus the system records the movement and generates its mirrored 3-dimensional simulation for to guide the patient’s exercise with the affected arm. During the execution of the physical exercise with the paretic arm, the system tracks the movement and measures its deviation from the movement performed with the non paretic arm. Using this measurement, which is done in real time, the system provides the patient with audiovisual feedback describing his performance on the task. At the end of the laboratory training phase, patients are also provided with a portable display device to practice at home. This approach combines action simulation processes, such as imaginative exercises, with VR stimulation. The protocol, by developing egocentric and allocentric upper-limb exercises and supporting them with VR multimodal stimulation and feedbacks, provides patients with the possibility of constructing their own personal image of the motor behaviour that has to be trained and all them to elaborate their own schema and sequences of movements.

In doing that the I-Learning approach introduces a revolutionary vision of VR application that doesn't require immersive technologies, such as HMD, and proposes direct and intuitive possibility of action, based on the patient's experience and on the perceptual responses to motor behaviours. Moreover this peculiar technology solution introduces the possibility of a new approach to VR systems design and development, essentially based on the innovative concept of enactive interfaces.

4. Enaction and enactive interfaces

The concept of enaction appears into cognitive science in 1991 by Varela, Thompson & Rosch with the aim of explaining how mental life relates to bodily activity in a form of embodied action. In their book The Embodied Mind, in fact, these authors suggested a sensorimotor coupling between the organisms and the environment in which they are living that determines recurrent patterns of perception and action that allow knowledge acquisition. Enactive knowledge unfolds through action and it is constructed on motor skills, such as manipulating objects or playing a sport. It is not simply multisensory mediated knowledge, but knowledge stored in the form of motor responses and acquired by the act of "doing". According to the enactive approach, the human mind, is embodied in our organism and it is not reducible to structures inside the head, but it is embedded in the world we are interacting with (Thompson & Varela, 2001). In rejecting the Cartesian mind-body dichotomy (in which there is a "mental" and a "physical" way to acquire knowledge, such as theoretical and procedural learning) the world become inseparable from the subject and humans primary way of relating to things is neither purely cognitive nor sensory, but rather bodily and skilful. Enactive knowledge is more natural than other forms of knowledge acquisition, because it is gained through perception-action interaction in the environment. Moreover, enactive knowledge is inherently multimodal because it requires the coordination of the various senses.

Traditional interaction with the information mediated by a computer is mostly based on symbolic or iconic knowledge. In contrast, enactive interfaces are multimodal interactive systems that coordinate action and perception using ad hoc devices, and allowing the organization and the transmission of this particular type of knowledge.

The basic tenet of enactive interfaces is the role of motor action for storing and acquiring knowledge (like in action-driven interfaces). Such interfaces are able to convey and understand gestures of the user, in order to provide an adequate response in perceptual terms. Enactive interfaces are characterized by a closed loop between the natural gestures of the user (efferent component of the system) and the perceptual activated modalities (afferent component). Thanks to this feature, they can recognize complex gestures.

We know from cognitive research that embodiment can be viewed in two possible ways. On one hand it could be defined as a subjectively lived state in which agents experience their own lives as embodied self. On the other hand embodied agents exist as living and biological organisms (Hanna & Thompson, 2003; Thompson, 2004).

We think that enactive technologies match both these definitions. On the one side, enactive technologies can propose novel training scenarios in which a wide variety of tasks can be easily practiced (embodiment as subjectively lived state). On the other side, if movements practiced in a virtual environment are kinematically similar to movements with physical objects, then the transfer of training to real-world situation might be possible (embodiment as living, biological organism).

The development of such interfaces requires a common vision among different research areas, like neuroscience and human-computer interaction, and more attention to the embodied interactive aspect of human cognition.

In paragraph 6, we provide an example of application of the enactive approach in rehabilitation. Specifically, we describe a protocol in which interactive simulation is used to support grasping task in hemiplegic patients following stroke.

5. The enactive interfaces for rehabilitation

Enactive technologies support a new perspective on rehabilitation that derives from a peculiar vision of motor behavior. This approach is summarized by Merleau-Ponty’s definition of motor intentionality (Merleau-Ponty, 1962). According to this philosopher, intentionality is grounded in the present situation and it is not driven by a pre-existent motor schema.

> In grasping something we direct ourselves toward it and thus our action is intentional. But the action does not refer to the thing by representing its objective and determinate features; it refers to it pragmatically in the light of a contextual motor goal effected by one's body (p.138)

This means that in picking up an object, agent identifies it not by its objective location, but by its egocentric relation to her/his hand. And she/he will grasp the object according to the goal of sipping from it. At the same time, the objects in the environment have "motor meanings", defined by Gibson (1977) as *affordances* that bring forth suitable intentional actions in relation to the motor skills of the subjects. In this way, objects are perceptually situated on the basis of the orientation that they have towards our moving and perceiving bodies. The use of an affordance implies a second reciprocal relationship between perception and action. Perception provides the information for action, and action generates consequences that inform perception. This information may not be only proprioceptive (letting the agent know how its body is performing), but also exteroceptive, and reflects the way the agent has affected the environment in respect to the affordance. The perception of this relationship allows the adaptive control of action, and of the environmental change.

The introduction of this approach in movement rehabilitation (and particularly in the rehabilitation of movement that directly relate humans body with the environment, such as reaching and grasping objects in the world) provides a fresh perspective for developing intervention treatments. Indeed the notion of enactive interfaces, allows the shift of the focus from the rehabilitation of a single motor task to the rehabilitation of global actions. By manipulating the environment, patients become aware of how to perform useful actions and the consequences of those actions. This "pure experiential" approach to rehabilitation requires a highly interactive environment that support agents in a wide experimentation of their action possibilities, while keeping patient safety.

Enactive systems appear to cope with all these needs. First of all they potentially have in input all patient actions, and are can transform these actions in alternative movement possibilities. Furthermore, enactive interfaces provides multimodal stimulation that provide patients with behavioural cues to multiple or alternate sensory ways, thus avoiding at the same time to over-stimulate the perceptual system. This feature supports more accurate knowledge integration and efficient learning. Finally, enactive technologies give the opportunity to localize patients within settings that could be unapproachable, dangerous or stressful for them in the everyday situation.

Despite the growing interest in the use of enactive interfaces for motor retraining, it may be questioned whether reaching and grasping movements in VR environments are performed in a way similar to the movements done in the physical world.

Recently, Viau, Feldman, Mc Fayden, & Levin, (2004) showed how both healthy subjects and individuals with motor impairment used similar movement strategies in a physical and a simulated environment, suggesting that enactive technology is a valuable tool for the study and the retrainment of reaching, grasping and placing movements.

If movements practiced in a virtual environment are kinematically similar to movements with physical objects, then the transfer of training to real-world situation might be possible. Furthermore, enactive technologies can open novel training scenarios in which a wide variety of tasks can be easily practiced. Indeed, recent evidence suggests that neuroplasticity after stroke (and consequently functional recovery), is influenced by the motivation of the patient and the intensity of the training (Kwaddel, Wagenaar, Koelman, Lankhorst, & Koetsier, 1999; Nudo & Milliken, 1996). Finally, the advent of home-based computers and tele-rehabilitation technologies may improve accessibility to training procedure for those patients who are unable to reach rehabilitation facilities.

On the basis of these premises, we are investigating the possibility of using enactive interface rehabilitation of brain-injured patients. In the following paragraph, we describe a rehabilitation protocol based on the use of an enactive interface (a virtual glove), in the rehabilitation of upper-limb hemiplegia following stroke.

6.The use of virtual glove as enactive device for upper limb rehabilitation in stroke

The main aim of this research protocol is to investigate the technical and clinical feasibility of using enactive technologies in the rehabilitation of upper-limb hemiparesis following stroke. Building on the enactive perspective on embodied agentivity described in paragraph 4, we start from the assumption that repetitive motor exercise customized on patient residual abilities could be appropriate for motor recovery of upper limb functionality after stroke. Clinical evidence shows that the neurological impairment after stroke is often associated with cognitive impairment, such as the inability to understand verbal indications, to memorize and correctly use the language for communication. Due to its action-based nature, the introduction of enactive interfaces allows us to overcome this failure in encoding and producing knowledge in a symbolic way. Indeed, the use of enactive interface provides intuitive motor information for the patients on how to perform the task, thereby reducing the necessity of verbal instructions. The mere presentation of the interface to patient supports him in finding the best way to perform the required activity. Moreover an immediate multimodal feedback will be presented to him when the motor task is correctly performed.

6.1 Clinical population

The clinical population will be selected according to two main parameters: *grading* and *staging* of their lesions. By *grading* we mean the severity of the impairment, as assessed with the most used motor function scales, disability scales, and speech/language/mental status scales. By *staging* we mean the time elapsed between the onset of the injury and the beginning of the rehabilitation treatment.

This interface is well-suited for patients who suffered form an ischemic or hemorrhagic stroke in the left hemisphere and to be used during their acute/sub-acute phase of recovery after stroke.

Patients who present the following are excluded from the study:

A severely impaired mental status (according to the *Folstein Mini-Mental State Examination*)

A severe disability (according to the *Modified Ranking Scale*)

Severe orientation/attention impairments

Spatial hemi-inattention and neglect.

6.2 Materials

For the feasibility study on stroke patients, we utilize a virtual glove to grasp objects in a dynamical 3D virtual environment.

The glove is the P5 glove developed for commercial use by Essential Reality. It is a an innovative, glove-like peripheral device, based on proprietary bend sensor and remote tracking technologies, which provides total intuitive interaction with 3D software and virtual environments. The use of the glove allows patients to move through an environment or to pick up objects on the interface. The flexions of all fingers as well as the wrist position are measured through a “base station” tower. The glove has an easy-to use design, with the sensing structure weighing only 128 grams and being placed on the back of the hand. It has 6 degrees of tracking (X, Y, Z, Yaw, Pitch and Roll) to ensure realistic movement. Each finger sensing structure has one resistive bend sensor, which measures the global bending with a 3.0-degree maximum resolution over a range of 0 to 90 degrees. The wrist 3D movement (translations and rotations) is tracked optically using infrared LED mounted on the backhand connector. This allows wrist measurements to be done 60 times every second, while the hand is kept at up to 1.2 meters from the base station.

6.3 Procedures

The exercise that we propose to stroke patients is to reach and grasp target items (e.g., virtual balls) on a graphical 3D surface. Targets appear randomly to patients and they that have grasp and throw them by using the virtual glove. Targets can vary for shape, dimensions, right/left and top/down appearance on the screen, increasing/decreasing velocity and depth. For the preliminary part of the feasibility study, in order to use this enactive interface in a wide range of clinical population, neutrally texturized and coloured 5cm balls are used as target objects. Patients are requested to grasp and throw target objects provided by the interface with a multimodal feedback (visual and auditory). A graphical summary of targets that has been reached or missed by the patient is continuously given to users during the performance.

6.4 Treatment

The treatment consists of 1 daily session, 5 days a week, for 4 consecutive weeks. Each therapeutic session includes 1/2 hour of standard physiotherapy, plus 1/2 hour of computer-facilitated training.

The patient is evaluated 4 times: 1) at the beginning of treatment (baseline assessment); 2) at the end of treatment; 3) three months after the end of the treatment 4) six months after the end of treatment.

The Motricity Index and the Wolf Motor Function Test are measured before and after treatment and during the follow-up. Additionally the quality of movement and the amount of use of the impaired limb is evaluated by using the Motor Activity Log.

The performance in technology-enhanced situations is evaluated through enactive interface response times and sensors data.

At the end of the treatment program, the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST), for the evaluation of the VR system, is administered to the patients. Patients included in the experimental treatment will be compared with a control group of patients who undergo traditional treatment.

7. Conclusions

In this article, we have provided a scientific rationale for using enactive technology in stroke rehabilitation. Our approach is based on the idea of an embodied cognition in which actions are not just the results of a information processing derived from an external world, as in classical perspective on motor behavior. In embodied cognition, the agents learn how to perform useful actions and what are the consequences which results from their recovered motor ability.

This approach requires a highly interactive environment that allows patients to experiment their action possibilities. The introduction of enactive interfaces that the recovery treatment could be focused on the rehabilitation of a more global notion of agency.

Furthermore, we have reported a specific interface for reaching and grasping objects in a three-dimensional space, specifically suited for upper limb recovery in stroke patients. According to the enactive perspective, the task of picking up an object requires the identification not only of the objective location, but also the egocentric relation of the object to our body. Thus, objects in the environment provide us a readiness to use, defined as *affordance*, bringing forth suitable intentional actions in relation to our motor skills. This implies a second reciprocal relationship between perception and action. Perception provides the information for action, not only in a proprioceptive way, but also in reflecting the way we have changed the environmental context in respect to the *affordance*.

Enactive systems are able to transform these action in different movement possibilities providing multimodal stimulation and action affordances on multiple or alternate sensory ways. This will support more accurate knowledge integration and an efficient learning.

In conclusion, the development of enactive interfaces for rehabilitation might contribute to fill the gap between the neuroscientific study of embodied interactive aspect of human cognition and the clinical practice. This link can highlight new challenges in the treatment of brain-injured patients.

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