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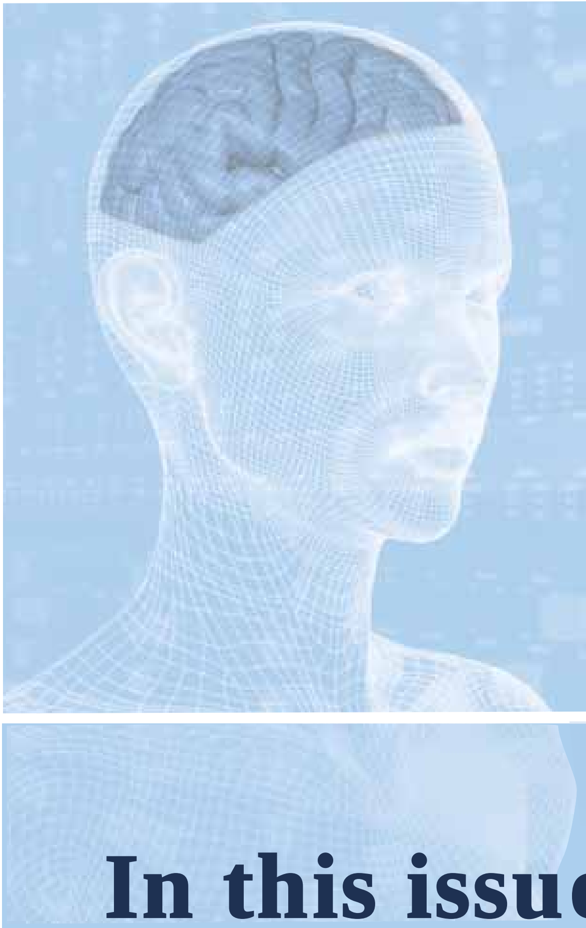

JCR

Journal of CyberTherapy & Rehabilitation

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In this issue

THE VIRTUAL REALITY
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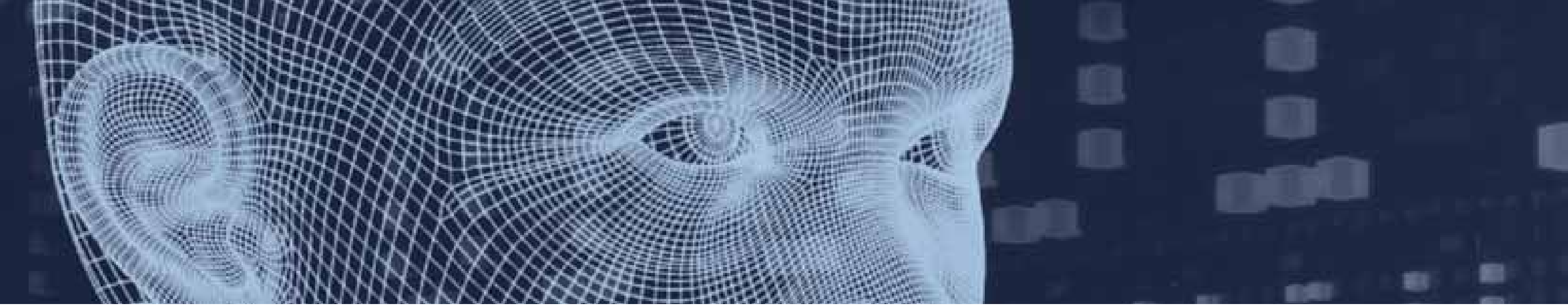

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The European Association of CyberTherapy & Rehabilitation (EACR) is an international association to promote Virtual Reality and other advanced technologies as adjuncts to more traditional forms of therapy, training, education, prevention, and rehabilitation. EACR will address the urgent need to develop a “roadmap” for the future of this rapidly growing field.

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- Need for shared operating standards/platforms
- Need for improved access to healthcare for all citizens
- Need for advanced interactive training and education for healthcare professionals
- Need to enhance existing healthcare treatments through the addition of advanced technologies
- Need to move healthcare and health promotion/disease prevention to the individual level, providing all citizens the opportunity to become active participants in their own healthcare

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EDITORIAL

Welcome to the inaugural issue of the *Journal of CyberTherapy and Rehabilitation* (JCR), a new peer-reviewed academic journal that explores the uses of advanced technologies for therapy, training, education, prevention, and rehabilitation. Published quarterly, JCR is unique among academic journals in that it focuses on the rapidly expanding worldwide trend of moving toward technological applications in healthcare. At JCR, our main areas of interest include, but are not limited to, psychiatry, psychology, physical medicine and rehabilitation, neurology, occupational therapy, physical therapy, cognitive rehabilitation, neurorehabilitation, oncology, obesity, eating disorders, and autism, among many others.

An exciting body of research regarding the utilization of advanced technologies in healthcare has emerged over the past decade, revealing the continuous advances and discoveries made by over 450 investigators to help patients with both mental and physical disorders. Advanced technologies–such as virtual reality (VR), robotics, non-invasive physiological monitoring, E-health, and adaptive displays–are now being applied to several areas of healthcare.

This premiere issue of JCR features comprehensive review articles by preeminent scholars in the field. These reviews cover some of the most promising applications for technology in therapy, and rehabilitation, surveying the concepts and studies that laid the groundwork for the field up to this point. It is my hope that this collection of papers will not only act as an introduction for those new to the field, but will also expand the knowledge of those well-established in their careers with newer applications for technology in healthcare. This set of articles is a repository for many of the most vital findings in CyberTherapy and Rehabilitation to date.

The first paper, by Professor Giuseppe Riva from Italy, focuses on using virtual reality (VR) as an embodied technology for managing body image. Many eating disorders (e.g. Anorexia Nervosa, Bulimia, Binge Eating Disorder) are associated with a distorted body image. Because of its immersive tendencies, VR is an effective tool for altering and adjusting body image in individuals with these disorders. In addition, VR can be used for nutrition education and training for those with obesity.

The second paper, "Virtual Reality for Posttraumatic Stress Disorder and Stress Inoculation Training," features ways in which VR and other advanced technologies can be used to help prevent and treat stress-related reactions in soldiers and the civilian population. Traumatic events such as motor vehicle accidents, assault, combat, or other threats to life can sometimes cause symptoms that interfere with daily life. VR exposure therapy has shown promise in alleviating these symptoms, restoring healthy function to those affected. It has also been shown to help train individuals to deal with stressors prior to exposure.

Next is an article on using video games for therapy and rehabilitation of the elderly by Professor Luciano Gamberini of Italy. This paper offers an overview of recent game-based applications used to improve elderly people's cognitive abilities and to treat psychological problems accompanying illnesses and social isolation. The authors present several examples of videogames adopted within training programs for elderly people, which have been tested through scientific procedures.

Pioggia and colleagues discuss the possible uses of robot-human interactions for the treatment and training of people with Autistic Spectrum Disorders (ASDs) in their article. Since individuals with ASDs have impairments in processing of social and emotional information, it has been suggested that robotic dolls, mobile robots and humanoids can act as social mediators to teach those with ASDs social interaction skills. It is proposed that ASD patients are better able to focus on and imitate human behavior with training from a biomimetic android.

Later in the issue Cameirão and colleagues present a review of the use of VR for cognitive neurorehabilitation following stroke. VR has revealed itself to be a beneficial tool in the diagnosis, monitoring, and recovery of motor and cognitive skills. This paper reviews cutting-edge VR applications for restoring function to the upper extremities after stroke.

Our colleagues from Canada, Côté and Bouchard, cover the history of VR use for treatment of specific phobias in their paper. They examine 39 studies on the treatment of specific phobias including acrophobia, aviophobia, claustrophobia, arachnophobia and fear of driving. In their paper these experts provide a critical analysis of research up to this point, and propose future directions for this original application of VR.

Professor Cristina Botella's team from Spain examines VR applications for both the treatment of chronic pain and distraction from acute pain generated by medical procedures or other stimuli. Many medical procedures produce acute pain, and often medication is not sufficient to counteract the distress patients experience. However, in many cases VR has been found to be an effective distracter from pain during medical treatment. The authors also address the new concept of using these advanced techniques for treating chronic pain.

And finally, Professor Sun I. Kim and fellow researchers from Hanyang University in Seoul, Korea evaluate the use of VR for patients with schizophrenia, a brain disorder that is characterized by disturbances in general cognition, such as abnormal expressions of emotion and ways of thinking, mental derangement, regression from reality, strange language or behavior, and delusion or illusion. Because VR is a medium that can present social and emotional situations via realistic human-computer interactions, it can be used for traditional forms of therapy, with the added advantage of being able to provide objective measurements.

The second issue of JCR will continue to explore the ways in which technology influences and enhances the healthcare of citizens in Europe and throughout the world. We are interested in receiving original research and ideas for future theme issues from our readership. Current topics being considered include technology for the elderly, for those with disabilities, and other specialized populations. Please contact us with your interesting manuscripts and ideas for additional topics for the Journal. Thank you for your support of this promising new publication.

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FROM VIRTUAL TO REAL BODY: VIRTUAL REALITY AS EMBODIED TECHNOLOGY

Giuseppe Riva, Ph.D.[1]

The emerging approach of "embodied cognition" is redefining the nature of cognition: cognition is no longer a set of formal operations on abstract symbols, but rather a situated embodied activity. On one side, the characteristics of our perceptual and motor systems play a foundational role in concept definition and in rational inference. On the other side, practical activity plays a role in giving meaning to the particular experiences of, and the representations generated by, a given individual agent.

Within this framework, virtual reality (VR) can be considered an embodied technology with potential that is wider than the simple reproduction of real worlds. By designing meaningful embodied activities, VR may be used to facilitate cognitive modeling and change. This paper will both discuss this claim and present a possible application of this approach: the therapeutic use of VR for the treatment of body image disturbances.

Introduction

For a long time cognitive science considered action, perception, and interpretation to be separate activities. A recent trend in cognitive science is seeing cognition instead as *embodied* (Prinz, 2006). This is a rethinking of the idea that cognition is primarily a matter of performing formal operations on abstract symbols that has little or nothing to do with the sensorimotor activity and the environment in which it occurs (Freeman & Núñez, 1999). As clearly outlined by Anderson (2003):

> For over fifty years... there has been a re-thinking of the nature of cognition. Instead of emphasizing formal operations on abstract symbols, this new approach focuses attention on the fact that most real-world thinking occurs in very particular (and often very complex) environments, is employed for very practical ends, and exploits the possibility of interaction with and manipulation of external props. It thereby foregrounds the fact that cognition is a highly embodied or situated activity–emphasis intentionally on all three–and suggests that thinking beings ought therefore be considered first and foremost as acting beings. (p. 91)

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, instead has deep roots in sensorimotor processing.

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To deepen this vision, in this paper we will discuss two of the most recent theories that have emerged in this area: the *Common Coding Theory*, and the *Situated Simulation Theory*. According to these theories, our conceptual system produces dynamically contextualized representations (simulations) that support situated action in different contexts.

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, 1997).

If concepts are embodied simulations, and VR is a simulation technology, it 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 with potential that is wider than the simple reproduction of real worlds (Riva, 2003). By designing meaningful embodied activities, VR may be used to facilitate cognitive modeling and change. This paper will also present a possible application of this approach: the therapeutic use of VR for the treatment of body image disturbances.

Virtual Reality: From technology to experience

Since 1989, when Jaron Lamier used the term for the first time, "virtual reality" has usually been described as a computer simulated environment with and within which people can interact. The following are some examples of such definitions:

The terms virtual worlds, virtual cockpits, and virtual workstations were used to describe specific projects. In 1989, Jaron Lanier, CEO of VPL, coined the term virtual reality to bring all of the virtual projects under a single rubric. The term therefore typically refers to three-dimensional realities implemented with stereo viewing goggles and reality gloves. (Krueger, 1991, p. xiii)
I define a virtual reality experience as any in which the user is effectively immersed in a responsive virtual world. This implies user dynamic control of viewpoint. (Brooks, 1999, p. 17)

It is a simulation in which computer graphics is used to create a realistic-looking world. Moreover, the synthetic world is not static, but responds to the user's input (gesture, verbal command, etc.). This defines a key feature of virtual reality, which is real-time interactivity. (Burdea & Coiffet, 2003, p. 2)

Virtual Reality as Technology

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. This computer generated world may be either a model of a real-world object, such as a house; an abstract world that does not exist in a real sense but is understood by humans, such as a chemical molecule or a representation of a set of data; or it might be a completely imaginary science fiction world.

A VR system is the combination of the hardware and software that enables developers to create VR applications. The hardware components receive input from user-controlled devices and convey multi-sensory output to create the illusion of a virtual world. The software component of a VR system manages the hardware that makes up the VR system. This software is not necessarily responsible for actually creating the virtual world. Instead, a separate piece of software (the VR application) creates the virtual world by making use of the VR software system.

Typically, a VR system is composed of (Brooks, 1999; Burdea & Coiffet, 2003):

- the *output tools* (visual, aural and haptic), that immerse the user in the virtual environment;
- the *input tools* (trackers, gloves or mice) that continually report the position and movements of the users;
- the *graphic rendering system* that generates, at 80-120 frames per second, the virtual environment;
- the *database construction and virtual object modeling software* for building and maintaining detailed and realistic models of the virtual world. In particular, the software handles the geometry, texture, intelligent behavior, and physical modeling of hardness, inertia, and surface plasticity of any object included in the virtual world.

Virtual Reality as experience: the concept of presence

As we have just seen, VR is usually described as a particular collection of technological hardware. However, 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, 1997).

Following this approach it is possible to describe virtual reality in terms of human experience, rather than technological hardware, using the concept of *presence* (Riva, 2007; Riva, Davide, & IJsselsteijn, 2003; Steuer, 1992): VR is a medium able to induce the experience of "presence" in a computer-generated world. Presence is usually defined as the "sense of being there" (Steuer, 1992), or the "feeling of being in a world that exists outside the self" (Riva, 2006, 2007; Riva & Waterworth, 2003; Riva, Waterworth, & Waterworth, 2004).

Lombard and Ditton (1997) describe presence as the "perceptual illusion of nonmediation," a level of experience where the technology and the external physical environment disappear from the user's phenomenal awareness; the term *perceptual* shows that the illusion involves continuous (real time) responses of the human sensory, cognitive, and affective processing systems to objects and entities in a person's environment. What's more, a subject experiences an *illusion of nonmediation* when he or she fails to perceive or acknowledge the existence of a medium in his/her communication environment and responds as he/she would if the medium were not there.

There is consensus that the experience of presence is a complex, multidimensional perception formed through an interplay of raw (multi-) sensory data and various cognitive processes (IJsselsteijn & Riva, 2003; Renaud et al., 2007; Riva et al., 2007).

Recently, different VR researchers have conceptualized presence more broadly to address the question of why people feel a sense of presence in any setting–computer generated or otherwise (Baños et al., 2005; Lee, 2004a, 2004b; Mantovani & Riva, 1999; Moore, Wiederhold, Wiederhold, & Riva, 2002; Renaud et al., 2007; Renò, 2005; Rettie, 2005; Riva & Davide, 2001; Riva, Davide et al., 2003; Spagnolli & Gamberini, 2005; Waterworth & Waterworth, 2001, 2003; Zahoric & Jenison, 1998). For instance, Renaud and colleagues (2007) recently found the existence of a strict link between presence and perceptual-motor dynamics. Their preliminary results suggest that presence is linked to fractal perceptual-motor complexity: we experience more presence during more active involvement in a virtual environment.

Expanding this vision, Riva considers presence as a neuropsychological phenomenon, evolved from the interplay of our biological and cultural inheritance, the goal of which is the enactment of volition (Riva, 2006): presence is the non-mediated (prereflexive) perception of successful intentions in action. Specifically, presence can be described as a sophisticated but unconscious form of monitoring of action and experience, transparent to the self but critical for its existence. As clarified by Russell (1996):

> Action-monitoring is a subpersonal process that enables the subjects to discriminate between self-determined and world-determined changes in input. It can give rise to a mode of experience (the experience of being the cause of altered inputs and the experience of being in control) but it is not itself a mode of experience. (p.263)

For this reason, the feeling of presence is not separated by the experience of the subject, but it is related to the quality of our actions (Riva, Castelnuovo, & Mantovani, 2006). In fact, a higher feeling of presence is experienced by the self as a better quality of action and experience: the more the subject is able to enact his/her intentions in a successful action, the more he/she is present. At this point we can argue that it is the *feeling of presence that provides prereflexive feedback to the subject about the status of its activity*: the self perceives the variations in the feeling of presence and adjusts its activity accordingly.

According to this approach, individuals may feel a greater degree of presence in different situations depending on the degree of meaning and agency experienced within it (Riva, Anguera, Wiederhold, & Mantovani, 2006). Thus, an inhabitant of the Amazon rainforest, rich in ethno-botanical knowledge, may feel a fuller sense of presence while walking through the forest than an urban visitor admiring the beauty.
Similarly, a computer-literate person may feel a greater sense of presence while surfing the Web than a computer novice. Specifically, the self tries to overcome any breakdown in its activity and searches for engaging and rewarding activities (optimal experiences).

To illustrate, imagine sitting outdoors engrossed in reading a book on a pleasant evening. As the sun sets and the light diminishes, one continues reading, engrossed in the story until one becomes aware that the light is no longer suitable for reading. In such conditions, before any overt change in behavior, what we experience is a breakdown in reading and a shift of attention from the book to the light illuminating the book.

Motor simulation: The link between perception, action, and cognition

The concept of presence as just detailed suggests a clear link between action, perception and cognition. But how are they related? An emerging trend within embodied cognition is the *analysis of the link between action and perception*. According to it, action and perception are more closely linked than has traditionally been assumed. In the next paragraphs we will discuss different recent theories developed by cognitive scientists that are steps toward understanding the link between action and perception.

The Common Coding Theory

According to the *Common Coding Theory* (Hommel, Müsseler, Aschersleben, & Prinz, 2001), the cognitive representations for perceived events (perception) and intended or to-be generated events (action) are formed by a common representational domain: actions are coded in terms of the perceivable effects they should generate.

In more detail, when an effect is intended, the movement that produces this effect as perceptual input is automatically activated, because actions and their effects are stored in a common representational domain.

The *Common Coding Theory* may be considered a variation of the *Ideomotor Principle* introduced by William James (1890). According to James, imagining an action creates a tendency to its execution if no antagonistic mental images are simultaneously present. Prinz (1997), suggests that the role of mental images is instead taken by the distal perceptual events that an action should generate. When the activation of a common code exceeds a certain threshold, the corresponding motor codes are automatically triggered.

This theory has received a strong empirical support from neurological data. In particular, as underlined by Gallese (2000b), ‘‘the so-called ‘motor functions’ of the nervous system not only provide the means to control and execute action but also to represent it.’’ (p. 23). This conclusion–which is very close to the claims of the *Common Coding Theory*–is the outcome of a long series of experiments of single-neuron recordings in the premotor cortex of monkeys (Rizzolatti, Fadiga, Gallese, & L., 1996; Rizzolatti, Luppino, & Matelli, 1998). Specifically, Rizzolatti and colleagues discovered that a functional cluster of premotor neurons (F5ab-AIP) contains “*canonical neurons*,” a class of neurons that are selectively activated by the presentation of an object in function of its shape, size, and spatial orientation (Gallese, 2000a, 2005; Rizzolatti, Fadiga, Fogassi, & Gallese, 1997). Specifically, these neurons fire during the observation of objects whose features–such as size and shape–are strictly related to the type of action that the very same neurons motorically code. Further, the *canonical neurons* are activated not only by observing the same object, but also by observing a group of objects that have the same characteristics in terms of the type of interaction they allow.

Two aspects of these neurons are important (Gallese & Lakoff, 2005; Rizzolatti, Fogassi, & Gallese, 2000). On one hand, what correlates to their discharge is not simply a movement (e.g. opening the mouth), but an action, that is, a movement executed to achieve a purpose (e.g. to tear apart an object, bring it to the mouth). On the other hand, the critical feature for the discharge is the purpose of the action and not the dynamic details defining it, like force or movement direction.

The Situated Simulation Theory

In a different cluster (F4-VIP) Rizzolatti and colleagues (Fogassi et al., 1996; Rizzolatti et al., 1997) identified a class of neurons that are selectively activated when a monkey heard or saw stimuli being moved in their peri-personal space. The same neurons discharged when the monkey turned its head toward a given location in peri-personal space. One possibility to explain the dual activation is that these neurons simulate the action (head-turning) in the presence of a possible target of action seen or heard at the same location (Gallese & Lakoff, 2005):

> We maintain that what integrates these sensory modalities is action simulation. Because sound and action are parts of an integrated system, the sight of an object at a given location, or the sound it produces, automatically triggers a “plan” for a specific action directed toward that location. What is a “plan” to act? We claim that it is a simulated potential action. (p. 460)

The existence of these functional clusters of neurons suggests that a constitutive part of the representation of an object is the type of interaction that is established with the object itself. In other words, different objects can be represented in the function of the same type of interaction allowed by them.

These experimental data match well with the *Converged Zone Theory* proposed by Damasio (1989). This theory has two main claims. First, when a physical entity is experienced, it activates feature detectors in the relevant sensory-motor areas. During visual processing of an apple, for example, neurons fire for edges and planar surfaces, whereas others fire for color, configural properties, and movement. Similar patterns of activation in feature maps on other modalities represent how the entity might sound and feel, and also the actions performed on it.

Second, when a pattern becomes active in a feature system, clusters of conjunctive neurons (*convergence zones*) in association areas capture the pattern for later cognitive use. As shown also by the data collected by Rizzolatti, a cluster of conjunctive neurons codes the pattern, with each individual neuron participating in the coding of many different patterns.

Damasio assumes the existence of different convergence zones at multiple hierarchical levels, ranging from posterior to anterior in the brain. At a lower level, convergence zones near the visual system capture patterns there, whereas convergence zones near the auditory system capture patterns there. Further, downstream, higher-level association areas in more anterior areas, such as the temporal and frontal lobes, conjoin patterns of activation *across* modalities.

A critical feature of convergence zones underlined by Simmons and Barsalou is *modality-specific re-enactments* (Barsalou, 2003; Simmons & Barsalou, 2003): once a convergence zone captures a feature pattern, the zone can later activate the pattern in the absence of bottom-up stimulation. In particular, the conjunctive neurons play the important role of reactivating patterns (re-enactment) in feature maps during imagery, conceptual processing, and other cognitive tasks.

For instance, when retrieving the memory of an apple, conjunctive neurons partially reactivate the visual state active during its earlier perception. Similarly, when retrieving an action performed on the apple, conjunctive neurons partially reactivate the motor state that produced it. This process has two main features:

- *It is similar, but never constitutes a complete reinstatement of the original modality-specific state*: even if some semblance of the original state is reactivated, a re-enactment is always partial and potentially inaccurate.
- *It is not necessarily conscious*: Although conscious re-enactment is viewed widely as the process that underlies mental imagery, re-enactments need not always reach awareness.

The process of re-enactment is at the core of the *Situated Simulation Theory* proposed by Barsalou (2003). For this author, conceptual representations are contextualized and dynamical multimodal simulations (re-enactments) distributed across modality-specific systems. As suggested by Barsalou (2003):

> A concept is not a single abstracted representation for a category but is instead a skill for constructing idiosyncratic representations tailored to the current needs of a situated action…More than the focal category is represented in a given simulation. Additional information as background settings, goal directed actions and introspective states are also typically included in these simulations, making them highly contextualized. (p. 521)

According to this view, a fully functional conceptual system can be built on reenactment mechanisms. As shown by Barsalou and his group (Barsalou, 2002, 2003; Barsalou, Simmons, Barbey, & Wilson, 2003), using these mechanisms, it is possible to implement the type-token distinction, categorical inference, productivity, propositions, and abstract concepts.

The *Situated Simulation Theory* fits well with the *Common Coding Theory*: first, modality-specific sensorimotor areas become activated by the perceptual input (an apple) producing patterns of activation in feature maps; then, clusters of conjunctive neurons (convergence zones) identify and capture the patterns (the apple is red, has a catching size, etc.); later the convergence zone fires to partially reactivate the earlier sensory representation (I want to take a different apple); finally this representation reactivates a pattern of activation in feature maps similar, but not identical, to the original one (re-enactment), allowing the subject to predict the action results.

If concepts are embodied simulations, and VR is a simulation technology, apparently it 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). What has been done in this area since then? We will try to answer this question in the next section.

Virtual Reality for therapeutic change

VR is starting to play an important role in clinical psychology (Riva, 2005; Riva & Wiederhold, 2006). One of the leading applications of VR in the medical field is psychotherapy, where it is mainly used to carry out exposure treatment for specific phobias (VR based Exposure – VRE), such as fear of heights, fear of flying, and fear of public speaking (Bouchard, Côté, St-Jacques, Robillard, & Renaud, 2006; Krijn, Emmelkamp, Olafsson, & Biemond, 2004; Wiederhold & Rizzo, 2005; Wiederhold & Wiederhold, 2003). Further applications of VR in psychotherapy include eating disorders and obesity (Riva, Bacchetta et al., 2006), posttraumatic stress disorder (Josman et al., 2006; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001; Stetz et al., 2007), sexual disorders (Optale, 2003; Optale et al., 1998), and pain management (Hoffman, 2004; Hoffman, Richards, Coda, Richards, & Sharar, 2003; Patterson, Hoffman, Palacios, & Jensen, 2006).

The key characteristics of virtual environments for most clinical applications are the high level of control of the interaction with the tool and the enriched experience provided to the patient (Schultheis & Rizzo, 2001). Typically, in VR the patient learns to manipulate problematic situations related to his/her problem. For this reason, the most common application of VR in this area is the treatment of anxiety disorders (Emmelkamp, 2005).

Indeed, VR based Exposure (VRE) has been proposed as a new medium for exposure therapy (Riva, 2005) that is safer, less embarrassing, and less costly than reproducing real world situations. The rationale is simple: in VR the patient is intentionally confronted with the feared stimuli while allowing the anxiety to attenuate. Avoiding a dreaded situation reinforces a phobia, and each successive exposure to the situation reduces anxiety through the processes of habituation and extinction. VRE offers a number of advantages over in vivo or imaginal exposure.

First, VRE can be administered in traditional therapeutic settings. This makes VRE more convenient, controlled, and cost-effective than in vivo exposure. Second, it can isolate fear components more efficiently than in vivo exposure. For instance, in treating fear of flying, if landing is the most feared part of the experience, landing can be repeated as often as necessary without having to wait for the airplane to take-off. Finally, the immersive nature of VRE provides a realistic experience that may be more emotionally engaging than imaginal exposure.

However, it seems likely that VR can be more than a tool to provide exposure and desensitization (Riva, 2005). As noted by Glantz and colleagues (1997), “VR technology may create enough capabilities to profoundly influence the shape of therapy“ (p.92). In particular, we suggest that VR, for its ability to modify the experience of the body, may be used to facilitate therapeutic change.

The change in therapy: the egocentric and allocentric approach

How is it possible to change a patient? Even if this question has many different answers according to the specific psychotherapeutic approach, in general, change comes through an intense focus on a particular instance or experience (Wolfe, 2002); by exploring it as much as possible, the patient can relive all of the significant elements associated with it (i.e., conceptual, emotional, motivational, and behavioral) and make them available for a reorganization of his or her perspective.

Within this general model we have the insight-based approach of psychoanalysis, the schema-reorganization goals of cognitive therapy or the enhancement of experience awareness in experiential therapies. What are the differences between them? According to Safran and Greenberg (1991), behind the specific therapeutic approach we can find two different model of change: bottom-up and top-down. Bottom-up processing begins with a specific emotional experience and leads eventually to change at the verbal-representational and conceptual level, whereas top-down change usually involves exploring and challenging tacit rules and beliefs that guide the processing of emotional experience. These two models of change are focused on two different cognitive systems, one for information transmission (top-down) and one for conscious experience (bottom-up), both of which may process sensory input (Brewin, 1989). The existence of two different cognitive systems is clearly shown by the dissociation between verbal knowledge and task performance: people learn to control dynamic systems without being able to specify the nature of the relations within the system, and they can sometimes describe the rules by which the system operates without being able to put them into practice.

Another way to conceptualize this difference is to use the egocentric/allocentric distinction. The distinction between egocentric and allocentric representations was first made in spatial cognition. As underlined by Viaud-Delmon and colleagues (2002):

> There are different ways of representing spatial information. One solution relies on the measurement of instantaneous relationships of one's self with respect to the features of the environment (egocentric representation). This type of representation must, therefore, be updated over self-motion. Alternatively, one can encode an environment on the basis of its invariant aspects, through its geometric shape for example (allocentric representation). This solution is independent of self-motion. (p. 198)

Extending this description, egocentric processing allows people to locate objects relative to their body center and their bodies in 3-D space. This body-centered system moves information from the primary visual processing areas at the back of the brain forward across the top-rear of the brain. Allocentric processing, instead, enables people to handle relationships centered among objects and identify objects. The allocentric system moves information from the back of the head, forward along its sides, and closer to parts of the brain that verbally categorize objects.

This dual encoding has been shown at the neural level in a distinction between two kinds of neurons in the parietal cortex (Sakata & Kusunoki, 1992). Some are dedicated to the position of the visual stimuli presented to an immobile observer in a frame of reference centered on the object. Others are dedicated to the stimuli in relation to the agent's actions in a frame of reference centered on the agent's body (relative to eye, head, and body position in space).

Given the strict link between action, perception and concepts described by the embodied cognition approach, Frith and deVignemont (2005) suggest that this basic difference in the way we represent spatial information is a specific stance of our way of organizing representations. Specifically, these authors suggest that we attribute mental states to our self and to others by adopting either an egocentric or an allocentric stance:

> Egocentric representations of the self derive from a direct knowledge attached to the self, while allocentric representations of the self derive from a detached knowledge of the person that one happens to be. In the former case, one has privileged direct self-knowledge, which one cannot have about anybody else. In the latter case, one represents oneself as a person among others. Similarly, we

> would like to suggest that the other could also be represented according to an egocentric or an allocentric stance…Taking an egocentric stance means that others are represented only because they are related to the self in one way or another. Conversely, taking an allocentric stance means that the existence and/or mental states of others are completely independent from the self. (p. 725)

Virtual reality and the body: the interaction between egocentric and allocentric frames

Even if many therapeutic approaches are based on just one of the two change models, a therapist usually requires both (Wolfe, 2002). Some patients seem to operate primarily by means of top-down/allocentric information processing, which may then prime the way for corrective emotional experiences. For others the appropriate access point is the intensification of their own emotional experience and their awareness of it. Finally, different patients who initially engage the therapeutic work only through top-down/allocentric processing may able later in therapy to make use of bottom-up/egocentric emotional processing.

A clinical area in which both change models are required is eating disorders. According to the DSM IV-TR (APA, 2000) both anorexia and bulimia share an intense fear of gaining weight or becoming fat (bottom-up/egocentric emotional processing) and a distorted significance of body weight and shape (top-down/allocentric information processing). For this reason, the therapeutic approaches include cognitive-behavioral, interpersonal and experiential therapies. However, the treatment of body image disturbances is the most difficult part of the therapy.

But what is body image? This term usually includes a complex set of intentional states and dispositions–perceptions, beliefs and attitudes–in which the intentional object is one's own body (Gallagher, 2005). Specifically, within this term we usually include:

- *body affect*: the emotional attitude toward the body;
- *body concept*: the conceptual description of the body in general;
- *body percept*: the perceptual experience of the body.

Some authors suggest that body image dissatisfaction is a form of cognitive bias (Thompson, 1996; Williamson, 1996). As noted by Williamson (1996):

> If information related to body is selectively processed and recalled more easily, it is apparent how the self-schema becomes so highly associated with body-related information. If the memories related to body are also associated with negative emotion, activation of negative emotion should sensitize the person to body-related stimuli causing even greater body size overestimation. (pp.49-50)

It is very difficult to counter a cognitive bias. In particular, Mou and McNamara's theory of spatial memory (Mou & McNamara, 2002; Mou, McNamara, Valiquette, & Rump, 2004) posits that people interpret spatial scenes by assigning a reference frame intrinsic to the layout and update their mental representation only if a later view provides a chance for superior encoding. This frame of reference determines the interpretation, and hence, the memory of the spatial structure of the layout. For this reason, biased information processing occurs automatically, and the subjects are not aware about it. So, for them, the biased information is real. They are not able to distinguish between perceptions and biased cognitions. Moreover, attempts at persuasion are usually useless and may even elicit strong emotional defense.

Can VR be useful in modifying this cognitive bias? We think so. Immersive VR can be considered an "embodied technology" for its effects on body perceptions (Lambrey & Berthoz, 2003; Vidal, Amorim, & Berthoz, 2004; Vidal, Lipshits, McIntyre, & Berthoz, 2003). First, VR users become aware of their bodies during navigation: their head

movements alter what they see. The sensorimotor coordination of the moving head with visual displays produces a much higher level of sensorimotor feedback and first-person perspective (egocentric reference frame).
Second, in VR the human operator's normal sensorimotor loops are altered by the presence of distortions, time delays and noise (Riva, 1997). Such alterations, which are introduced unintentionally and usually degrade performance, affect body perceptions too. The somesthetic system has a proprioceptive subsystem that senses the body's internal state, such as the position of limbs and joints and the tension of the muscles and tendons. Mismatches between the signals from the proprioceptive system and the external signals of a virtual environment significantly alter body perceptions (Riva, 1998; Sadowsky & Massof, 1994).

As noted by Gallagher (2005) "[different] studies indicate that changes in various aspects of body schemas have an effect on the way subjects perceive their own body. More generally, changes in body schemas also affect spatial perception, the perception of objects, and intentional action." (p. 144).

Through the use of immersive VR, it is possible to induce a controlled sensory rearrangement that facilitates the update of the biased body image. When a particular event or stimulus violates the information present in our spatial memory (as occurs during a virtual experience), the information itself becomes accessible at a conscious level (Baars, 1988) and can be modified more easily. This facilitates modification of the body image through the differentiation and integration of new information, leading to a new sense of cohesiveness and consistency in how the self represents the body. This effect is strengthened by the integration of all the different methods (cognitive, behavioral and visual-motor) commonly used in the treatment of body experience disturbances within a virtual environment.

In particular, we applied some elements (for a detailed description of the VR component see Thompson and colleagues (1999), p. 322-325) of the protocol for body image disturbances defined by Cash (Cash, 1996, 1997) within a VR environment. A critical part of the protocol is the shift between egocentric and allocentric modes using different recognition tasks: the widest chair in a group of five (allocentric reference frame); the chair that is wide enough to allow seating (egocentric reference frame); etc. Since perception was done in an egocentric reference frame and the recognition task in an allocentric/egocentric reference frame, a reference shift is performed by the subject at different times during the session.

This approach was validated through case studies (Riva, Bacchetta, Baruffi, Rinaldi, & Molinari, 1999) and trials. In the first uncontrolled study, three groups of patients were used (Riva, Bacchetta, Baruffi, Rinaldi et al., 2000): patients with Binge Eating Disorder (BED), patients with Eating Disorders Not Otherwise Specified (EDNOS), and obese patients with a body mass index higher than 35. All patients participated in five biweekly sessions of VR therapy. All of the groups showed improvements in overall body satisfaction, disordered eating, and related social behaviors, although these changes were less noticeable in the EDNOS group.

More recently, the approach was tested in different controlled studies. The first one involved twenty women with BED who were seeking residential treatment (Riva, Bacchetta, Baruffi, & Molinari, 2002).

The sample was assigned randomly to virtual reality based (VR) or to cognitive-behavioral (CBT) based nutritional therapy. Both groups were prescribed a 1,200-calorie per day diet and minimal physical activity. Analyses revealed that although both groups were binge free at 1-month follow-up, VR was significantly better at increasing body satisfaction. In addition, VR participants were more likely to report increased self-efficacy and motivation to change.
In a second one, the same randomized approach was used with a sample of 36 women with BED (Riva, Bacchetta,

Cesa, Conti, & Molinari, 2003). The results showed that 77% of the ECT group quit binging after 6 months versus 56% for the CBT sample and 22% for the nutritional group sample. Moreover, the VR sample reported better scores in most psychometric tests including EDI-2 and body image scores. In the final one (Riva, Bacchetta et al., 2006), VR was compared with nutritional (NT) and cognitive-behavioral (CBT) treatments, using a randomized controlled trial, in a sample of 211 female obese patients. Both VR and CBT produced a better weight loss than NT after a 6-month follow-up. However, VR was able to significantly improve, over CBT and NT, both body image satisfaction and self-efficacy. This change produced a reduction in the number of avoidance behaviors as well as an improvement in adaptive behaviors.

The group led by Cristina Botella, Ph.D. has compared the effectiveness of VR to a traditional cognitive-behavioral (CBT) treatment for body image improvement (based on Cash (1996)) in a controlled study with a clinical population (Perpiña et al., 1999). In particular, they developed six different virtual environments including a 3D figure whose body parts (arms, thighs, legs, breasts, stomach, buttocks, etc.) could be enlarged or diminished. The proposed approach addressed several of the body image dimensions: the body can be evaluated wholly or in parts; the body can be placed in different contexts (for instance, in the kitchen, before eating, after eating, facing attractive people, etc.); behavioral tests can be performed in these contexts; and several discrepancy indices related to weight and figure can be combined (actual weight, subjective weight, desired weight, healthy weight, how the person thinks others see her/him, etc.).

In the published trial, eighteen outpatients who had been diagnosed as suffering from eating disorders (anorexia nervosa or bulimia nervosa) according to the DSM-IV criteria, were randomly assigned to one of the two treatment conditions: the VR condition (cognitive-behavioral treatment plus VR) and the standard body image treatment condition (cognitive-behavioral treatment plus relaxation). Thirteen of the initial 18 participants completed the treatment. Results showed that following treatment, all patients had improved significantly. However, those who had been treated with the VR component showed a significantly greater improvement in general psychopathology, eating disorders psychopathology, and specific body image variables.

Conclusions

For a long time cognitive science considered action, perception, and interpretation to be separate activities. A recent trend in cognitive science is instead seeing cognition as embodied (J. Prinz, 2006): our conceptual system produces dynamically contextualized representations (simulations) that support situated action in different contexts. In this picture, what is the role of VR? The basis of VR is that a computer can synthesize a three-dimensional (3D) graphical environment from numerical data. Using visual, audio or haptic devices, the human operator can experience the environment as if it were a part of the real world. Because of 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, 1997).

If concepts are embodied simulations, and VR is a simulation technology, it apparently should be possible to facilitate cognitive modeling and change by designing targeted virtual environments. For this reason, VR is starting to play an important role in clinical psychology (Riva, 2005). Virtual environments (VEs) are being used in the treatment of anxiety disorders (Krijn et al., 2004; Wiederhold & Rizzo, 2005; Wiederhold & Wiederhold, 2003), posttraumatic stress disorder (Josman et al., 2006; Rothbaum et al., 2001), sexual disorders (Optale, 2003; Optale et al., 1998), and pain management (Hoffman, 2004; Hoffman et al., 2003; Patterson et al., 2006).

Typically, in VR the patient learns to manipulate problematic situations related to his/her problem. For this reason, the most common application of VR in this area is the treatment of anxiety disorders (Emmelkamp, 2005). However, it seems likely that VR can be more than a tool to provide exposure and desensitisation (Riva, 2005). As noted by Glantz and colleagues (Glantz et al., 1997), "VR technology may create enough capabilities to profoundly influence the shape of therapy" (p.92). In particular, we suggest that VR, for its ability to modify the experience of the body, may be used to facilitate therapeutic change.

Immersive VR can be considered an "embodied technology" for its effects on body perceptions (Lambrey & Berthoz, 2003; Vidal et al., 2004; Vidal et al., 2003). First, VR users become aware of their bodies during navigation: their head movements alter what they see. The sensorimotor coordination of the moving head with visual displays produces a much higher level of sensorimotor feedback and first person perspective (egocentric reference frame).

Second, in VR the human operator's normal sensorimotor loops are altered by the presence of distortions, time delays and noise (Riva, 1997). Such alterations, which are introduced unintentionally and usually degrade performance, affect body perceptions, too. The somesthetic system has a proprioceptive subsystem that senses the body's internal state, such as the position of limbs and joints, and the tension of the muscles and tendons. Mismatches between the signals from the proprioceptive system and the external signals of a virtual environments significantly alter body perceptions (Riva, 1998; Sadowsky & Massof, 1994).

As noted by Gallagher (2005) "[different] studies indicate that changes in various aspects of body schemas have an effect on the way subjects perceive their own body. More generally, changes in body schemas also affect spatial perception, the perception of objects, and intentional action." (p. 144). For this reason we suggested to use it to counter body image dissatisfaction, a form of cognitive bias (Thompson, 1996; Williamson, 1996) common in eating disorders and obesity.

Through the use of immersive VR, it is possible to induce a controlled sensory rearrangement that facilitates the update of the biased body image. This allows the differentiation and integration of new information, leading to a new sense of cohesiveness and consistency in how the self represents the body. This effect is strengthened by the integration of all of the different methods (cognitive, behavioral and visual-motor) commonly used in the treatment of body experience disturbances within a virtual environment. The results of this approach are very promising. As shown by different experimental research, VR is effective in producing rapid changes in body experience (Murray & Gordon, 2001; Riva, 1998) and body dissatisfaction (Perpiña, Botella, & Baños, 2003; Riva, Bacchetta, Baruffi, Cirillo, & Molinari, 2000; Riva et al., 2002; Riva, Bacchetta, Baruffi, Rinaldi, & Molinari, 1998; Riva, Bacchetta et al., 2006; Riva, Bacchetta, Cesa, Conti, & Molinari, 2004).

Apparently, a similar approach may be used in other pathologies. Lambrey and Berthoz (2003) showed that subjects use conflicting visual and non-visual information differently according to individual 'perceptive styles' (bottom-up processes) and that these 'perceptive styles' are made more observable by subjects changing their perceptive strategy, i.e. re-weighting (top-down processes). For instance, Viaud-Delmon and colleagues (Viaud-Delmon et al., 2002; Viaud-Delmon, Ivanenko, Berthoz, & Jouvent, 2000) showed that subjects with high trait anxiety, like subjects with symptoms of panic and agoraphobia, have a strong dependence on a particular reference frame in which the sensory information is interpreted and in which the subject would remain anchored. A VR experience aimed at modifying the sensory reference frame may be useful in speeding up the process of change. Future studies are needed both to identify specific perceptive styles in different pathologies and to define the best protocols for changing them.

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VIRTUAL REALITY FOR POSTTRAUMATIC STRESS DISORDER AND STRESS INOCULATION TRAINING

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Over the past decade, virtual reality (VR) has made a significant impact on behavioral healthcare, permeating the field with its multiple effective uses. One arena in which VR shines is in providing training and treatment for those exposed to traumatic or especially stressful events. Though traditional treatment methods for Posttraumatic Stress Disorder (PTSD) include medication, psychotherapy, and exposure therapy, none of these treatments has been sufficient to alleviate symptoms in many of those who suffer from the disorder. However, when imaginal exposure is replaced with VR exposure, many non-responders seem to receive relief. Over 15 studies entailing diverse populations have shown VR exposure therapy to enhance traditional cognitive behavioral treatment regimens for PTSD. Most studies reveal a treatment success rate of 66%-90%.

Another area in which VR is contributing to success is in prevention or attenuation of stress-related reactions through Stress Inoculation Training (SIT). SIT is a type of training used to prepare individuals for stressful situations (such as combat or medical emergencies), diminishing the potential for a negative psychological reaction like PTSD. In cognitive-behavioral therapy, SIT is accomplished through gradual, controlled, and repeated exposure to a stressor. The goal behind this exposure is to desensitize the person to the stressful situation, avoiding a panic or "fight or flight" response to the real thing. This not only allows the individual to accomplish the tasks at hand in a stressful environment, but also may act to prevent long-term psychological reactions to stress such as PTSD. Though a relatively new area, several researchers have begun to use VR to enhance SIT techniques. The results to date appear to be quite promising.

Introduction

Many have heard the term "shell shock" in the context of soldiers returning from war. However, this condition can affect anyone who has experienced a traumatic event such as serious injury or threat of injury or death. Its technical name is Posttraumatic Stress Disorder (PTSD). Symptoms can include increased anxiety or arousal, dissociation, and flashbacks of the event, though the disorder manifests differently in each individual. Although there may be a delayed onset of symptoms following a trauma, most symptoms of PTSD begin occurring within three months, and these symptoms must exist for at least one month for a diagnosis of PTSD (American Psychiatric Association, 2000). The distress caused by PTSD symptoms, especially if left untreated, can lead to anxiety, depression, and even suicide.

According to the National Institute of Mental Health PTSD affects an estimated 5.2 million Americans in any given year, often resulting in a diminished quality of life and considerable emotional suffering. In at-risk individuals, such as

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combat veterans and victims of natural disasters or criminal violence, prevalence rates can be much higher. The current rate of PTSD among Army and Marine Corps troops returning from duty in Iraq is approximately 19%. Military experts believe the rate is still increasing. A continuing upward trend seems especially likely given the unique nature of the terrain and combat situations in the Iraq theater. According to recent reports, the number of Iraq War soldiers who will experience PTSD is higher than the Gulf War due to such factors as ground combat and long deployments (Litz, 2004).

Because PTSD has such varied symptoms, a combination of treatments is often necessary. Anxiety-reducing medications, antidepressants, support from friends and family, and cognitive-behavioral therapy involving exposure can help with recovery (Barlow, 1988). However, these types of traditional therapies do not have acceptable recovery rates. Front-line antidepressant medications for the disorder–such as selective serotonin reuptake inhibitors–rarely yield better than a 40% reduction in Clinician Administered PTSD Scale (CAPS) scores, and most patients will still meet criteria for PTSD at the end of an adequate treatment trial (Hamner, Robert, & Frueh, 2004). Regarding traditional psychotherapy, based on a meta-analysis published in 2005, only 44% of all those who enter treatment will be classified as improved at the end of the treatment period (Bradley, Greene, Russ, Dutra, & Westen, 2005).

In the treatment of PTSD, exposure seems to be an integral part of almost all treatment regimens. In fact, a panel of experts has published a consensus opinion that exposure therapy is the most appropriate therapy for PTSD; the possibility of “retraumatizing” the individual was not considered cause for concern (Ballenger et al., 2001). Prior to the availability of VR therapy applications, the existing standard of care for PTSD was imaginal exposure therapy, in which patients “relive” the traumatic event in a graded and repeated process (Difede & Hoffman, 2002).

Exposure therapy is based on emotional processing theory (EPT). Applying EPT to PTSD, fear memories are stored as a “fear structure” and include psychological and physiological information about stimuli, meaning, and responses (Foa & Kozak, 1986). Once accessed and emotionally engaged, the structure is open to modification through CBT and, over time, will result in extinction of the fear response.

Although exposure therapy has been shown to be effective (Laor et al., 1998; Wiederhold & Wiederhold, 2004), one hallmark of PTSD is avoiding reminders of the trauma (Difede & Hoffman, 2002). Because of this, many patients are unable or unwilling to effectively visualize the traumatic event during imaginal therapy. In studies that address treatment non-responders, failure to engage emotionally or visualize well enough to elicit an emotional response are cited as most predictive of non-response to treatment, since the fear structure is not accessed during therapy and is therefore not open to change (Jaycox, Foa, & Morral, 1998; Kosslyn, Brunn, Cave, & Wallach, 1984; Van Etten & Taylor, 1998).

Virtual Reality Treatment for PTSD

This is where VR can step in to enhance treatment. In recent years, VR has been shown to improve treatment efficacy for PTSD in survivors of many types of trauma, including motor vehicle accidents, war veterans, and those involved in the 9/11 World Trade Center attacks (Difede & Hoffman, 2002; Rothbaum et al., 1999; Walshe, Lewis, Kim, O’Sullivan, & Wiederhold, 2003; Wiederhold & Wiederhold, 2000; 2004). By placing people with PTSD in an environment where a trauma has occurred (in veterans it could be a virtual combat setting), and then having them slowly experience that situation in a controlled way, the patient may begin to habituate to their PTSD symptoms and come to reappraise the instigating situation. This allows emotional processing to occur, and may free PTSD sufferers from their intrusive memories and disturbing symptoms.

With its inherent immersive nature, VR overcomes many of the shortcomings of imaginal exposure. VR provides external visual and auditory stimuli for the patient, thus eliminating the need for intense imaginal skills. And, unlike in vivo therapy, which takes the patient into real-world scenarios (which is not practical or even possible with war veterans), VR permits the patient to interact with anxiety-inducing scenarios in the safety and confidentiality of the therapy room. The patient's ability to exert initial control over the situation (e.g. deciding to go to therapy, controlling the level of anxiety they are willing to experience) also seems a safer, more tolerable starting point for many. In VR exposure therapy the therapist and patient, in their therapeutic alliance, create a hierarchy of anxiety-inducing situations. These situations can then be recreated in VR under the therapist's control. Audio and visual stimuli can be added and subtracted to create the exact "dosage" required for treatment. In addition, both the patient and therapist can determine the duration and intensity of treatment, creating a safe environment in which the patient can re-process their fear. Moreover multiple exposures can be completed during a single therapy session, making for more efficient time usage and reducing costs (Wiederhold & Wiederhold, 2004).

There are a number of studies that have been conducted using VR to enhance traditional treatments for PTSD. An initial case study using VR therapy to treat PTSD in Vietnam veterans was done in 1999 (Rothbaum et al). After exposure to virtual environments including a helicopter and jungle terrain, the patient experienced a 34% decrease in clinician-rated PTSD symptoms and a 45% decrease in self-ratings. In a second study, ten veterans were treated. Eight of these participants who were contacted at 6-month follow-up reported a decrease in symptoms ranging from 15% to 67%. Participants reported that intrusion symptoms were significantly lower 3 months after therapy, yet this statistical significance did not hold at the 6-month follow-up, though less avoidance and fewer intrusive thoughts were still visible (Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001).

In a second case study (meant to replicate the findings of the 1999 paper), at both 3- and 6-month follow-up the patient reported a dramatic drop in symptom levels, which was verified by standard PTSD (Rothbaum, Ruef, Litz, Han, & Hodges, 2003). In 2006, Ready and colleagues examined 21 participants. Though two patients experienced significant increases in symptoms during treatment, all patients' PTSD symptoms (including those two) were below baseline by the 3-month posttreatment assessment. Clinically meaningful and statistically significant reductions in PTSD symptoms were found and maintained at 6-month follow-up.

VR exposure therapy also has been used successfully to treat survivors of the World Trade Center attacks of September 11, 2001. In a published case study by Difede & Hoffman (2002), a female patient initially non-responsive to imaginal exposure showed a 90 percent reduction in symptoms of PTSD and an 83 percent reduction in symptoms of depression after only six VR treatment sessions. After the patient completed therapy, an independent evaluator determined that the patient no longer met the criteria for PTSD, major depression, or any other psychiatric disorder. In a second, larger study, nine participants experienced VR exposure. When compared to the wait list, the treatment group showed significantly greater post-treatment decline in Clinician-Administered PTSD Scale (CAPS) scores. The preliminary data suggests that VR is an effective tool for enhancing exposure therapy for both civilians and disaster workers who suffer from post-9/11 PTSD (Difede, Cukor, Patt, Giosan, & Hoffman, 2006). Finally, in a study that included 13 participants who underwent VR exposure therapy the VR group showed a significant decline in CAPS scores compared with the waitlist group, indicating that even in a larger sample, VR shows promise in treating post-9/11 PTSD (Difede et al., 2007).

In a 2003 study by Basoglu, Livanou, and Salcioglu, earthquake survivors in Turkey were given one session of exposure to simulated earthquake tremors. Assessments were conducted at pre- and post-session and at 2, 4, 8, and 12 weeks post-treatment. All measures showed significant improvement at all assessment time periods. Eight patients were markedly improved and two patients slightly improved at follow-up. A second study in Greece used a virtual earthquake simulator to treat PTSD in earthquake survivors. Results from 209 participants indicated that 78% were improved after one session in the simulator and 89% were improved after two sessions (Tarnanas & Manos, 2004).

VR has also been used successfully to treat those who developed PTSD after a motor vehicle accident (MVA). The first, by Wiederhold, Jang, Kim, and Wiederhold (2001) described the treatment of eight patients using virtual driving scenarios in residential areas and on freeways. The study revealed an 88% treatment success rate. Wald and Taylor (2003) exposed six participants to six different driving conditions (varying traffic, etc). There was a clear reduction of both anxiety and avoidance in four out of the six patients. Next, Walshe and colleagues (2003) found that after VR exposure, all 14 of their participants experienced significant post-treatment reductions on all measures and a drop in travel distress. In 2007 Beck, Palyo, Winer, Schwagler, and Ang examined the effects of VR exposure on 6 participants with driving-related PTSD. Results showed a significant reduction in the symptoms of PTSD, including intrusive memories of the experience, avoidance of driving-related stimuli, and emotional numbing. Patients were satisfied with the treatment overall. Finally, Saraiva et al. (2007) examined the effect of VR exposure therapy on a single patient with driving-related PTSD. Results indicated that the patient experienced a decrease in intrusion and avoidance scores, though PTSD criteria were still met. The treatment has also shown to be successful when moving from the laboratory setting to the general clinical setting. The Virtual Reality Medical Center (VRMC) has treated 72 patients with over a 90% success rate using VR exposure in combination with physiological monitoring and feedback protocols as part of an established cognitive-behavior therapy protocol. Patients show marked improvement on self-report questionnaires, subjective units of distress, and physiological measures of arousal. The most important finding, though, is that the skills transfer over into real world driving situations, with patients able to begin driving once more.

Additionally, in Israel, researchers are using a new virtual environment called BusWorld to provide VR therapy for terrorist bus bombing victims (Josman et al., 2006). BusWorld is graded by severity of trauma from Stage 1 (views of a public bus stop with the usual urban din of voices and sounds) through to Stage 12 (view of the bus exploding, flames, bus and body parts strewn all over, real voices of people screaming and emergency vehicle sirens). Preliminary research focused on physiological reaction to the environment in healthy volunteers. Though reaction varied, results of this analog study have verified the ability of BusWorld to provide graded exposure to trauma for use in VR-based exposure therapy for individuals suffering from PTSD due to suicide bus bombing.

Finally, the most recent application of VR exposure therapy has been for veterans of the Iraq war who suffer from PTSD. Though there are only two studies published reporting data (Wood, Murphy, Center, McLay, Reeves, Pyne, Shilling, & Wiederhold, 2007a, 2007b; Wood et al., 2008) on the efficacy of VR treatment for combat-related PTSD from the Iraq War, many groups are working on potential virtual environments and have published protocols for this purpose (Miyahira, Hoffman, & Folen, 2006; Rizzo et al., 2005; Rizzo, Rothbaum, & Graap, 2007; Roy, Sticha, Kraus, & Olsen, 2006; Spira, Pyne, & Wiederhold, 2006; Spira et al., 2006; Reeves et al, 2007; Stetz et al., 2007; Wiederhold & Wiederhold, 2008; Wood et al., 2008).

In research funded by the Office of Naval Research (ONR), the VRMC has begun to explore whether exposure therapy for PTSD-diagnosed troops using a CBT approach is more effective when enhanced with VR. With input from focus groups consisting of returning troops from Iraq & Afghanistan, VRMC graphic designers and software developers created a Virtual Baghdad environment as a clinical therapy aid for military personnel with PTSD. The Virtual Baghdad environment is an immersive, highly realistic environment in which users can freely navigate the terrain and interact with virtual people. The virtual world, which can be viewed on a laptop computer or with a head-mounted display (HMD), features a market, a battlefield (with a car, helicopter, humvee, and explosions), a battalion aid station, and houses. Three computers are used to deliver treatment: 1) one on which the therapist can track where the patient is located in the virtual environment and can, with a simple click, trigger events to occur based on the state of the patient; 2) another on which the virtual world is displayed (and observed by the patient if wearing the HMD is too overwhelming at the beginning of treatment); and 3) a computer on which the patient's physiological functions are monitored and feedback is projected. The environment is comprised of sights and sounds, such as Arabic prayer from a temple, helicopters thundering overhead, distant explosions, vehicles burning, terrorists running while firing guns, and the voices of Iraqi civilians (see Figure 1).

Based on interviews with a population of Marine and Navy personnel recently diagnosed with combat-related PTSD and receiving treatment, researchers have found that these were some of the most salient memories veterans associate with recurring, intrusive thoughts (Spira, Pyne, & Wiederhold, 2006). The focus groups of military personnel enabled developers to build a highly realistic environment which included features most important for the end user (in this case, the patient with PTSD). By project completion participants will include 136 US Navy Seabees and medical personnel who have acute PTSD stemming from combat exposure.

Outcome measures focus on the general symptom categories targeted by exposure therapy, such as re-experiencing traumatic memories, avoidance of these memories, and physiological arousal. Due to the intense nature of the VR treatment, troops' mental status is monitored closely by the lead psychologist as well as a staff psychiatrist and assessed during every visit for suicide risk. In addition, an on-call person is available 24 hours a day to address any problems troops experience during treatment, and all patients are given a "survival plan" at the onset of treatment.

Figure 1. Soldiers can use VR both for medical skill and stress inoculation training pre-deployment, and treatment of posttraumatic stress disorder post-deployment, creating a continuum of care for troops exposed to war time situations.

VRMC's system is being used to treat PTSD in multiple geographical areas of the U.S.: California, Arkansas, Florida, and Iowa. In addition, the VR system is now in place in Warsaw, Poland and Zagreb, Croatia. Initial pilot testing of the system indicates that VR therapy produces both subjective (self-report) and objective (physiological) arousal in individuals suffering from PTSD. In our previously reported first case study of a soldier undergoing VR enhanced cognitive behavioral therapy with this system positive results were obtained. At the end of 10 treatment sessions, the patient scored below the PCL-M "strict" criteria for a PTSD diagnosis (Wood et al., 2007). Data from the first six treatment completers also shows continuing positive results. In the six participants to finish ten VR exposure therapy session, 100% reduced their PCL-M scores from the start of treatment. Four out of six (67%) participants no longer met criteria for PTSD and both anxiety and depression were reduced (Wood et al., 2008).

Table 1. The Use of VR in PTSD Treatment.

Year	Author (s)	Type of PTSD	Subjects	VR Content	Results
1999	Rothbaum et al.	Vietnam War	1	Helicopter ride & Vietnam terrain	Decrease in clinician-rated and self-rated PTSD, retained at follow-up Symptoms decreased (Clinician-Administered PTSD Scale [CAPS] total score)
2001	Rothbaum et al.	Vietnam War	16	Helicopter ride & Vietnam terrain	Post-treatment improvement on all PTSD measures, retained at follow-up
2001	Wiederhold et al.	Driving	8	Residential & freeway driving	88% treatment success; improvement on self-report questionnaires, SUDS, physiology, and transfer of skills to real world
2002	Difede & Hoffman	Sept. 11th	1	World Trade Center (WTC)	83% decrease in depression levels and 90% reduction in PTSD symptoms
2003	Basoglu et al.	Earthquake trauma	10	Earthquake simulator	Significant improvement in all measures, retained at follow-up
2003	Rothbaum et al.	Vietnam War	1	Helicopter ride & Vietnam terrain	Improvement in PTSD symptoms at post-treatment and at follow-up
2003	Wald & Taylor	Driving	6	6 driving conditions	Clear improvement in anxiety level and decreased avoidance in 66% of patients
2003	Walshe et al.	Driving	14	Various driving scenarios	Significant post-treatment reductions on all measures & drop in travel distress
2004	Tarnanas & Manos	Earthquake-trauma	209	Earthquake virtual simulator	Treatment improved all stress and depression related symptoms. The cumulative proportion of improved cases was 78% after one session and 89% after two sessions
2005	Wiederhold & Wiederhold	Driving	72	Various driving scenarios	Effective treatment for PTSD after motor vehicle accident 90% success rate
2006	Ready et al.	Vietnam	21	Vietnam terrain	Two patients experienced significant increases in symptoms during treatment, but all patients' PTSD symptoms were below baseline by the 3-month posttreatment assessment. Clinically meaningful and statistically significant reductions in PTSD symptoms were found and maintained at 6-month follow-up
2006	Difede et al.	Sept. 11th	17	World Trade Center Attacks	The VR group showed significantly greater post-treatment decline in CAPS scores compared to the waitlist.
2007	Beck et al.	Driving	6	Driving scenarios	Significant reductions in reexperiencing, avoidance, and emotional numbing; patients reported satisfaction with treatment.
2007	Difede et al.	Sept. 11th	21	World Trade Center Attacks	The VR group showed a significant decline in CAPS scores compared with the waitlist group

Year	Author (s)	Type of PTSD	Subjects	VR Content	Results
2007	Gamito et al.	Combat	1	Combat Scenario	Patient did not complete study due to a distressing flashback experienced after the 7th session
2007	Saraiva et al.	Driving	1	Four Lane Highway	Reduction in intrusion and avoidance scores, though the subject remains within the severe PTSD - cohort. Reduction on psychophysiological activity.
2007	Wood et al.	Iraq War	1	Iraq scenarios	Patient scored below the PCL-M “strict” criteria for a PTSD diagnosis post-treatment.
2008	Wood et al.	Iraq War	6	Iraq scenarios	100% reduced PCL-M scores 67% no longer met criteria for PTSD; anxiety and depression were reduced

In a second study funded by ONR, the same Virtual Baghdad environment, in addition to other scenarios encountered in Iraq, are being used in Stress Inoculation Training (SIT) protocols to determine if providing stress-hardening skills prior to deployment can decrease incidence of PTSD in returning troops.

In a separate project, funded by the Telemedicine and Technology Research Center (TATRC), VRMC shipped a VR system to Iraq. There, the system was tested and valuable user feedback was obtained for further system development and improvement. Feedback indicates that in-country clinicians would appreciate the ability to use a VR PTSD tool as part of an early intervention protocol. Having the end user as a participant in the development loop has always been an essential part of system development at VRMC and a part of patient success in overcoming their disorders.

The outcomes of studies that have used VR to treat PTSD are presented in Table 1.

Stress Inoculation Training (SIT)

Stress Inoculation Training (SIT) is a type of training used to prepare individuals for stressful situations, to help diminish the potential for a negative psychological reaction. In CBT, SIT is accomplished through gradual, controlled, and repeated exposure to a stressor. The goal behind this exposure is to desensitize or “inoculate” the person to the possible stimuli of a stressful situation, avoiding a panic or “fight or flight” response to the real thing. This repetition allows the individual to calmly and accurately accomplish the tasks at hand in a stressful environment. Developed in the late 1970s by Donald Meichenbaum, SIT was originally designed for use with multiple populations of individuals (Meichenbaum, 1977).

Since SIT is a technique to help harden individuals to future potentially traumatizing stressors, it also makes intuitive sense to use this method to help train those in the military. Deployed personnel must often perform in extremely stressful environments, and optimum performance under such conditions requires effective management of physiological, psychological, and emotional responses to stressful stimuli. An acute stress reaction (ASR) or combat and operational stress reaction (COSR) can occur during exposure to exceptionally stressful events like those encountered in combat, resulting in extreme sympathetic nervous system arousal and impaired performance. Longer term reactions to these situations can include acute stress disorder and PTSD. During VR-enhanced preventative SIT, military personnel “experience” highly stressful situations in a virtual environment. Repeated exposure enables performers to gradually become desensitized to stimuli that may initially elicit such strong physiological arousal that performance is impeded (i.e., “freezing in the line of fire”), and therefore psychological trauma should be less likely.

SIT is intended both to create more effective troops and to help prevent or reduce rates of PTSD in returning troops. There is existing evidence that SIT can reduce PTSD. In a 2000 study by Deahl et al., a group of 106 male British soldiers preparing for a 6-month tour of duty in Bosnia received a combination of pre-deployment stress training and post-deployment psychological debriefing. After deployment, participants demonstrated a drastically reduced incidence of PTSD and other psychopathology as compared to controls, approximately 10 times less than figures reported from other military samples. In fact, the level was so low that it precluded any possible debriefing effect.

Virtual Reality for Stress Inoculation Training

Similar to the use of VR for treating anxiety disorders like PTSD, VR can enhance the effect of SIT by providing vivid and customizable stimuli. For example, in a 2001 study by Tarnanas and Manos, researchers hoped to train students in a procedure for evacuating their classroom after an earthquake. A group of 50 Greek children (30 healthy preschool aged children and 20 children with Down Syndrome) were randomized to one of two VR conditions: behaviorally realistic avatars with unfamiliar faces or similar avatars with the faces of classmates. Children were then led by the avatars through a stress inoculation training scenario on how to escape from their classroom in case of an earthquake. It was found that avatars with familiar faces were superior in generating emotion-focused variables such as fear-related coping abilities. VR allows for environments to be customized to individual situations, an attribute that can increase the efficacy of SIT not only for civilian training, but also for the military population.

In a 2003 study, researchers used VR for training 120 employees to cope with hostile work environment situations (Tarnanas, Tsoukalas, & Stogiannidou). They found that those who were exposed to VR environments with behaviorally realistic avatars performed better in post-tests than those in the other groups.

A three-year study (completed in July 2005) sponsored by the Defense Advanced Research Projects Agency (DARPA), showed the effectiveness of even a low-fidelity laptop simulator to effectively train military personnel for stressful situations (Wiederhold & Wiederhold, 2006b). The purpose of the study was to maximize performance through advanced training techniques. One such technique was to implement training under stressful conditions and those that allow the individual to benefit from exposure to maximal variation in outcomes.

Phase I results indicated that those trained in a VR simulation while having stressors added (being shot at while tending to the wounded) were able to perform skills more effectively in the test phase of the study when compared to those trained in a “sterile” VR environment (no one shooting at them while tending to the wounded). Participants who trained under stress scored significantly higher in the test phase while those who trained in the sterile environment were pulled off task, which caused mistakes to be made (“patients died”).

In addition, physiological monitoring showed that those who trained under stress remained calm and relaxed in the test phase while the stress of those who trained in a sterile environment rebounded to near-initial levels. Physiological testing showed that individuals were unaware when they were becoming too physiologically aroused and perhaps not in the optimum training state. Investigators were also able to see changes in heart rate, brain wave activity, and skin conductance that correlated with peak performance (Wiederhold & Wiederhold, 2004b).

Table 2. The Use of VR in SIT.

Year	Author(s)	Type of SIT	Subjects	VR Content	Results
2001	Tarnanas & Manos	Children earthquake skills	50	Earthquake scenario	SIT success in 87% of children in the VR plus panic control therapy (PCT) group compared to 50% in the PCT and 33% of controls
2003	Tarnanas, Tsoukalas, & Stogiannidou	Work-place skills	120	Hostile environment situations	Behaviorally realistic avatar group performed better in terms of cognitive appraisals, emotions, and attributions than the first-person perspective or WLC groups
2004b	Wiederhold & Wiederhold	Combat and medical skills	8	Warzone and evacuation images	Those trained in a stressful VR simulation were able to perform skills more effectively than those trained in a "sterile" VR environment
2006b	Stetz, et al	Military medical females prior to deployment	1	Iraqi village and other scenes for combat and flight medics	Preliminary results showed promising findings for VR as a prophylactic against combat stress
2006	Wiederhold & Wiederhold	Tactical and medical training for Iraq	970	Iraqi village, ship, shoot house and other scenes for combat and medical personnel	SIT produced effective transfer of skills to real world
2007	Stetz, Long, Schober, et al.	Combat training for Iraq	25	Iraqi village, and other scenes for combat and flight medics	Those who received VR SIT had a lower stress level than controls

In the Phase II DARPA study, groups of participants (a total of 970) performed tactical exercises in a virtual environment before performing similar tasks in a real-world training environment. When compared with control groups who received no virtual training, the VR groups scored higher in every exercise. For example, the VR group completed a weapons search of a house about 2 minutes faster than the group without VR training. The non-VR group, for all trials, located and cleared rooms successfully, but 2 exercises resulted in teams clearing rooms multiple times (93% accuracy). The VR group, for all trials, located and cleared rooms successfully with no rooms cleared multiple times (100% accuracy). Playing a task-irrelevant video game before performing the real-world exercises produced a statistically insignificant change in performance.

In the second part of the study, one group trained on the virtual shoot house via laptop computer for 10 minutes before entering the shoot house. A control group was monitored over 4 runs in the real-world shoot house without any virtual training. Then the groups' performances were compared. The result showed that 10 minutes on the laptop produced the same result as 4 runs and 1 hour in the real-world shoot house. Essentially, the study's investigators saw that virtual training can reduce real-world training by 75% in terms of training sessions. Feedback from the training officers suggests that VR training promoted critical thinking skills and improved participants' ability to remain flexible and adapt to unknown and/or challenging situations. Performance data also suggests that VR training facilitated teamwork (Wiederhold, 2003).

The VRMC has provided VR SIT training systems for the U.S. Army's Aeromedical personnel at Fort Rucker, AL. Data was collected during training (n = 63-75), and trainees will now be tracked once they return from deployment. Preliminary findings with a sample of 25 medics suggest that those who learned coping techniques during the VR training, exhibited lower levels of stress than the control group (Stetz, Long, Schober, Cardillo, & Wildzunas, 2007). Uses for the data may include: 1) studying the relationship between physiological arousal and performance outcomes; 2) evaluating adjunctive training techniques (such as relaxation training) to manage physiological arousal and enhance performance; and 3) longitudinal tracking of personnel physiological levels during training to determine the fidelity of the relationship between blood pressure/heart rate and combat operational stress reactions (COSRs) and PTSD, which could eventually act as a predictive tool for screening troops before they are deployed (Stetz, Wildzunas, Wiederhold, Stetz, & Hunt, 2006a; Stetz, 2007; Stetz, Thomas, Russo, Stetz, Wildzunas, McDonald, et al., 2007).

In addition to decreasing stress, SIT for military personnel is designed to improve performance. Training under stressful conditions pre-deployment improves performance by training personnel to recognize signs of physiological and emotional arousal and control their stress levels. In our ongoing SIT studies, we train military personnel in virtual environments such as an Iraqi village, a shoot house, or a ship. These simulations can be viewed on desktops, laptops, through a head-mounted display (HMD), or as a 3-wall CAVE (computer automatic virtual environment) projection system, depending on the needs of the specific population to be trained. This training is then transferred to real-world exercises in structures designed specifically for tactical training. This ensures a transfer of training from virtual to real world, with remediation if skills have not been learned sufficiently. We also have worked variously with civilian medical personnel, US Coast Guard groups, SWAT Teams, and police officers to teach skill training, reduce stress, and ensure transfer of training to the real world setting with equal success.

The VRMC, along with other organizations around the world, is hoping that this type of fully-immersive, customizable training can be used not only to enhance the skills of military personnel, but also others who perform in high-stress situations (doctors, emergency responders, etc.). A recent study has also examined the use of VR for medical team training (Lee et al., 2007). Finally, it is hoped that this type of training can act as a preventative measure against PTSD and other stress-related reactions.

The outcomes of studies that have used VR for SIT are presented in Table 2.

Conclusions

Since its inception, VR has proven itself as a useful technology for many aspects of behavioral healthcare. It has been used to successfully treat anxiety disorders and other psychological disturbances. It has played a role in the development of both cognitive and physical rehabilitation techniques. It has proven effective for distraction from painful or anxiety-inducing medical procedures. And finally, it provides the stimulus necessary for effective exposure therapy for the treatment of PTSD. Of the nearly 20 studies that have been published on using VR exposure therapy to enhance traditional cognitive-behavioral therapy for PTSD, all but one showed some measure of improvement in participants' PTSD symptoms, with several studies revealing a treatment success rate of 66%-90%.

In addition, VR appears to be useful in helping to prevent or attenuate stress-related reactions through Stress Inoculation Training (SIT), a type of training used to prepare individuals for stressful situations (such as combat). Large-scale studies have revealed that VR-enhanced SIT is more effective than real world training in terms of time expenditure and helping participants adapt to stressful stimulus and perform efficiently. As access to VR technology and techniques for this type of training improves, it is hoped that the incidence of stress-related psychological reactions like PTSD will diminish.

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PLAYING FOR A REAL BONUS: VIDEOGAMES TO EMPOWER ELDERLY PEOPLE

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This paper offers an overview of recent game-based applications for therapy and rehabilitation of elderly people. Information and Communication Technologies represent a viable solution to meet the various physical and psychological needs of a population growing at an incredibly fast rate. In particular, videogames have proven to improve elderly people's cognitive abilities and take care of psychological problems accompanying illnesses and social isolation. We will present several examples of videogames adopted within training programs for elderly people, and tested through scientific procedures. We will include both old-fashioned games and recent ones. Characterized by a higher naturalness in the input system, the latter rely on already established usage practices with non-digital tools (a pen, a bowling ball, etc) that make the interface more accessible. Finally, we will describe a current European project that aligns with these efforts towards natural interfaces and aims at developing a mixed reality game for cognitive training and sociability of elderly users.

Introduction: Technologies in an ageing society

The Department of Economic and Social Affairs of the United Nations released the 2006 revision of the World Population Prospects, highlighting "an unprecedented transformation brought about by the transition from a regime of high mortality and high fertility to one of low mortality and low fertility" (Population Division of the Department of Economic and Social Affairs DESA of the United Nations Secretariat, 2007, p.1). According to the UN document, compared to the other continents "the population of Europe is today the oldest, with a median age of 39 years. It is followed by the population of Northern America, with a median age of 36 years and then by Oceania whose median age is 32 years. The population of Asia has a median age slightly lower than 28 years and that of Latin America and the Caribbean is 26 years. Only Africa's population still has a median age below 20" (Population Division of the Department of Economic and Social Affairs DESA of the United Nations Secretariat, 2007, p.1). A main effect of this transformation is the fast increasing percentage of older adults. By 2025 there will be 1.2 billion people aged 60 and over, double the same population in 2000 (World Health Organization, 2002).

A similar expansion of the senior population constitutes an important social and economical issue, since aging is also accompanied by limitations in carrying out everyday activities (Nehmer, Karshmer, Becker, & Lamm, 2006) or by physical and mental impairments that have to be taken care of. On one hand, this has been addressed by initiatives to facilitate successful aging, where older people's involvement in physical, cognitive, and social activities is encouraged.

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"Active aging", for instance, is a multidisciplinary field focusing on the possible ways to ensure that elderly people's habits meet good life quality standards (e.g. World Health Organization, 2002). On the other hand, assistive and clinical needs are pressing the elderly population and the oldest portion, namely people aged 80 or over, who "*will likely increase more than four-fold, from 88 million in 2005 to 402 million in 2050*" (Population Division of the Department of Economic and Social Affairs DESA of the United Nations Secretariat, 2007). Many of these individuals require long-term medical, social, psychological and personal care, which calls for effective strategies, possibly taking advantage of the opportunities of Information and Communication Technology (ICT). This means not only adapting already existing tools to the needs of older users (Gamberini, Alcañiz, Fabergat, Seraglia, Gòmez, & Montesa, 2007), but also developing tools especially devoted to prevent or treat their precise impairments and diseases.

Several technological solutions have appeared aimed at ameliorating the quality of life of older people, paying particular attention to their cognitive, social and health needs (Burdick & Kwon, 2004). Some scholars warn against too much optimism, arguing that no evidence of a positive impact of computers and technology on the well-being of elderly people has been properly collected (Dickinson, & Gregor, 2006). However, information and communication technologies offer a solution to reduce the costs and complexity of intervention; through the constant acquisition of data regarding psychological, cognitive and neuropsychological behaviors, and by communicating at a distance, they offer the potential to reach and improve the well-being of a larger number of elderly people (Weiner et al., 2003). Since technology improves in efficiency and usability as its costs decrease, ICTs are conveying accessible and valuable environments to treat many different psychological and behavioral diseases such as anxiety, addiction disorders, depression and phobias (Wiederhold & Wiederhold, 2004; 2006). Therapeutic and rehabilitative procedures carried out with computer technologies are constantly being developed and evaluated (Rizzo & Kim, 2005; Rizzo, Schultheis, Kerns, & Mateer, 2004) side-by-side with more traditional ones (LoPresti, Mihailidis, & Kirsch, 2004).

Games offer complex scenarios that can stimulate discussion, collaboration and imagination, or train skills such as hand-eye coordination, strategic abilities and problem solving (Gaggioli, Gorini, & Riva, 2007; Young, 2004; Barr, Noble & Biddle, 2007). Cognitive scientists consider videogames, in which objects move faster than usual and multiple items have to be monitored at the same time, as stimulating the peripheral processing. Experimental studies have registered an improvement of some cognitive and perceptual capacities (e.g. spatial abilities and reaction time; Lager & Bremberg, 2005) in gamers compared to non-gamers (Green & Bavelier, 2006, 2007). Computer games also seem to be able to affect neurocognitive functions (also neurochemical levels, Koepp et al., 1998), thereby showing a high potential for rehabilitation (Cameirao, Bermúdez i Badia, Duarte Oller, Zimmerli & Verschure, 2007). While cognitive improvements would appear insignificant to most people, to a sub-set of the population such as elderly people, stroke patients or military personnel, they would be extremely beneficial.

In this paper, we will focus on game-based applications for therapy and rehabilitation of older people. First, we will explore the opportunities for cognitive training offered by classic and recent videogames. Then, we will focus on the treatment of psychological problems accompanying illnesses and social isolation. Finally, we will describe a current European project that fits the scenario depicted in the previous paragraphs and aims at developing a mixed reality game for elderly people to facilitate their cognitive training and sociability.

Videogames for Cognitive Training and Rehabilitation

Cognitive training is a set of procedures to help people re-acquire a useful level of performance in everyday tasks for different functions (e.g. attention, memory, reasoning). For instance, the ACTIVE (Advanced Cognitive Training for Independent and Vital Elderly; Jobe et al., 2001) program is focused on memory training (remembering lists of words, sequences of items), reasoning training (solving problems after pattern presentation), and speed of processing training (finding items, locating visual information). The efficacy of these training programs has been shown in several studies; cognitive training has improved the episodic memory in people affected by mild cognitive impairment (MCI) and healthy elderly people (Belleville, Gilbert, Fontaine, Gagnon, Ménard & Gauthier 2006). Inductive reasoning trainings were more predictive of subsequent mental status than spatial orientation trainings (Boron, Willis & Schaie, 2007). Willis et al. (2006) found long-term effects of reasoning training on everyday performances for the elderly, reducing their natural functional decline.

Everyday problem-solving in healthy older adults is more complex, flexible and emotionally balanced than is usually supposed: elderly people are able to take actions directed toward the source of the problem while at the same time controlling their emotions to manage psychological stress (Blanchard-Fields, 2007). This suggests the opportunity to exploit everyday engagement and tasks to support cognitive functioning. Stine-Morrow, Parisi, Morrow, Greene & Park (2007) developed a team-based program of creative problem-solving, named Senior Odyssey, to test the engagement hypothesis, i.e. that social and intellectual engagement can buffer cognitive senescence (Schooler, Mulatu & Oates, 1999 in Stine-Morrow, Paris, Morrow, Greene & Park, 2007). Game-based trainings, possibly integrated with existing activities and habits, also work as educative interventions and preventive tools for mental deficiency, cognitive deterioration and dementia (Morales-Sanchez, Arias-Merino, Diaz-Garcia, Cabrera-Pivaral & Maynard-Gomez, 2007). Wang et al. (2006) showed that a board game like Mahjong could reduce the risk of cognitive impairment in older adults, whereas television constituted a factor enhancing the risk of age related deficits within a group of the same cohort.

Even physical activity can improve the cognitive function of healthy but sedentary elder people: according to a meta-analysis of Colcombe and Kramer (2003), fitness produces strong but selective enhancements of cognition (in particular, for executive-control processes), mostly depending on factors such as gender or type and temporal length of task and training. Colcombe, Erickson, Scalf, Kim, Prakash, McAuley, et al. (2006) found that cardiovascular fitness can increases brain volume in elderly people. These findings confirm the presence of cognitive and neural plasticity along the life span. Fabre, Chamari, Mucci, Masse-Biron and Prefaut (2002) observed that the combination of fitness training and cognitive training is able to enhance memory performance more than the each training alone.
The cognitive training obtained from carrying out everyday operations, social entertainment and physical activity can be easily provided by specially designed videogames, both classic non-immersive ones and innovative augmented technologies (Van Noorden, 2006), as described in the next two sections.

First Generation Games

Several “first generation games” of the past century inspired researchers who started using them as tools for cognitive rehabilitation of older adults. For instance, Clark, Lanphear and Riddick (1987, in Green & Bavalier, 2006) had an experimental group of elderly people playing with either ‘Pac Man’ and ‘Donkey Kong’ two hours a week for seven weeks, and observed a reduction of their reaction time. The reaction time test was conducted with a special device, composed of two buttons and two lights (each button was positioned under one of the lights); when one light emitted a flash, the participants pressed a button: the button under the flashing light (compatible condition) or the button under the off light (incompatible condition). Participants improved in both conditions, contrary to a control group with no videogame training. In another study, elderly people playing ‘Crystal Castle’ one hour a week for two months improved their manual dexterity, hand-eye coordination, verbal and non-verbal intelligence measured by WAIS-R (Drew & Waters, 1986 in Green & Bavelier, 2006).
In the study of Goldstein, Cajko, Michielsen, VanHouten and Salverda (1997), a group of non-institutionalized elderly people (aged 69 to 90) was positively affected in terms of reaction time (Sternberg Test) and emotional being (self-

report questionnaire) through gaming sessions with Super Tetris (5 hours a week for 5 weeks) more than the non-playing group; in the cognitive/perceptual adaptability at Stroop Color Word Test both groups had similar improvements. The studies reviewed by Whitcomb (1990) report several playing-induced enhancements of information processing, reading, comprehension, memory, and self-image for older adults. Finally, 'FreeCell', a solitaire game installed in many home computers, has been used as tool for Alzheimer diagnosis (Jimison, Pavel, McKanna & Pavel, 2004); a change in consistency of game performance across a short period of time is able to reveal the presence of a cognitive decline in the elderly.

Innovative Games

The advances in information and communication technology have made available new, enticing videogame interfaces. The VividGroup's Gesture Xtreme™ (GX) VR is a system to create an interactive image of the user in a simulated environment, thanks to a vision-based tracking system (IREX - www.irexonline.com). This entertainment tool is able to augment the mediated experience without the use of a Head Mounted Display (HMD), and it has been adapted to cognitive rehabilitation aims, although the high price of the GX™ VR limits its usage. A cheaper option to a similar end is the Sony PlayStation II EyeToy® (www.eyetoy.com; Rand, Kizony & Weiss, 2004). This device displays real-time images of the user on the monitor, where s/he can see him/herself surrounded by the virtual environment; the user can play with active movements individually (e.g. painting), or in multiplayer modality (e.g. boxing). The elderly healthy subjects participating in the study played Wishy-Washy, Kung-Foo and Keep-Ups and enjoyed using the tool, as the usability questionnaire indicated. Acute stroke patients showed interest and involvement, but also frustration because of their left-side impairment with sensory, cognitive, language and hand deficits; in this case, therapists are necessary in order to help patients. These games seem more powerful as treatment tools for mild stroke or chronic patients, and EyeToy is an ideal tool for home autonomous rehabilitation, involving active movement of the body, attention and quick reactions (Rand, Kizony & Weiss, 2004). The environments implemented for this tool cannot be graded according to low functioning patients or for specific therapies. TheraGames is another video capture VR system to enhance interaction of elderly people with rehabilitative systems thanks to highly motivating game setting (Kizony, Weiss, Shahar & Rand, 2006).

An unusual interactive system is also offered by two commercial platforms, Nintendo DS® and Nintendo Wii® (http://www.touchgenerations.com), which permits the manipulation of virtual objects displayed on the screen thanks to intuitive gestures performed with a physical tool (a pen in the former, a remote control in the latter). Several training programs exploit the properties of these interfaces. The DS is also a portable platform, permitting users to perform cognitive training tasks designed according to scientific results from neuroscience anywhere (Kawashima et al., 2005). A study by Korczyn, Peretz, Aharonson & Giladi (2007) on another commercial product for computer-based cognitive training, called MindFit™, shows that the training can improve cognitive performance more than classic computer games.

The PositScience Corporation (http://www.positscience.com) offers a computer-based Brain Fitness Program™ and provides scientific support to the exercises proposed, like the study by Mahncke et al. (2006). The study reports that intensive plasticity-engaging training can improve memory in healthy older adults. A web-based, game-like training program called Lumosity™ (http://www.lumosity.org) has been used in two studies, involving different tasks for different functions (visual attention in Scanlon, Drescher & Sarkar, 2007; working memory in Sarkar, Drescher & Scanlon, 2007). The evidence collected suggests that specific experimental and clinical tasks can be implemented in games to accomplish function-specific trainings. For instance, Green and Bavelier (2007) observed that action games seem to be able to alter the spatial resolution of vision, enhancing visual acuity.

Finally, the design and usability issues of these technologies are not less important than their direct training functions (Gamberini, Alcaniz, Barresi, Fabregat, Ibanez, & Prontu, 2006). Whitcomb (1990) reviewed several games to find the issues limiting elderly people's use of electronic entertainment and identified the small dimensions of visual objects, the requests of low reaction times, inappropriate sound effects as responsible for diminishing the satisfaction and involvement of older adults. Åstrand (2006) adopted an iterative design cycle approach to develop ACTIONPET, a network word game for older people (based on the ACTION project for healthcare (Assisting Carers using Telematics Interventions to meet Older persons' Needs). The users were involved during the design process. Khoo and Cheok (2006) introduced a mixed-reality system named "Age Invaders" as a context for intergenerational gaming between grandparents and kids, with remote monitoring by the parents. Age Invaders is a social, physical, family videogame derived from the famous Space Invader arcade game (www.spaceinvader.de) that uses a 3D online virtual interface. The system consists of a platform for real-time playing, with wireless tools and an unconventional floor display. Players have to move following a predetermined path; the tracking system gives the input for the synchronization of the real and virtual scene to create the shared real time scenario. Design solutions to meet the specific needs of elderly users, which should be a constant concern (Heller, Jorge, & Guedj, 2001; Jorge, 2001), are included: the game's parameters of difficulty and speed adjust to the age of the participant so that the potential disadvantages of elderly people is compensated; for example, rockets of grandparents are faster, in order to compensate for possible motor disadvantages.

Dealing With Affective and Social Diseases

As a consequence of health problems related to aging, some psychological and social problems can emerge as well. When cognitive and physical deficits confine elderly people at home, they also start to feel isolated from their relatives, companions and public life. Assistive Technologies could intervene to facilitate contact with caregivers and family. We will concentrate on the so-called Comfort Systems (Nehmer, Karshmer, Becker, & Lamm, 2006), namely those technologies that are designed to increase physical and social well being of older adults. They can be used as an alternative or as an integration of more conventional treatments of many psychological diseases, such as phobias or depression. We selected some examples, where technologies offer a means to deal with psychological aspects of physical diseases, or with social isolation.

Physical Diseases And Their Psychological Consequences

The first example refers to breast cancer and tries to relieve patients from some of the psychological consequences of chemotherapy. Breast cancer affects 180,000 women each year, 84% being older women. Schneider, Ellis, Coombs, Shonkwiler and Folsom (2003) assessed the potential of virtual reality as a means to distract patients from the stress generated by chemotherapy. They used a head-mounted display to show images from three possible game-scenarios: 'Oceans Below®', 'A World of Art®' and 'Titanic: Adventure Out of Time®'. Before and after the treatment, researchers administered the Symptom Distress Scale, the Revised Piper Fatigue Scale and the State Anxiety Inventory (one pre-test and two post-test measures). The results showed a significant decrease in the values of the State Anxiety Inventory; all old women involved in the research declared that they would use Virtual Reality during chemotherapy treatment again.

Another physical disease, chronic pain, can be dealt with psychologically; pain generates a negative loop in which the decrease of physical activity causes an augmentation in pain level when activity is undertaken. The research conducted by Tse, Pun and Benzie (2005) demonstrated that through a non-pharmacological treatment (i.e. the presentation of affective images) the levels of pain experienced by elderly users diminished, while cooperation and participation during and after treatment sessions increased.

Falls and fractures constitute a typical source of trouble in the everyday life of elderly people. In addition to that, Giotakos, Tsirgogianni & Tarnanas (2007) report that about 20% to 60% of them are afraid of falling (Howland, Lachman, Peterson, Cote, Kasten & Jette, 1998) and about 20% to 55% decrease their activity as a consequence of that fear (Fletcher & Hired, 2004) with negative consequence in terms of independence and quality of life (Cumming, Salked, Thomas, & Szonyi, 2000). Giotakos, Tsirgogianni and Tarnanas (2007) used a virtual reality exposure scenario (VRET) to convey a sense of control over risks and fear of falling. The VR represented Kozani city and its surroundings, through which participants could move by walking on a treadmill and wearing pressure-sensor shoes. Their task was to go shopping in the city; the therapist could add some obstacles on the path, and patients could practice their ability to generate appropriate responses in dangerous situations. The effectiveness of the treatment was evaluated by administering the Falls Efficacy Scale-International (FES-I), the Activities-specific Balance Confidence scale (ABC) and the Physiological Profile Assessment (PPA). Preliminary results showed that fear of falling, related to a traumatic hip fracture experience, was highly reduced by the use of virtual reality exposure scenarios, with 98% success.

With retirement and the ensuing increase of free time, elderly people can engage in several leisure activities. Reid and Hirji (2003) report that leisure improves the quality of life (Suto, 1998) and serves as a coping strategy to face stress (Kleiber, Hutchinson & Williams, 2002). Yet, the engagement of elderly people in leisure activities declines, probably because of age-related physical and social constraints; and this decline is more evident for stroke survivors, due to depression or visual/motor dysfunctions (Drummond & Walker, 1996 in Reid & Hirji, 2003). The Virtual reality system called ‘Mandala gesture Xtreme Virtual Reality’ was used in a study to affect stroke survivors’ “volition”, namely their motivation, enjoyment and satisfaction (Kielhofner & Forsyth, 1997 in Reid & Hirji, 2003). The system provided users with real life experiences, such as playing sports or games. The Volitional Questionnaire (de la Heras, Geist, & Kielhofner, 1998) was administered to measure spontaneity, involvement, hesitancy or passivity in a series of behavioral indicators, such as “seeking challenges” or “showing curiosity”. A global measure of satisfaction with life (Satisfaction with Life Scale; Diener, Lemmons, Larsens & Griffin, 1985), a test to screen cognitive disturbance (Mini-Mental State Exam; Folstein, Folstein & McHugh, 1985) and a measure of depression (Centre of Epidemiological Studies Depression Scales; Radloff, 1977) were also deployed. Results showed that the system involves people in a ‘volitional’ way; scores in the Volitional Questionnaire were related to those of life satisfaction and depression.

Social isolation

Some technological applications have been developed in recent years in order to face social isolation, providing tools to maintain or reinforce elderly people’s social network. For example, ‘Nostalgia’ is a system to listen music and news through a tangible interface, which proved capable of facilitating social contacts between elderly users and stimulating their affective experience (Nilsson, Johansson, & Hakansson, 2003). Morris (2005) proposed a system to provide elderly users with continuous information on their network of social contacts; the visualization was also accessible to caregivers, who then had the opportunity to observe and monitor their relatives’ social status and intervene in cases of isolation. The results of a study with this system showed that the exposure to the social networks display increased social engagement, and made older people more active in maintaining social ties. Moreover, the visualization enhanced contacts within the family and helped caregivers to cope with their responsibilities.

Dancing is not only an entertainment but also a physical activity useful for maintaining or promoting health; it can increase sociability, provide companionship and emotional support, and act as entertainment for both dancers and people watching them. The Human-Computer Interaction Institute at Carnegie Mellon has developed an augmented dancing environment, ‘DanceAlong’, which enables aged people to dance with the protagonists of well-known movies (Keyani, Hsieh, Mutlu, Easterday & Forlizzi, 2005). Users choose a dance scene from a classic movie; the scene is then projected on a large screen, and users join the dancers alone or in a group with other users.

Social involvement, amusement and physical activity are also promoted by playing together. The Age Invaders game already mentioned above is worth being considered also from this perspective (Khoo & Cheok, 2006). In addition to the physical and cognitive training already described, it is meant to be an intergenerational game involving young people, elderly people and adults. It reinforces interaction and ties among family, providing social support: children interact with grandparents in the physical media space, while parents participate from a distance via Internet connection.

How Videogames Can Help the Elderly Stay Active: The Eldergames Project

ElderGames (http://www.eldergames.eu/) is an EU funded project in which partners are designing, developing and ergonomically testing an interactive-play board (ElderGames). It represents a great opportunity to scientifically explore how emerging advances in ICT can be adapted, applied and combined with play activities to improve cognitive skills and quality of life (affective, physiological and social) in elderly people. Eldergames prototypes are meant to help counter the natural physical and cognitive decline of elderly people by having them engaged in individual and social game activities, and by using a low-budget mixed reality system that can make ICT usage more natural, in accordance with current trends analyzed above (Gamberini et al, 2006).

The project involves geriatric and gerontologist experts, universities, and specialists in elderly care, as well as companies specialized in the development of commercial systems. Several categories of professionals (across Spain, the United Kingdom and Norway) have been involved to exploit a large and various field of experience: ICT experts, occupational therapists, social educators, medical doctors, psychologists, nurses, social workers, physiotherapists, ergonomists, and sociologists.

Eldergames includes problem-solving exercises, performance measurements, psychomotor activities, and readapted classic games such as quizzes, puzzles and riddles to provide cognitive training and fun simultaneously; they are aimed to enhance selective attention, divided attention, short-term memory, categorization, problem solving, fine psychomotor skills, perceptual functions, language and calculation. A set of tests is also being incorporated or adapted to the platform, such as the Stroop Test and Trail Making Test (Strauss, Sherman & Spreen, 2006).

Eldergames prototypes will also offer a communication environment that enhances involvement; multiple players can participate in the game session, both by sitting around the same table, or by connecting to the game table by way of a normal Internet connection. Remote players can be of a different nationality than those sitting around the table, thanks to a communication system that tries to overcome linguistic differences.

Eldergames: the games module

The games module is one of the main components of the Eldergames device, and is divided into two sections: the Eldergames zone, hosting the main game, and the mini-games zone, a collection of different cognitive games and exercises, which also allows psychological experts to personalize the session for specific needs. In the Eldergames zone, up to four players face a classic card pairing memo game. Success or failure in the game involves bonuses and penalties: when they succeed in a round of the Memo game, users gain extra time to play; incorrect responses, instead, activate a mini-game, where cognitive abilities chosen by therapists according to a stimulation program are practiced. If the mini-game is finished unsuccessfully, then a penalty is assigned. The process continues until the Memo game ends. After the Memo session, users resolve, cooperatively or competitively, another quiz game, in which the time necessary for the solution is based on success in the previous Memo game. Players collecting the greatest number of cards at the end of the entire session win the game; a scoreboard with the results is also presented.

Interfacing elderly: a mixed environment on a comfortable table-top solution

The physical support of the Eldergames digital environment is an ergonomic table-top incorporating a 3D interactive-play platform working by way of a camera-based visual pattern recognition system. Table-top solutions to structure the interaction between humans and computers are currently growing, given the ease with which they afford the collaboration of a small group of users on the same mediated activity. TeleTable, for instance, is a similar technological application developed to improve social life in the elderly (Donaldson, Evnin & Saxena, 2005). TeleTable is composed of several parts: a touch-screen digital surface, which enables the user to sort and organize items by means of a stylus or hands; a mobile container for physical-digital information, called Pitara; a Placeholder through which users can associate digital media of the TeleTable with physical objects contained in Pitara; and a specialized operating system and hardware, which permits the table to receive input from other devices. Users can play games, like board or card games, write digital letters with the help of a stylus and of a visual address book, and collect, store and manage photos in a natural way in order to share them with others. Another example of a tabletop application for elderly people was proposed by Apted, Kay and Quigley (2006), and consisted of a multi-user, multi-touch, gestural, photograph sharing application, called 'SharPic'. It allows the user to use both hands to move, rotate and resize images over the table, as well as capturing and deleting them. The validation of SharPic showed that elderly people took twice as long to complete exercises as younger users; however, they succeeded in completion, and understood the interface and manipulation concepts well.

The concept design of the Eldergames interface adds the possibility of mixed reality systems to an ergonomic and comfortable table-top solution; it deploys a 3D pattern recognition system allowing participants to interact both with virtual and with real objects in a more natural way. Players access the digital content with objects that belong to their everyday experience, such as a pen or a card or simply their hands. Intercultural exchange is supported by using non-verbal communication based on icons, symbols, mathematics, pictures, visual geometry and metaphors.

In the next step of the project, the prototype under development, after an in-depth ergonomic and accessibility evaluation, will be tested in Northern, Central and Southern Europe in places where the elderly habitually spend much of their free time. The goal is to measure the effectiveness of the games and exercises proposed, and the overall satisfaction with the prototype of elderly users in different contexts.

Conclusions

Our aging society is launching a serious challenge that opens new possibilities for research and development in usable, empowering and effective technologies. In several contexts, ICTs allow scientists to reach and take care of elderly people more effectively than by providing personal human assistance. A range of novel solutions for elderly cognitive training is reviewed by Rebok, Carlson and Langbaum (2007), where these technologies emerge as a valuable alternative to classic ways of stimulating the users' cognitive processes.

In addition, communication technologies allow users to overcome physical impairments that limit participation in social life. All of these applications are just starting to be explored, posing scientific questions about the precise cognitive process stimulated by a certain kind of game, on game categorizations, on the advantage of collective training over individual training, on the long-term motivating effects of games, on the changing abilities and needs of new cohorts of aging populations, and on the tradeoff between age-specific tools and intergenerational integration.

Finally, a bottleneck is created by the extent to which interfaces go further in the direction of natural interaction; for elderly people, who may not be motivated to learn completely new usage practices, to memorize complex commands and to deal with alien interaction devices, natural interfaces are not just a fancy product, they can make a real difference in defining whether ICTs are persistently adopted or not in their daily life.

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EXPLORING EMOTIONAL AND IMITATIONAL ANDROID-BASED INTERACTIONS IN AUTISTIC SPECTRUM DISORDERS

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Individuals with Autistic Spectrum Disorders (ASDs) have impairments in processing of social and emotional information. To widen emotive responsiveness, the employment of robotic systems to engage proactive interactive responses in children with ASDs has been recently suggested. Understanding and teaching the processing of socio-emotional abilities is the inspiring principle of this novel approach and could be of tremendous clinical significance. Encouraging studies with robotic dolls, mobile robots and humanoids acting as social mediators have provided important insights and demonstrate the necessity of long term studies. In this study we report on a series of experiments on four subjects affected by ASDs as they interact with a biomimetic android. We assessed both their spontaneous behavior and reactions to therapist presses in correlation with the time course of the physiological and behavioral data, as well as the focusing of attention towards the android's eye movements and the spontaneous ability to imitate gesture and facial expressions. Overall, subjects demonstrated a decrease in dysfunction in the areas of social communication, implying a marked improvement in these areas after interacting with the android.

Introduction

Although symptoms belonging to the Autistic Spectrum Disorders (ASDs) were first described 50 years ago (Kanner, 1943), improved understanding of this complex spectrum of disorders has emerged over the past two decades, and, despite recent intense focus, it continues to be an art and science that is quickly evolving. ASDs refer to a wide continuum of associated cognitive and neuro-behavioral disorders. People with ASDs demonstrate impairments in processing of social and emotional information within core deficits in reciprocal social interactions, verbal and nonverbal communication, and restricted and repetitive behaviors or interests. In addition to being a spectrum disorder, ASD has a marked variability in the severity of symptomatology across patients, and level of intellectual function can range from profound mental retardation through the superior range on conventional IQ tests, which indicates that there may be additional subtypes on the spectrum.

The term ASDs in this work is used to refer to the broader umbrella of pervasive developmental disorders (PDD), whereas the specific term autistic disorder is used in reference to the more restricted criteria as defined by the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2000). Recent publications reported that early in the new millennium the best estimate of current prevalence of ASDs in Europe and North America is approximately 6 per 1,000 (Johnson, Myers, & the Council on Children With Disabilities, 2007). A multi-

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plicity of genetic and environmental factors play a role in ASDs, but the exact cause is still unknown. ASDs are believed to be mainly genetic, but environmental exposures in early gestational life can modulate spontaneous mutations and/or alterations in genetic imprinting following an epigenetic heritable mechanism. Only 10% of ASD cases may be associated with a medical condition or a known syndrome (Johnson, Myers, & the Council on Children With Disabilities, 2007).

In recent years, novel neuropathology and neuroimaging studies have indicated cues for a neurobiological basis of ASD. Fundamental differences in brain growth and organization in people with ASDs were revealed, such as a reduced numbers of Purkinje cells in the cerebellum, an abnormal maturation of the forebrain limbic system, abnormalities in frontal and temporal lobe cortical minicolumns, developmental changes in cell size and number in the nucleus of the diagonal band of Broca's area, and brainstem abnormalities and neocortical malformations (Johnson, Myers, & the Council on Children With Disabilities, 2007).

There are very useful instruments that can create comparability across clinicians and researchers, as well as instruments that can individuate more homogeneous groups for research: Autism Diagnostic Interview - Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) and Autism Diagnostic Observation Schedule - Generic (ADOS-G; Lord et al., 2000) are complementary instruments currently defined as the "gold standard" diagnostic instruments. The CARS scale (Childhood Autism Rating Scale; Schopler, Reichler, & Renner, 1988) was developed in order to aid in the diagnostic process, but it is also used to assess changes in autistic symptomatology. The CARS scale is subdivided into 15 items relative to the main behavioral areas. It is assigned a variable score from 1 to 4 for every item; a score of 1 indicates a behavior appropriate to the age, while a score of 4 indicates an abnormal behavior. The total score obtained after the CARS test has an undeniable diagnostic and clinical usefulness. By examining the score of the single items of the test it is also possible to characterize other patient behaviors.

Individuals with ASDs have impairments in assessing face and emotion recognition, eye-to-eye gaze, imitation of body movements, and interpretation and use of gestures. Imitation is thought to play a key role in developing theory of mind, and subjects with ASDs have limited and schematic means of processing and reproducing emotions and gestures (Baron-Cohen, 1997; Dawson, Meltzoff, Osterling, & Rinaldi, 1998). Marked impairments in social interaction and communication seen in ASDs are far more complex than presumed and share some similarities with the deficits seen in children with developmental language disorders or specific language impairments. There are few efforts that tackle the problem of how social and physical interactions contribute to the development of the network architecture of the brain, and there are also few that examine what features of the brain are essential to make social behavior possible. Typically developing infants show preferential attention to social rather than inanimate stimuli; in contrast, individuals with ASDs seem to lack these early social predispositions (Spelke, Phillips, & Woodward, 1995; Maestro et al., 2002).

When viewing naturalistic social situations, people with ASDs demonstrate abnormal patterns of social pursuits. For example, healthy children usually imitate the behavior of an interlocutor, whereas children with ASDs do not, and this can have serious consequences. Individuals with ASDs have "mindblindness," deficits in conceiving other peoples' mental states (Baron-Cohen, Ring, Bullmore, Wheelwright, Ashwin, & Williams, 2000). It has been suggested that their difficulty in conceiving of people as mental agents often leads to typically inappropriate reactions or behaviors in a variety of social interactions (Baron-Cohen, 1997). Recently it has been proposed that the social impairments of ASDs can be caused by a dysfunction of the mirror neuron system, speculating that the ability to imitate actions and to understand them could have subserved the underdevelopment of communication skills (Hamilton, Brindley, &

Frith, 2007; Iacoboni & Dapretto, 2006). Following recent studies showing how individuals, particularly those with high functioning autism, can learn to cope with common social situations if they are made to enact possible scenarios they may encounter, it can be hypothesized that the imitation skills of children, and thus their social development, could be enhanced through specifically designed treatments based on imitation (Nadel, Revel, Andy, & Gaussier, 2004).

The abovementioned considerations indicate that robotic technology may be used to help subjects with ASDs because understanding and teaching face recognition and emotion processing could be of tremendous clinical significance. State of the art robot-based therapy has shown the usefulness of the interaction of a robot with autistic patients within a highly structured environment where it is possible to recreate social and emotive scenarios that can be used to incentivize and anticipate actions of a subject (Duquette, Michaud, & Mercier, 2007). People with ASDs focus their attention on specific details; therefore interaction with a robot may allow an autistic subject to concentrate herself/himself on the limited number of communication modalities of the robot. In addition, while the stress of learning with a teacher can often be excessive, interaction with a robot, which young patients often associate with media and/or cinema characters, can reduce the emotional and social pressure of the situation, allowing the child to better learn from the environment at his or her own speed.

Several groups are developing and studying robots for use in the treatment of ASDs (Dautenhahn & Werry, 2004; Kozima, Nakagawa, & Yasuda, 2007). In these studies, robotic artifacts are used to act as social mediators in order to increase the social interaction skills of children with ASDs. Their encouraging studies demonstrate the necessity of more long term studies. An android-based treatment focused on the embodiment of emotions, empathy and interactive imitation represents a cutting-edge technological achievement (Pioggia et al., 2007). In this approach the three dimensional life-like android, FACE, presents emotional information in a structured and stepwise manner in order to engage a child with an ASD in social interaction based on mutual exchange of emotion through reciprocated imitation and learning emotion through the robot's facial expressions and gestures.

This could enhance the capability of the child to process emotions. In this paper we report on four subjects affected by ASDs and their interaction with FACE, while assessing both their spontaneous behavior and reactions to therapist presses in correlation with the time course of the physiological and behavioral data. The focusing of attention towards the android's eye movements and the spontaneous ability to imitate gesture and facial expressions were also investigated.

ASD and robots: social interaction and communication

The use of robotic technology aimed to help autistic subjects in everyday life began in 1976 with the work of Sylvia Weir and Ricky Emanuel (Weir & Emanuel, 1976). They used a mobile turtle-like robot, LOGO, to interact with a person with ASD. More recently François Michaud and his research team (Michaud, Salter, Duquette, & Laplante, 2007) at the University of Sherbrooke investigated the use of mobile robots as a treatment tool. They tested several robots, different in shape, color and behavior, in order to determine the main characteristics that may capture the attention of people with ASD. They obtained important insights for the idea of human-robot interaction in autism, sustaining the robot hypothesis as useful. By involving four children in a pilot study, they showed how a mobile robot can facilitate reciprocal interaction such as imitative play (Duquette, Michaud, & Mercier, 2007). In particular, they found that children paired with the robot mediator demonstrated increased shared attention (visual contact, physical proximity) and imitated facial expressions (smile) more than the children paired with a human mediator.

A more structured approach to the use of autonomous robots is the AuRoRA project (AUtonomous RObotic platform as a Remedial tool for children with Autism; Dautenhahn, Werry, Rae, Dickerson, Stribling, & Ogden, 2002; Robins, Dautenhahn, te Boekhorst, & Billard, 2004a; Robins & Dautenhahn, 2006). AuRoRA represents the first systematic study on a therapeutic approach utilizing robots for autism. In this project, people with ASD are invited to interact in coordinated and synchronized social actions with robots and their environment. The focus is on assessing if and how simple imitation and turn taking games with robots can encourage social interaction skills in children with autism. Moreover, how the robot, assuming the role of a mediator and an object of shared attention, can encourage social interaction with peers (other children with or without autism) and adults is investigated. Behavior-based control architectures and different robotic platforms such as mobile and humanoid robots are used. Examples of mobile robots in AuRoRA are Labo-1, a flat-topped robot buggy equipped with eight infrared sensors and optional heat sensors, and Pekee, an oval shaped robot with a plastic casing, two motorized wheels, and freely rotating caster wheel. Examples of humanoids, which allow the interaction to be based on empathy, are Kaspar, a child-sized robot equipped with a silicon-rubber face and two Degrees of Freedom (DOF) eyes fitted with video cameras, and Robota, a series of humanoid robotic dolls able to drive the arms, legs and head giving one DOF to each. Kaspar is aimed to mimic some human behaviors and to teach social skills; it is able to blink its eyes, to open/close the mouth and smile, as well as to act startled at a sudden gesture, although it is not able to produce subtle facial expressions.

Table 1. Autism rating scale for the selected subjects

Subjects	**Age**	**IQ**
S1	10y6m	105
S2	9y6m	87
S3	8y11m	85
S4	20y6m	52

Robota is the name of a series of doll-shaped mini-humanoid robots developed in a project headed by Aude Billard (Billard, Robins, Dautenhahn, & Nadel, 2007). The possible therapeutic effects of human-Robota bodily interaction, including eye gaze and touch, with ASD children was tested in imitative interaction games. Such games, based on requests for the child to imitate the robot, are important factors in a child's development of social skills and could help children with autism in coping with the normal dynamics of social interactions. Researchers also studied Robota's behavior, appearance, Robota-mediating joint attention, and interaction informed by conversation (Dautenhahn & Billard, 2002; Robins, Dautenhahn, te Boekhorst, & Billard, 2004a; Robins, Dautenhahn, te Boekhorst, & Billard, 2004b; Robins, Dickerson, Stribling, & Dautenhahn, 2004; Robins, Dautenhahn, te Boekhorst, & Billard, 2005; Robins, Dickerson, & Dautenhahn, 2005).

A similar approach inspired Infanoid and Keepon (Kozima, Nakagawa, & Yano, 2004; Kozima, Nakagawa, & Yasuda, 2007) developed by Hideki Kozima at the National Institute of Information and Communications Technology (NICT) in Japan. Infanoid is an upper-torso child-like robot, capable of pointing, grasping, and expressing a variety of gestures, while Keepon is a creature-like robot capable of expressing its attention (directing its gaze) and emotions (pleasure and excitement). They observed that contingency-games with Infanoid could benefit children in learning communication skills (Kozima, Nakagawa, & Yano, 2002; Kozima, Nakagawa, & Yasuda, 2006), and interaction with Keepon facilitates social interactions in 2- to 4-year-old children with ASD (Kozima, Nakagawa, & Yasuda, 2007).

In our study, we adopted a biomimetic approach in order to explore the field of assessment and treatment of subjects with ASD in a dynamic, activity-dependent manner based on embodiment of emotions, empathy, and interactive imitation with a believable android (Pioggia et al., 2004; Pioggia, Igliozzi, Ferro, Ahluwalia, Muratori, & De Rossi, 2005; Pioggia et al. 2006; Pioggia et al. 2007). In our FACE project (Facial Automaton for Conveying Emotions), the recent developments of emotional cognitive architectures and smart materials allowed an embodied interaction scheme based on imitation and empathy to be adopted in a more naturalistic setting in order to help children with ASD to learn, interpret, use and extend emotional information in a social context. The FACE android is used to engage the child in simple interactions based on exchange of emotions and learning emotion through imitation of the android's facial expressions and behaviors. FACE can also be employed in more complex situations, through the recreation of social and emotive scenarios which can be used to incentivize and anticipate actions of a subject. FACE captures expressive and psychophysical correlates from its interlocutor and actuates behaviors with kinesics, a non-verbal communication conveyed by body part movements and facial expressions. Both physiological and behavioral information from the patient is acquired in real time by means of an unobtrusive sensitized wearable interface (life-shirt) during treatment. In the framework of a social therapy, FACE itself, the sensitized life-shirt, and the therapeutic protocol acting between a patient and a trained therapist in a specially equipped room, all represent the FACE-T system (T as in "therapy"). This approach provides a structured environment that people with autism could consider to be "social," helping them to accept the human interlocutor and to learn through imitation. On the basis of a dedicated therapeutic protocol, FACE is able to engage in social interaction by modifying its behavior in response to the patient's behavior. If such learned skills can be extended to a social context, the FACE-T system will serve as an invaluable tool for the evaluation and treatment of ASD. The involvement of FACE-T could also provide the necessary assessments for a robot's effectiveness in socio-emotive exchanging in ASD.

FACE, an embodied interactive social interface

In the FACE-T scheme of embodied interaction between humans and systems, we considered both innovative devices and communications paradigms for the social and physical interface with the human sensory system. We used a new generation of unobtrusive monitoring interfaces known as smart clothing. They consist of electronic sensing textile interfaces as a novel artificial embodiment concept where both vital signs (Paradiso, Loriga, & Taccini, 2005) and/or behaviors in terms of body segment position reconstruction and posture classification (Tognetti, Bartalesi, Lorussi, & De Rossi, 2007), as well as relevant information from the environment can be unveiled. Emerging wearable systems will be able to detect psycho-physiological responses by extracting features from a subset of physiological and behavioral signals needed for the evaluation of an egocentric psycho-emotional, as well as an allocentric status, based on the mirroring of others' emotional reactions within the framework of a visionary interacting emotional prosthesis. While physiological and behavioral signals provide streams of allocentric information, FACE conveys emotional responses, eye movements and bodily gestures, taking into account the actuation of a behavior-based control, as well as an imitative learning strategy. The latest prototype of FACE is shown in Figure 1. FACE's visage is able to express and modulate the six basic emotions (happiness, sadness, surprise, anger, disgust, fear) in a repeatable and flexible way. The strictly humanoid design underlines a high degree of believability in the semblance, placing the socio-emotional relationship domain of the android close to human beings. In fact, FACE consists of an anthropomorphic body equipped with a believable face based on biomimetic principles. FACE's artificial sensing skin provides streams of spatial and temporal information, where-

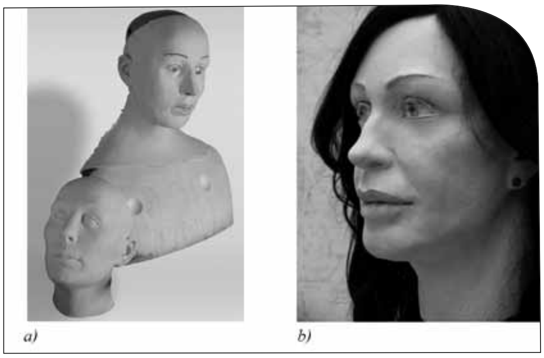


Figure 1. a) the latest FACE prototype; b) a detail of the android

as servomotors allow FACE to modulate facial expressions. The hybrid multisensory signals are generated from a synergy between an android-centered polymorphic perception system (*egocentric sensing system*) and a human-centered one (*allocentric sensing system*). Together they encode both FACE's and the subject's presence as well as their behaviors and emotional states.

The *egocentric sensing system* consists of an artificial sensing skin which accounts for proprioceptive mapping and a visual eye-like system. The FACE artificial sensing skin is three-dimensional latex foam, under which lie sensing layers, connections, and digital pre-processors able to detect the overall shape, stress, strain and localized deformations of the skin. The integral impedance pattern is in fact a function of the overall shape of the sensorized fabric and allows mapping between the electrical space and the shape space. The sensing layer responds to simultaneous deformations in different directions by means of a piezoresistive network which consists of a Conductive Elastomer (CEs) composite rubber screen printed onto a cotton lycra fabric. CE composites show piezoresistive properties when a deformation is applied and can be easily integrated into fabrics or other flexible substrates to be employed as strain sensors. They are elastic and do not modify the mechanical behavior of the fabric. CEs consist of a mixture containing graphite and silicon rubber. In the production process of sensing fabrics, a solution of CE and trichloroethylene is smeared on a lycra substrate previously covered by an adhesive mask. The mask is designed according to the desired topology of the sensor network and cut by a laser milling machine. After the deposition, cross-linking of the mixture is obtained at high temperature. Furthermore, by using this technology, both sensors and interconnection wires can be smeared by using the same material in a single printing and manufacturing process. FACE's artificial eyes scan the environment to track a human face and generate a visual signal which encodes essential information about the interlocutor's expressions, as well as emotional reactions. This signal is pre-processed by a retina-like dedicated unit and then it is sent to a neurocontroller.

The *allocentric sensing system* consists of a biomimetic wearable suit (life-shirt) integrated into the FACE-T system, for the unobtrusive acquisition of physiological and behavioral signals from the interlocutor. The life-shirt integrates smart sensors within a garment together with on-body signal conditioning and pre-processing, as well as the power supply and the wireless communication systems. Three key points make up the life-shirt: the fabric electrodes based on interconnecting conductive fibers, a piezoresistive network, and a wearable wireless communication unit. Electrodes and connections are interwoven within the textile by means of natural and synthetic conductive yarns. Their suitable positioning provides real-time acquisition of the electrocardiographic signal as well as skin temperature and electrodermal response. Simultaneously, intelligent reading strategies of unobtrusive piezoresistive networks developed by direct screen printing of CEs and physiological modeling allow human kinematic variables and breath rhythm to be acquired. The integrated and processed outputs are observable patterns of activity emerging from interactions. Predefined stereotypical behaviors of activity can be represented in terms of FAPs (Fixed Action Patterns) followed by a continuous interaction. FAPs can be classified according to the action schemes they belong to. Gestures and stance can be coded in terms of FAPs by means of the life-shirt. Such a code can enable the recognition of the interpretation of the individuals' activities. Due to subject variability of FAPs and the novel FAPs emerging from the usual motor actions within the environment, instruments such as adaptive artificial neuronal networks are devoted to personal gesture recognition and interpretation, as well as FAP classification.

Acquired signals are transmitted to a common framework that performs the processing tasks. The great variety of the sensory signals acquired by all the interfaces are input to a neurocontroller in the form of an integrated signal. This represents a challenging task both in signal processing and in data mining, which is managed by an ad-hoc developed framework architecture. The framework manages and synchronizes data and signals from all elements of FACE's embodied interactive interfaces in order to perform their comprehensive dynamic integration to generate an input for FACE's neurocontroller.

FACE's control strategy during the sessions follows a behavior-based approach supervised by a therapist. An essential prerequisite to emulate imitation in a robot is a connection between the sensory systems and the motor systems such that percepts can be mapped onto appropriate actions. Through imitation, FACE will get the necessary training to encode the patient's emotional expressions, and through the feedback and actuation described, it will be able to reproduce them to imitate the interacting subject's emotions. FACE's emotional expressions can also be structured on the basis of the clinical treatment protocol or tailored to each subject. During the clinical trials, the therapist can also directly control FACE's emotional expressions in real-time. Moreover, through the presentation of different social situations within the experimental set-up, FACE can contribute to enhance the pragmatic use of emotions. The cognitive architecture of FACE is shown in Figure 2. The external world is sensed by FACE and the different stimuli are extracted in terms of neural group activities.

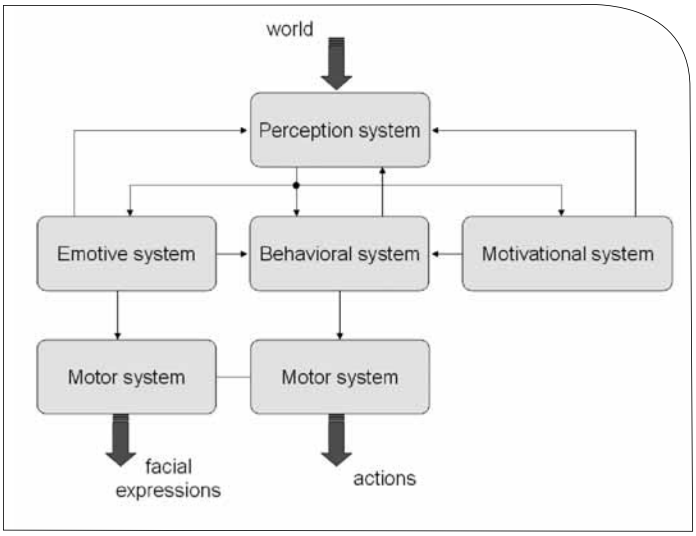


Figure 2. FACE's cognitive architecture

In the Perception System, these activities are bound by threshold controlled processes that encode the current set of beliefs about the internal and external state of the android and its relation to the world. The result is a set of response-specific thresholds that serve as antecedent conditions for specific behavioral responses. The Emotive System sends feedback to the Perception System in order to participate in the evaluation of the stimulus, to the Behavioral System in order to participate in the selection of the behavior selection, and to the Motor System to activate the facial expression consistent with the emotion. The Motivational System is aimed at influencing behavior selection.

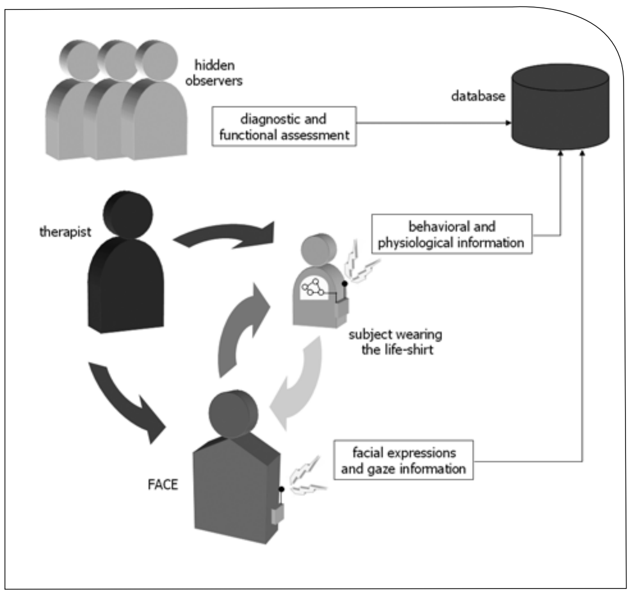


Figure 3. FACE-T set-up diagram

FACE - people with ASD interaction: experimental results

The FACE-T system (Figure 3) consists of a spe-

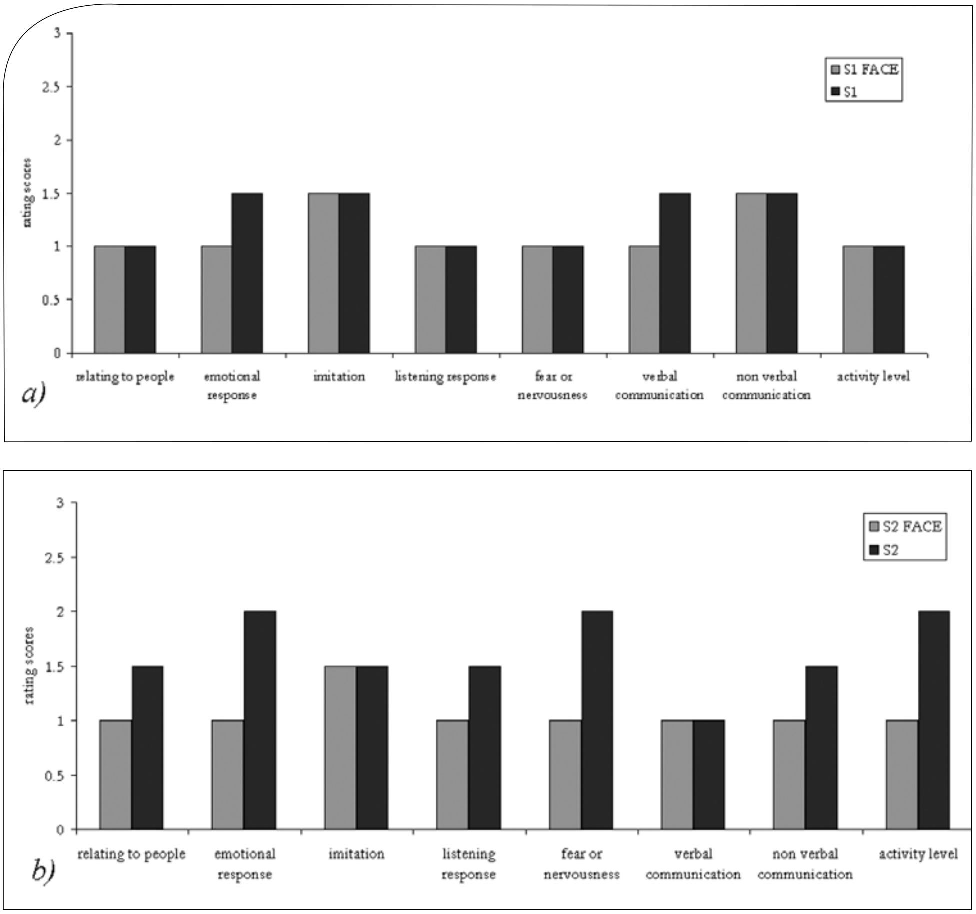
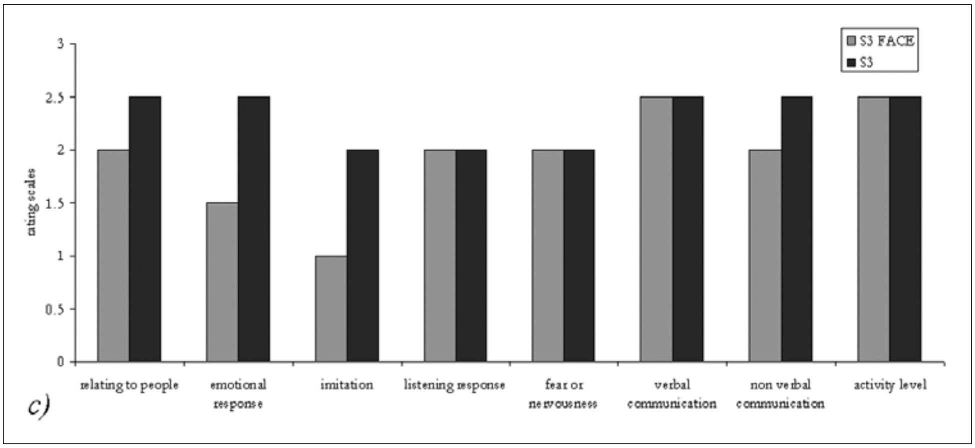
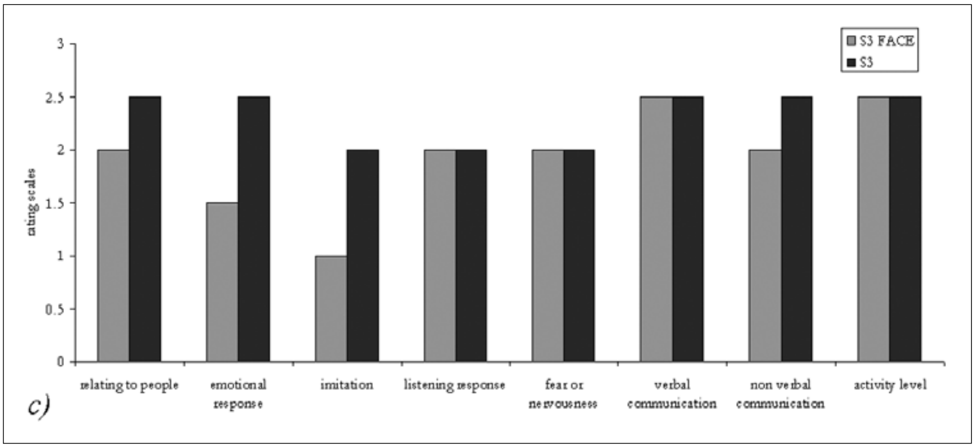


Figure 4. CARS score obtained from the experimental session with FACE (Sx FACE) and CARS score obtained from the observation of session with psychological tests (Sx); a) Subject 1 (S1) ; b) Subject 2 (S2); c) Subject 3 (S3); d) Subject 4 (S4).

cially equipped room with two remotely orientable video cameras, in which the child, under the supervision of a therapist, can interact with FACE. The subject wears the life-shirt for recording physiological and behavioral data. The database also contains data from the audio visual recording system present in the room. Other therapists or hidden observers compile evaluation sheets during sessions, and the data scanned from these will also be added to the database and used for successive analysis.

In order to obtain a preliminary evaluation of the behavior of children affected by ASD when exposed to FACE, we set up experimental sessions in which the reactions of four subjects (three male and one female) between 7 and 20 years old, were monitored and compared. In these sessions, a technician was also present to monitor the android's functioning and troubleshoot if necessary. The technician did not speak and was completely passive throughout the





sessions. The children with ASD had been diagnosed using ADI-R and ADOS-G with high functioning autism, and are currently under treatment at the Stella Maris Institute (IRCCS) in Pisa, Italy. Experiments were carried out in order to study the interaction with FACE during twenty minute sessions. Each session had a duration of about an hour and varied from individual to individual according to their reactions. We structured the session in five phases in order to examine specific aspects of the subjects' behaviors and reactions to FACE:

- spontaneous behavior of the child when the android and the therapist are present;
- shared attention of the child, i.e. the capacity of the child to focus the therapist's attention on the android;
- ability of the child to imitate gesture and expressions of the android upon the therapist's request;
- spontaneous ability of the child to imitate gesture and expressions of the android;
- verbal presses to the child to solicit interpretation of the behavior and facial expressions of the android.

In general, we observed that all the subjects were not afraid of FACE, but rather were attracted to the android. Some subjects walked up to touch FACE, whereas others remained seated but with their eyes on the android. We observed that none of the subjects paid any attention to the technician, as if this person did not exist. This behavior confirms the relevance of robots for social interaction in people with ASD. The evaluation of the sessions as described above

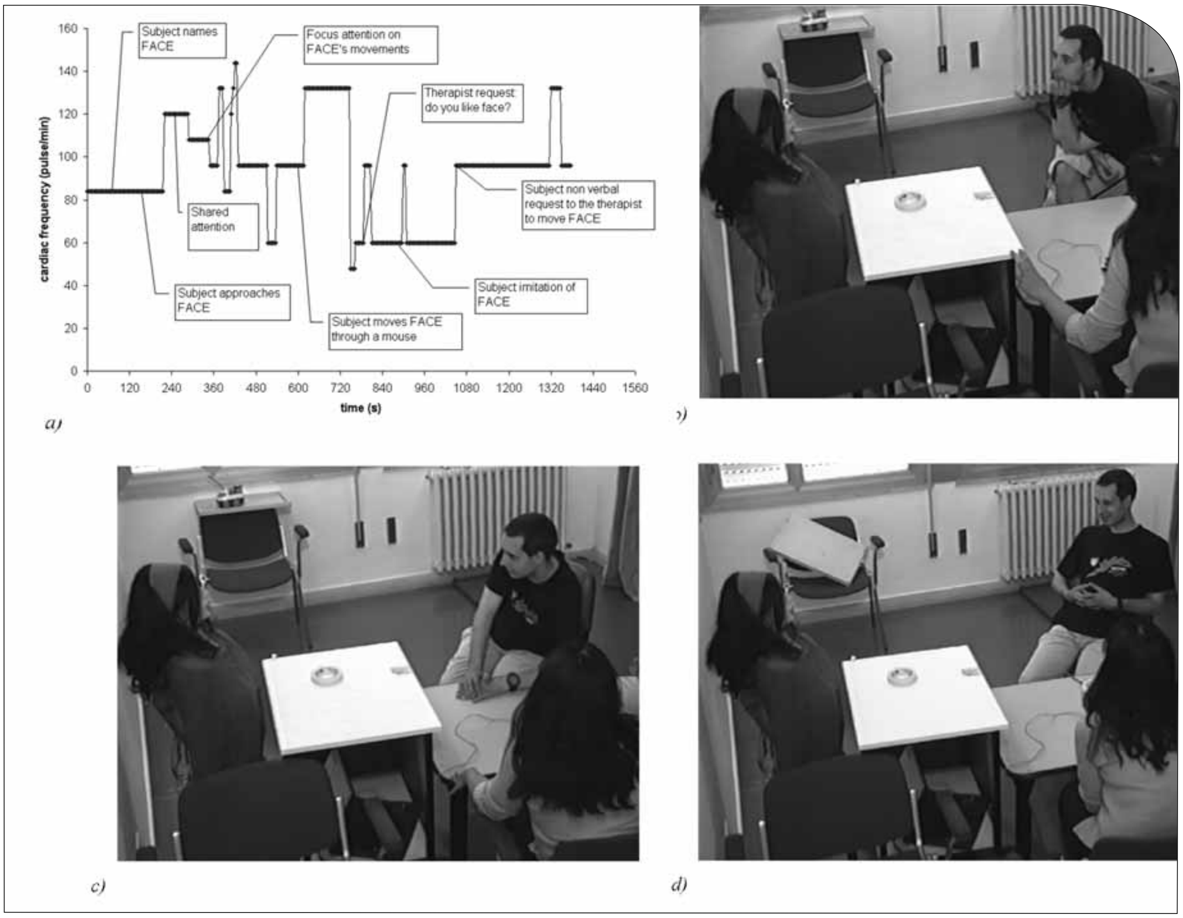


Figure 5. Experimental sessions; a) typical trace of a subject's heart rate during the treatment; b) focus of attention on FACE (S4); c) spontaneous approaching for eye contact with FACE; d) non verbal requesting through conventional gesture (S4).

was performed using eight relevant items from the CARS scale. Figure 4 supplies a graphical comparison between the score obtained in items of CARS scale in previous interactions during psychological assessment and the one obtained with FACE. In particular, we observed that the CARS score decreased or remained the same for all items in Subjects 2 and 3 after the therapy session. Only Subject 4 (the oldest, with the lowest IQ and highest ADOS rating) showed an increase of 0.5 points for listening, fear, and verbal communication. More importantly, all the subjects demonstrated a decrease in the score of emotional response in the CARS scale of between 1 and 0.5 points, and imitation in 3 out of 4 children, implying a marked improvement in these areas after interacting with FACE.

Even though these are the first set of clinical trials, it is clear that the presence of FACE in a therapeutic environment can lead to improvements in the areas of social communication and imitation. As shown in Figure 5a, the cardiac frequency of the patient increases after his or her attention is focused on the robot, and remains fairly high until he or she is forced to focus on his emotional relationship with FACE. Figures 5b, 5c and 5d show snapshots of an experimental session. In Figure 5b the subject is shown to completely focus his attention on FACE. Figure 5c illustrates spontaneous approaching of the subject to make eye contact with FACE. Figure 5d shows the non-verbal requesting of the subject through a conventional gesture (a wink). All four subjects (as well as controls) show no fear in the presence of FACE, and all subjects with ASD showed some improvement in CARS scores, particularly regarding imitation, communication and emotional response. Future work in this direction will focus on identifying specific criteria for evaluation of subject response, conducting a larger range of trails, and repeating treatment to monitor signs of progress in patients. These initial results illustrate the validity of the android-based FACE-T approach in social and emotive treatments for ASDs. We believe that its potency lies in the fact that FACE is based primarily on learning by imitation, and imitation is one of the core deficits implicated in ASD.

Conclusion

The interactive FACE-T scenario provides a novel semi-naturalistic tool that is able to engage in emotive exchange with subjects with ASD. This could be conveniently used to support cognitive behavioral therapy in order to enhance comprehension and expression of imitation, shared attention, and facial mimicry in people with ASDs. We carried out a series of trials on subjects affected by ASD, assessing both spontaneous behavior of the participants and their reactions to therapist presses in correlation with the time course of the physiological and behavioral data, as well as the focusing of attention towards FACE's eye movements and the spontaneous ability to imitate gesture and expressions of the android. Overall, subjects demonstrated a score decrease in the areas of social communication, implying a marked improvement in these areas after interacting with FACE. Our hypothesis is that treatment with FACE could develop pragmatic emotional responsiveness in several social scenarios.

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VIRTUAL REALITY BASED UPPER EXTREMITY REHABILITATION FOLLOWING STROKE: A REVIEW

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In the last decade there have been major developments in the creation of interactive virtual scenarios for the rehabilitation of motor deficits following stroke. Virtual reality technology is arising as a promising tool to diagnose, monitor and induce functional recovery after lesions to the nervous system. This evidence has grown in the last few years, as effort has been made to develop virtual scenarios that are built on the knowledge of mechanisms of recovery. In this paper we review the state of the art virtual reality techniques for rehabilitation of functionality of the upper extremities following stroke. We refer to some of the main systems that have been developed within different rehabilitative approaches such as learning by imitation, reinforced feedback, haptic feedback, augmented practice and repetition, video capture virtual reality, exoskeletons, mental practice, action observation and execution, and others. The major findings of these studies show that virtual reality technologies will become a more and more essential ingredient in the treatment of stroke and other disorders of the nervous system.

Introduction

The use of virtual reality (VR) in the field of neurorehabilitation has grown immensely in the last decade. VR is a set of computer technologies that provides an interactive interface to a computer generated environment. In this environment, the individual can see, hear and navigate in a dynamically changing scenario in which he or she participates as an active user by modifying the environment according to his or her actions. VR has also been deployed in different rehabilitation contexts and a number of preliminary studies suggest that this technology has a positive impact on functional recovery (see Rose, Brooks, & Rizzo, 2005 and Holden, 2005 for reviews).

The use of virtual reality technologies in rehabilitation has a number of distinguishing features. First, they can be used as training tools to promote intensive training directed towards specific deficits. Second, training can be defined within scenarios that allow the patients to engage in task-oriented activities. Third, it is a real-time high-resolution monitoring tool, allowing for the quantitative assessment of relevant properties of deficits, performance and recovery.

This latter aspect can be combined with more standard clinical evaluation methods, providing complementary data for measuring diagnostics. Fourth, the versatility of VR technologies can play an important role in engaging motiva-

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tional factors, a key factor in recovery (Maclean, Pound, Wolfe, & Rudd, 2002). Fifth, VR based rehabilitation systems easily transfer from clinic-based training to at-home applications for telerehabilitation, creating a continuum of diagnostic and training possibilities (Holden, Dyar, Schwamm, & Bizzi, 2005; Piron, Tonin, Trivello, Battistin, & Dam, 2004). In this review we will analyze a number of studies with the objective of identifying the underlying principles and routes for future research and applications in this area. In particular, we will describe and analyze different virtual reality systems and methods that have been developed for motor rehabilitation, focusing on rehabilitation of the upper extremities following stroke. We start by briefly summarizing the problematic elements of stroke and its rehabilitation strategies. Subsequently, we review studies of virtual reality systems for the rehabilitation of upper extremity deficits after stroke and describe their major results. Although in the concrete application we have limited ourselves to this specific range of deficits and patients, the core principles and observations will generalize to a wide range of other pathologies.

Stroke and its Rehabilitation

Stroke represents one of the main causes of adult disability and it is estimated that it will still be one of the main contributors to the burden of disease in 2030 (Mathers & Loncar, 2006). Following stroke, up to 85% of patients initially show a motor deficit of the arm contralateral to the lesion, and 55 to 75% display persistent functional limitations three to six months after stroke (Lai, Studenski, Duncan, & Perera, 2002). Several cognitive and motor deficits may be present depending on the lesion site, such as paralysis or weakness, abnormal posture, neglect, abnormal movement or loss of coordination. Moreover, about 60% of people who survive a stroke experience impairments that last throughout life (Parker, Wade, & Langton Hewer, 1986).

After a stroke, the recovery of the motor capacity of the hand is of particular interest since it is very relevant in overall functionality and the ability to perform instrumental activities of daily living (IADL). However, the optimal type of physiotherapy is still under discussion (Dombovy, 2004).

There is a considerable variety of treatment concepts and therapies, but their effectiveness is difficult to measure and compare since there are many variables to take into account. In stroke, as in many other neuropathologies, one of the main problems in assessing the impact of new methods is the difficulty of performing studies with homogenous groups of patients in terms of stroke type and functional deficit. Although traditional physiotherapy-oriented approaches emphasize the manipulation of the peripheral skeletal motor system and the training of IADL, currently the emphasis is shifting to methods that directly address the central nervous system and take into account our understanding of the neural mechanisms underlying recovery (Kalra & Ratan, 2007). An important basic research question, however, is what the best way is to exploit plasticity and functional reorganization.

Irrespective of the technology involved, the effectiveness of stroke therapy has been shown to depend on a number of parameters. First, treatment frequency and intensity has been shown to correlate with recovery (Kwakkel et al., 2004; Sonoda, Saitoh, Nagai, Kawakita, & Kanada, 2004). Increasing therapy time in the first months post-stroke has been shown to promote increased independence in IADL and a reduction of the hospitalization period. In addition, movement practice and repetition seems to play a fundamental role in recovery (Karni, Meyer, Jezzard, Adams, Turner, & Ungerleider, 1995).

Second, the specificity of rehabilitation training with respect to the deficits and required functional outcomes has an impact on recovery (Krakauer 2006). Specificity is also seen as a central concern in occupational therapy (Steultjens, Dekker, Bouter, van de Nes, Cup, & van den Ende , 2003). VR based rehabilitation systems can capture these two core parameters of effective neuro-rehabilitation, while combining them with a number of additional features that are specific to this technology.

VR Rehabilitation

Several virtual reality systems and methods have been developed for motor rehabilitation of the upper extremities following stroke based on different paradigms and hypotheses. Here we delineate a number of specific studies that elucidate the different dimensions that guide the development of deployment of VR-based rehabilitation methods.

Learning by Imitation

Holden and collaborators have developed a VR system based on the so called, "learning by imitation" paradigm (Holden & Dyar, 2002; Holden, Todorov, Callahan, & Bizzi, 1999). This system makes use of a virtual teacher, whose movements are to be followed by the user. The hypothesis is that the repeated observation of this virtual tutor may lead to recovery as a result of direct input to the primary motor area (M1) provided by the bi-modal mirror neuron or action recognition system. Mirror neurons have the property of being active during the execution of goal-directed movements performed with the hand, foot and mouth, and also during the observation of the same actions performed by another individual (Rizzolatti & Craighero, 2004). In a specific experiment, two chronic stroke patients used the system to train reaching movements in a task that consisted of placing an envelope in a virtual mailbox positioned in different locations (Holden et al., 1999). The subjects were asked to follow the instructions of the virtual teacher in this task and both virtual and real movements were used to provide augmented feedback about the patient's performance. Results showed that both patients improved in the virtual tasks and also in the real world reaching tasks, showing the ability to transfer VR task abilities to the real world. However, there were no significant changes in the standard clinical measures, with only one of the subjects presenting a slight increase of 17% in the total Fugl-Meyer Test for the upper extremities (Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975).

Moreover, as with other studies in this domain, the statistical power from an impact study with such a small sample size cannot be considered adequate. In a later study, nine patients practiced reaching tasks in a new version of this system; besides the "virtual mailbox" it also included new virtual scenes and a scoring system to provide feedback (Holden & Dyar, 2002). This system captures the patient's movements by means of electromagnetic motion tracking sensors and these movements are mapped onto the movement of a virtual representation of the upper extremity. Moreover, when the subjects hold a real object, e.g. a ball, is also represented in the virtual scenes. The purpose of this is to increase the sense of immersion during the task and also to elicit the execution of natural movements. Patients showed improvements in the virtual task and also significant improvements in standard clinical tests such as the Fugl-Meyer Test and Wolf Motor scale (Wolf, Catlin, Ellis, Archer, Morgan, & Piacentino, 2001). The authors emphasize that although the results are quite promising, they do not warrant definite statements on what exact characteristics of their system triggered the improvements in function. Moreover, there is the added problem of not having controls for a comparison standard in any empirical validation. In a follow-up study, further tasks were added to this virtual environment to train different movements (reaching, hand-to-body, and hand grasp/release) and it was used within a telerehabilitation system (Holden, Dyar, Schwamm, & Bizzi, 2005). Preliminary tests with two chronic stroke patients showed the advantages of these kinds of systems in remote training. For clinical evaluation, the authors used the Fugl-Meyer Test, the Wolf Motor Test, and strength tests for shoulder flexion and hand grip. The patients showed improvements in the performance of the virtual task and also in the associated clinical measures, with sustained gains at follow-up. In a later study, an improved version of this system was used with eleven stroke patients (Holden, Dyar, & Dayan-Cimadoro, 2007). The patients followed a treatment course of 30 one-hour sessions, and the evaluation was performed at admittance, session 15, session 30, and 4-month follow-up. The results revealed significant changes in the group mean on the clinical measures (Fugl-Meyer Test, Wolf Motor Test and strength tests) after 15 and 30 sessions, with gains maintained at follow-up except for grip strength. Unfortunately, no controls were used in this study.

Reinforced Feedback

Piron and colleagues base their work on the hypothesis that convenient feedback may improve motor recovery (Piron, Tonin, Piccione, Iaia, Trivello, & Dam, 2005). This feedback can be delivered regarding the quality of the movement (knowledge of performance) and the goal of the task (knowledge of results). The authors want to investigate whether continuous information provided on the quality of the movement of the patients combined with the observation of correct movement may lead to an enhancement in recovery. The setup used, the virtual environment training (VET) system, has a set of exercises that promote several reaching tasks through imitation of a virtual therapist. Subjects were asked to grasp real objects (envelope, ball, cube and glass) in which a magnetic sensor was placed. Movements were first performed by the virtual tutor and afterwards by the subject. The software is the same used by the group above (Holden & Dyar, 2002). The movement trajectories were displayed during the execution of the task and were also presented to the subjects in the end of the task. Forty-five chronic stroke patients used the system during for one hour, five days a week, during one month. In a general overview all the patients increased in clinical scores, with a 15% increase in the mean Fugl-Meyer score. However, the impact on activities of daily living performance was low, with a 6% increase in the mean FIM (Functional Independence Measure) score (Keith, Granger, Hamilton, & Sherwin, 1987). There were also observed improvements in the kinematic parameters of the reaching movements (mean velocity and mean duration). Moreover, the pattern of the grasping movements of the paretic arm approached the correct pattern of movements of the non-paretic one. In a later study, this same type of virtual reality training was used with patients in the early stage of stroke (first three months; Piron, Tombolini, Turolla, Zucconi, Agostini, Dam, et al., 2007). Thirty-eight patients participated in this study and were separated into two groups: 25 subjects received reinforced feedback in the virtual environment (RFVE) and 13 patients (control group) received the same amount of conventional therapy. After the treatment period, the RFVE group showed significant improvements in the mean scores of the Fugl-Meyer Test and of the FIM. The control group presented no significant improvements. This supports the idea that reinforced feedback provided in the early stages of stroke may lead to an enhanced recovery.

Haptic Feedback

Virtual reality training has also been combined with haptic feedback. Regarding arm reaching training, there is a setup proposed by Broeren and colleagues (Broeren, Rydmark, Bjorkdahl, & Sunnerhagen, 2007; Broeren, Rydmark, & Sunnerhagen, 2004). The system is composed of a haptic force feedback interface (PHANToM) connected to a virtual environment and a stereoscopic view setup, allowing for a sense of touch with virtual solid objects. The task consists of knocking down bricks in a pile with a ball with a variable velocity, where the force feedback is provided by a haptic stylus. In a case study with a three month post-stroke patient, the patient improved finger dexterity, grip force and endurance after a four month VR treatment (Broeren et al., 2004). In addition, the patient reported an increase in the use of the paretic arm during activities of daily living. In a later study, five chronic stroke patients with hemiparesis used the system for five weeks (Broeren, et al., 2007). All patients progressed to the highest difficulty in the game level and some improvements in aspects of motor performance were also observed.

Augmented Practice and Repetition

Intensive training of different manual skills has been one of the focuses of the Rutgers group (Jack, Boian, Merians, Tremaine, Burdea, Adamovich, et al., 2001; Merians, Jack, Boian, Tremaine, Burdea, Adamovich, et al., 2002; Merians, Poizner, Boian, Burdea, & Adamovich, 2006). Their system is based on the notion that intensity of training and systematic feedback are important factors to improve motor function (see above). The proposed system makes use of two complementary data glove systems (CyberGlove, Immersion Co., San Jose, USA) and the Rutgers Master II force feedback glove (Bouzit, Burdea, Popescu, & Boian, 2002) to train range of movement, speed of movement, finger fractionation (the ability to move fingers independently) and strength (Jack et al., 2001). This project is associated with an older system developed by the same group for ankle rehabilitation (Girone, Burdea, Bouzit, Popescu, & Deutsch, 2000). The CyberGlove is comprised of strain-gauge sensors that measure finger joint angles, abduction, and wrist flexion, allowing for an appropriate capture of hand movement. On the other hand, the Rutgers Master II force feedback glove is an exoskeleton that applies force to the fingertips by means of pneumatic actuators, allowing for strength training exercises. Four virtual tasks were implemented to train the different hand parameters. First, the range of movement task, designed to improve finger flexion and extension, consisted of moving a window wiper to clean a fogged window, revealing a pleasant landscape. The range of finger flexion controls the rotation of the wiper. Second, the speed of movement task is a catch-the-ball game where the subject is asked to close either the thumb or the other four fingers as fast as possible when required. Third, the finger fractionation task that is used for all fingers except the thumb uses a piano keyboard on which keys depress and highlight when the correspondent fingers move. Fourth, the strength task, used for grasp training, presents a virtual model of the Rutgers Master II glove that is directly controlled by the user. Reacting to the forces applied on the fingertips, schematic pistons start to fill from top to bottom in proportion to the exerted force. In these tasks feedback is provided with respect to the movement goal (knowledge of results) and also related to the movement that was produced (knowledge of performance). A study with three chronic stroke patients showed improvement in some of the trained parameters and also functional gains after the training period, but with variable improvement patterns (Merians et al., 2002). The authors, however, hesitate in attributing the functional changes to their VR-based approach since it cannot be distinguished with certainty from the contribution of real world training. In a later study, eight chronic stroke patients intensively used this system (with an updated speed of movement task) in a three-week program (Merians, Poizner, Boian, Burdea, & Adamovich, 2006). As a group, the patients showed improvements, with retained gains, in the virtual reality measures and in the clinical evaluation measures (Jebsen Test of Hand Function (Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969) and reach to grasp test). Moreover the improvements were transferred to real world tasks. However, this study has the limitation that the patient group was not homogeneous, making it difficult to establish comparisons and make statements on the efficacy of the proposed method.

Video Capture Virtual Reality

Weiss and colleagues use video capture virtual reality, a technique that consists of tracking a user's movements and mapping them onto an image that is embedded in a virtual environment (Weiss, Rand, Katz, & Kizony, 2004). The users can see themselves within a virtual scenario in a mirror image view, as opposed to the first person point of view provided by head mounted displays. Therefore, users can have feedback about their body posture and quality of movement. Studies carried out to date suggest a positive impact on the recovery of functionality in stroke patients and several platforms have been used and compared. For instance, Weiss et al. (2004) modified the VividGroup's Gesture Xtreme VR (www.vividgroup.com; a platform formerly used for entertainment and education) in order to use it in neurological rehabilitation. In a preliminary usability study, its impact on the recovery of a stroke patient six months post-stroke was assessed (Kizony, Katz, & Weiss, 2003). In this case the proposed virtual tasks were: 1) touching virtual balls that emerge from different locations and fly towards the user; 2) being a goalkeeper in a soccer game, preventing balls from entering the goal area; and 3) being a snowboarder, skiing downhill and avoiding collisions with objects by leaning the whole body to the side. The system had good acceptance, and the patient was able to interact within the virtual scenarios without feeling side effects. Afterwards, a study was carried out with thirteen stroke patients (Kizony, Katz, & Weiss, 2004). After the tests the patients completed a questionnaire to assess their sense of presence, the perceived difficulty of the task, and their overall impressions during the tasks. Cognitive, motor and sensory measures were also taken. The questionnaires revealed that the patients enjoyed the virtual tasks, suggesting a positive contribution to the patient's motivation. Moreover, this study suggested that a relationship exists between the patients' personal characteristics and preferences and the properties of the virtual environment that influence performance. However, such questionnaires can (at best) be seen as a suggestion and not as an unbiased quantitative measure (Nisbett & Wilson, 1977).

Exoskeletons

More recently, VR systems have been augmented with advanced interface systems such as exoskeletons that allow arm gravity support. These systems have been combined with virtual reality scenarios for functional exercising of the upper limbs (Housman, Le, Rahman, Sanchez, & Reinkensmeyer, 2007; Montagner, Frisoli, Borelli, Procopio, Bergamasco, Carboncini, et al., 2007; Reinkensmeyer & Housman, 2007; Sanchez, Liu, Rao, Shah, Smith, Rahman, et al., 2006). One of these systems is the T-WREX, comprised of an orthosis that assists the movement of the arm in a broad range, a grip sensor for grasp training, and software to train functionality (Sanchez et al., 2006). Patients can train with different games related to activities of daily living with emphasis on the repetitive training of different ranges of movement and grips. For simplicity, two of the five degrees-of-freedom of the T-WREX are used for these tasks including: 'Shopping', 'Washing the Stove', 'Cracking Eggs', 'Washing the Arm', 'Eating', 'Making Lemonade' and 'Ranging the Arm'. The system was tested with five chronic stroke patients during two months in order to assess the effect of gravity balance on static positioning and the effect of gravity assisted movements in recovery (Sanchez et al., 2006).

After training, the movements of the patients were shown to be more effective when gravity balance was present, with an increase in the properties of reaching. The subjects also displayed improvements in their ability to move their arms, with some of them showing increased grip strength and augmented distance of reaching with and without support. In a later randomized controlled study, chronic stroke patients were divided in two groups: 11 patients were assigned to eight weeks of therapy with the T-WREX and 12 patients received only conventional therapy for the upper extremities and formed a control group (Housman et al., 2007). The group that used T-WREX showed significant improvements in their Fugl-Meyer scores when compared to the control group. Moreover, subjective questionnaires revealed a preference for the T-WREX when compared with standard therapy (Reinkensmeyer & Housman, 2007).

Montagner and colleagues are also working with an exoskeleton for rehabilitation of the arm following stroke (Montagner et al., 2007). The L-Exos is a five degree-of-freedom arm exoskeleton, therefore allowing for several joint configurations, and also supination and pronation of the wrist. Moreover, the L-Exos is a force feedback exoskeleton, allowing for the application of a controlled force to the palm of the user's hand. The virtual reality scenarios are composed of tasks that promote different movements: Reaching Task, where objects are to be reached at different positions; Constrained Motion Task, where the subject has to move along a circular trajectory while being constrained by an impedance control; and Manipulation Task, which consists of manipulating and arranging different configurations of cubes. In a pilot, three chronic stroke patients used the L-Exos in one-hour sessions, three times per week, during six weeks. After the study, patients presented improvements in the therapy-dependent measures, with a higher impact in reaching movements (Montagner et al., 2007). As in the case of the T-WREX, with the L-Exos user acceptance and satisfaction was also high. Although results to date are very promising, ongoing studies are needed in order to infer which properties of these systems are crucial for recovery.

Mental Practice

Mental practice techniques based on motor imagery have also been assisted by virtual reality systems to help generate and maintain images (Gaggioli, Meneghini, Morganti, Alcaniz, & Riva, 2006). Gaggioli and colleagues developed the VR Mirror, a system to guide mental practice in the rehabilitation of the upper limbs following hemiplegia due to stroke. The system consists of a table with a backprojected horizontal screen, a projector, a mirror and sensors for movement tracking. Basically, this system displays to the patient the previously recorded mirror movements of their non-paretic arm. The observed movement is used to support mental rehearsals of that movement, and to promote the movement of the impaired limb by following the mirror image. In a pilot, a chronic stroke patient used the VR Mirror during a period of four weeks, administered in three sessions per week.

The treatment focused on training the flexion and extension of the wrist, rotation of the forearm, and flexion and extension of the elbow. Mental practice always followed the observation of the virtual representation of the mirrored movements of the healthy arm. Moreover, after the four weeks of training the subject was provided with a portable device to allow training at home during an additional four weeks. Clinical evaluation measures included the Fugl-Meyer Assessment Test for the upper extremity and the Action Research Arm Test (Lyle, 1981). The patient showed an improvement on all these scores after the four weeks of training, followed by limited further improvement after the training at home. In addition, improvements in range of movement and grip strength were reported. The same system and training protocol was later used with nine chronic stroke patients during eight weeks (Gaggioli Meneghini, Pigatto, Pozzato, Greggio, Morganti, et al., 2007). Unfortunately, no significant improvements were observed in the Fugl- Meyer and Action Research Arm scores. However, some patients reported an improvement in the performance of activities of daily living.

Action Execution/ Observation

Verschure and colleagues develop their work based on the paradigm of action execution coupled with motor imagery and action observation (Cameirao, Bermudez i Badia, Zimmerli, Duarte Oller, & Verschure, 2007). Their underlying hypothesis is that functional recovery can be promoted by capitalizing on the life-long plasticity of the brain and the assumption that neuronal plasticity is governed by a few computational principles or objectives (Wyss, König, & Verschure, 2006). To exploit these principles the authors explore a system that combines movement execution with the observation of correlated action of virtual limbs that are displayed in a first-person perspective. The claim is that within such a scenario, recovery can be accelerated and enhanced by driving the mirror neuron system (Rizzolatti & Craighero, 2004). The mirror neuron system is seen as an interface between the neuronal substrates of visual perception and motor planning and execution. Hence, these neurons would allow for a direct pathway to drive the motor systems affected by stroke and in this way provide a task and context relevant state of the afferent and effer-

Figure 1. The Rehabilitation Gaming System (RGS) setup. The RGS constitutes a standard paradigm comprising all the key elements of any VR based cognitive-neurorehabilitation system. Motion capture is achieved through a video based system. The user wears color patches that are tracked by the motion capture system and that are mapped onto a virtual character through a biomechanical model. Data gloves provide finger flexion data. The screen displays a first person view of the gaming scenario in the virtual environment. The versatility of the used gaming technology (Torque, Garage Games, www.garagegames.com) allows the rapid development of new rehabilitation scenarios.

ent pathways that are disrupted by the lesion. In this way, the authors assume that two important objectives of rehabilitation can be achieved: *rescue* where healthy but functionally pathological tissue can be salvaged and protected combined with *recovery* of function through reacquisition. Following these premises, and as a means to evaluate the general predictions of this approach, the authors have developed the Rehabilitation Gaming System (RGS). In its first applications, the RGS has been used as a tool for the evaluation and rehabilitation of motor deficits of the upper extremities in stroke patients. The RGS consists of a vision-based motion tracking system, data gloves and a conventional LCD display (Figure 1). The tracking system detects color patches located on the wrists and elbows of the subjects; a biomechanical model of the upper body allows the reconstruction of the movements. These movements are mapped in real-time to the movements of a virtual character displayed in a first-person perspective. In addition, data gloves capture finger flexure, allowing for a realistic representation of the movements of the arm. The RGS as applied to upper extremity rehabilitation proceeds according to a structured multi-level rehabilitation process with graded difficulty and specificity: 'Hitting' to train range of movement and speed; 'Catching' to train finger flexure; and 'Grasping' to train grasp and release. In a first study RGS was used to investigate the transfer of performance and performance deficits between real and virtual tasks (Cameirao, Bermudez i Badia, Zimmerli et al., 2007) and the effect of different task conditions on stress and arousal measurements (Cameirao, Bermudez i Badia, Mayank, Guger, & Verschure, 2007). RGS is currently being used with acute stroke patients (within the first three weeks of stroke) in a controlled randomized study. The study includes three different therapy conditions: the RGS group and two control conditions. In the visual stimulus control condition the effect of the visual stimulus and the role of the mirror neuron system are removed. Here subjects perform similar motor tasks (as the ones promoted by the RGS), but in the absence of further visual stimulus. The task is performed on a table and includes object manipulation, placement and object grasping with increasing complexity (object drag, object grasp and drag, object grasp-displace-release). The second control group assesses the impact of computer use. The subjects allocated to this group perform non-specific games with the Nintendo Wii (Nintendo, Tokyo, Japan). Each subject follows a three month program, with three weekly sessions of 20 minutes.

The main inclusion criteria are: the patient (age<80 years) should suffer a first event stroke and is in the acute or subacute phase of stroke (<3 week post-stroke), display a severe deficit of the paretic arm in the absence of cognitive deficits. The evaluation of function of the subjects is performed at admittance (beginning of the program), at session 15 (approximately five weeks after the beginning of the study), month three (end of the program) and month six (follow-up). The evaluation scales include, among others, the FIM (Functional Independence Measure), the Motricity Index (Collin & Wade, 1990), the Fugl-Meyer Assessment Test for the upper extremity, and the CAHAI (Chedoke Arm and Hand Activity Inventory; Barreca, Gowland, Stratford, Huijbregts, Griffiths, Torresin, et al., 2004). To date, only one patient completed five weeks of training (15 sessions). This patient is using the RGS, and so far has displayed improvements in the evaluation measures, including an improvement of 35% in the FIM, 41% in the Motricity Index, 27% in the Fugl-Meyer Test, and 21% in the CAHAI. Moreover, this patient largely increased independence in the performance of activities of daily living. However, more data needs to be collected in order to fully assess the impact of the RGS training approach.

Other systems

Other systems explore the combination of different features within virtual environments. Rizzo and colleagues developed different scenarios that aim to assess and rehabilitate relevant perceptual-motor activities such as eye-hand coordination and range of motion (Rizzo, Cohen, Weiss, Kim, Yeh, Zali, et al., 2004). Some of these scenarios are applicable for persons with dysfunctions of the nervous system, such as stroke and brain injury. The systems are based on stereoscopic graphic scenarios where the user interacts with virtual stimuli within a full 360-degree space using a head mounted display. The environments promote reaching and targeting tasks, and allow analysis of body posture and body movement, as well as quantification of motor performance. The work of Stewart and collaborators takes a similar approach (Stewart, Yeh, Jung, Yoon, Whitford, Chen, et al., 2007). Their system encompasses four different virtual tasks for motor skill learning, namely: 'Reaching', to reach for objects; 'Ball Shooting', to reach and intercept a ball launched from a wall; 'Rotation', to train forearm pronation and supination; and 'Pinch' for precision grasp. In this case, the subject experiences a three dimensional view that is provided by shutter glasses. Magnetic trackers attached to the hand and objects are used for movement detection in the first three tasks; while for the 'Pinch' task, two coupled PHANToM devices (SensAble Technologies, Woburn, MA, United States) are used. As a feasibility test, two acute stroke patients with different impairment severity used the system during 12 sessions of 1-2 hours. Results showed that this system facilitates the control of practice intensity and difficulty based on the capabilities of movement of each subject and in this way provides for personalized training. Studies with larger populations are needed, however, to investigate the overall effect on recovery following stroke.

Subramanian et al. combine practice and feedback elements to achieve rehabilitation of the upper extremities (Subramanian, Knaut, Beaudoin, & Levin, 2007; Subramanian, Knaut, Beaudoin, McFadyen et al., 2007). A virtual elevator was created to train pointing movements. Repetitive reaching in different directions is promoted and feedback about motor performance is provided, supporting knowledge of performance and knowledge of results. The system is comprised of a head mounted display, a motion capture system and a data glove, and allows real-time integration of hand, arm and body movements. Comparisons were made between hemiplegic subjects performing real and virtual pointing tasks within this study. Preliminary results suggest that the training in the virtual environment leads to more consistent improvements in movement execution.

Conclusions

In the last decade, extraordinary improvements have been made regarding the development of virtual reality systems for motor neurorehabilitation. Several target populations have been considered, but within these stroke sufferers have received special attention, especially in the rehabilitation of the upper extremities. In the context of virtual reality applied to the rehabilitation of the arm, we reviewed some of the main systems that have been developed and describe their major findings. Different paradigms and therapy concepts have been used, which we grouped in different categories: learning by imitation, reinforced feedback, haptic feedback, augmented practice and repetition, video capture virtual reality, exoskeletons, mental practice, and action execution/observation. However, most of these virtual reality systems are built taking into account the knowledge of the mechanisms of recovery and the therapeutic context. We consider that this is a major step in motor rehabilitation that is also witnessed by the rapid development of this specific technology-based approach towards neuro-rehabilitation in the last few years. In particular, VR-based approaches allow us to shape the technology on the basis of a well-defined hypothesis on the mechanisms underlying recovery. Another improvement is the existence of a larger number of studies that include a relevant number of patients. In general, the patients that used virtual reality environments showed significant improvements in various aspects of performance, with an impact on the activities of daily living. Nevertheless, only a few studies used control groups and this is still an important methodological limitation if we want to assess the efficacy of virtual reality, or any other therapy, in rehabilitation.

In summary, the advantages of the use of virtual reality technologies are vast, and we believe that important developments will take place in the next few years that will establish this as a major breakthrough in the treatment of pathologies of the nervous system.

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VIRTUAL REALITY EXPOSURE FOR PHOBIAS: A CRITICAL REVIEW

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This article is a review of the literature on efficacy and outcome studies using *in virtuo* exposure treatments to treat specific phobias. Thirty-nine studies were examined for this review: 56% were case studies or small sample studies, 13% were studies using larger samples, but no control or comparison condition, 13% used a comparison group (waiting list, placebo), 8% used a comparative treatment condition (usually *in vivo* exposure) and 13% used both. The specific phobias that were treated in these studies were acrophobia, aviophobia, claustrophobia, arachnophobia and fear of driving. The majority of these studies demonstrated that *in virtuo* exposure is effective and constitutes an interesting alternative to *in vivo* exposure. However, as the area is still taking its first steps, more studies with stronger methodological validity (control and comparative treatment conditions) are needed.

Introduction

The DSM-IV-TR (American Psychiatric Association, 2000) defines a specific phobia as an unjustified, lasting and intense fear that occurs in the presence of or with the anticipation of an object or specific situation. Exposure to the phobogenic stimulus provokes an immediate and systematic anxious reaction that can take the form of a panic attack that is linked or facilitated by the situation.

The only empirically supported treatment for phobias is called exposure therapy (Antony & Barlow, 2002). Marshall (1985) defines exposure as "all procedures that confront an individual to a stimulus that generates an undesirable behavior or an undesired emotional response" (p.121). Empirical studies demonstrate that a treatment of three to five hours is sufficient to eliminate phobias, even in severe cases (Davey, 1997). Of course, there are many ways to confront a fear, namely exposure through imagination (*in imago*) or exposure in real-life situations (*in vivo*).

For several years, a new exposure option has been available. Indeed, virtual reality offers particularly interesting therapeutic potential in the treatment of phobias. It has been called virtual reality exposure, but Tisseau and Harrouet (2003) suggested and supported the new term "*in virtuo* exposure", which will be used in this document. *In virtuo* exposure relies on the same principles as *in imago* or *in vivo* exposure, namely, to help patients gradually face their fears, except that the stimuli used in therapy are computer-generated. It is very important to note that *in*

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virtuo exposure has not been developed as an attempt to surpass *in vivo*'s efficacy, but rather to offer a more flexible and useful alternative to it.

The aim of this article was to examine the efficacy and outcome studies that have been done on *in virtuo* exposure so far. Given that the majority of studies were done on specific phobias, the focus will remain on specific phobias. A brief overview of the available literature reviews targeting specific phobias will be presented, followed by an introductory overview of the basics of *in virtuo* exposure and by the critical review itself.
Among the review articles already available in the literature, two are general reviews of VR-related therapies (Gregg & Tarrier, 2007; Riva, 2005), two are meta-analyses on virtual reality exposure treatments and specific phobias (Parsons & Rizzo, 2007; Powers & Emmelkamp, 2007), and two are review articles about a variety of treatments for specific phobias (Choy, Fryer & Lipsitz, 2007; Grös & Antony, 2006). One of the general reviews concludes that the available literature does not support VR-related therapies' effectiveness (Gregg et al., 2007).

Unfortunately, the authors base their conclusions on the fact that VR-related therapies were not shown to be *more* effective than traditional therapies, whereas most, if not all, VR therapy-related studies aim to demonstrate its potential as an *alternative* treatment. In their meta-analysis, Parsons and Rizzo (2007) emphasized that *in virtuo* exposure seemed to produce a large decrease in anxiety after treatment across studies, and Powers and Emmelkamp (2007) reported that *in virtuo* exposure was not demonstrated as more effective than standard *in vivo* treatments, which is somewhat to be expected since VR is presented as an alternative way of delivering exposure rather than a significantly more effective approach. Choy and colleagues' comprehensive review (2007) commented on the short versus long-term effects of phobia treatments across phobia subtypes and concluded that treatments' efficacy varies greatly across subtypes. The originality of the current review is to specifically target *in virtuo* exposure for specific phobias and examine the studies in greater detail.

Virtual reality relies on the integration of real time computer-generated situations, of information about the individual's position in space, and of auditory and visual stimuli. This integration creates a computerized interactive environment that seems real to the observer. It aims to maximize the degree of realism in the environment. Therefore, virtual therapy exposes the individual to situations that are generated by a computer. With monitors installed in a helmet that looks like a pair of glasses, the individual experiences a virtual environment where he or she is gradually exposed to fear-provoking stimuli. The exposure techniques that are available, though resting on the same theoretical background (for a good description of the basics of exposure, see Antony & Barlow, 2002), differ on the advantages and disadvantages that they present to the clinician as well as to the patient.

Offering services for phobic disorders in general with virtual reality has a few disadvantages when compared to traditional exposure techniques for phobias (*in vivo* or *in imago*):

1) The use of new technology means that therapists have to acquire some skills to be able to manipulate the software and hardware at will in order to adapt to their patients' needs. Although those skills do not need to be extensive (e.g., skills in computer programming are not required; Virtual Reality (VR) environments can be bought or downloaded in a ready-to-use format), this can discourage clinicians from using this new technology, just as the use of software is not widely accepted among clinicians for session notes and evaluation reports (Bouchard, Côté & Richards, 2007).
2) Costs: VR headsets and peripheral devices can easily cost thousands of dollars. Whether such an expense is cost-effective will ultimately depend on the incremental treatment utility of VR interventions. However, on a more positive note, costs are likely to decrease significantly. For example, a good Head Mounted Display would have

cost almost $6,000 Canadian seven years ago, while currently it would cost only $1,100 Canadian in 2007. New and very powerful products are now being sold for even less. Nevertheless, using VR still involves some expense.

3) Cybersickness: it has been reported in the literature that immersion in VR can induce unpleasant side effects, such as nausea, dizziness or headache (see Lawson, Graeber, Mead & Muth, 2002). These authors concluded that about 5% of people immersed in a virtual environment might experience significant side effects; although they are generally mild and temporary, they are not present in other forms of exposure.

On the other hand, offering services for phobic disorders with virtual reality has many advantages when compared to traditional exposure techniques for phobias (*in vivo* or *in imago*):

1) The virtual environment allows the therapist to control unpredicted events that can occur in real environments (e.g., the elevator can be out of order, there could be turbulence in the plane, the traffic could be too intense). More importantly, VR allows the therapist to control the intensity of exposure as needed and adapt it even better to the patient's needs (e.g., create a wide range of storm intensities for storm phobias). In addition, the virtual environment allows the client to be exposed to certain fears that could be difficult or dangerous to reproduce in real situations (e.g., fear of flying).
2) Avoidance is the behavior that is the most common in phobic individuals. It also manifests itself in therapy during exposure. With virtual therapy, it is much more difficult for the client to avoid the phobic stimulus, as he or she is directly confronted by it under the supervision of the therapist. In addition, it is possible to repeat the anxiety-provoking situation as many times and as often as the patient wishes. VR allows the therapist to manage sessions according to the patient's own pace.
3) VR reduces the costs associated with traditional therapy (e.g., renting a plane, driving costs). Virtual therapy has the advantage that the client and the therapist remain in the therapy office, which also ensures confidentiality, an aspect of treatment that is often compromised during exposure in public places. In addition, many insurance com panies do not pay for therapy sessions of long duration, such as when exposure takes place outside of the office. This is not a problem in virtual therapy, as everything takes place in the therapist's office during less than an hour per week. Finally, in the case of a client suffering from a fear of animals or insects, virtual therapy does not require the maintenance of the exposure stimuli (e.g., concerns about hygiene, nutrition).
4) Social cost: it is well-known that anxiety disorders represent a high cost for Canadian society, in terms of missing school or work days, medical consultations, exams, medication, etc. (Koerner et al., 2004; Santé Canada, 1996). In addition, fear of flying is a pervasive problem associated with significant economic impact. Estimates are that up to a quarter of the flight population experiences anxiety when flying, and 20% of those with flight phobia utilize sedatives or alcohol to cope with flying (Greist & Greist, 1981). Therefore, fast and effective treatments are necessary.
5) Propensity to seek treatment: Garcia-Palacios, Hoffman, See, Tsai and Botella (2001), in a study with 162 people suffering from arachnophobia, found that 81% of the participants chose virtual exposure therapy over *in vivo* exposure therapy. When the research team conducted the same survey with 102 patients diagnosed with specific phobia, 70% of them chose *in virtuo* exposure (Garcia-Palacios, Botella, Hoffman, Villa & Fabregat, 2004). When asked whether they would refuse to go into therapy if one form of exposure or the other was used, 23.5% would have refused *in vivo* exposure, compared to 3% in the case of *in virtuo* exposure. Statistics suggest that only 15 to 20% of phobic people seek treatment; this new form of therapy could possibly attract more phobic people to treatment.

Some authors have argued that *in imago* exposure shares many of these advantages, notably the advantage of exposing clients to stimuli that are difficult to reproduce *in vivo* (Walters & Oakley, 2003), sometimes underlining that virtual reality's level of realism can also be achieved with hypnosis (Kraft & Kraft, 2004). All these authors mention that, as opposed to *in virtuo* exposure, *in imago* exposure does not require expensive hardware and software to be effective. Even if this difference might be an advantage for *in imago* exposure, one might wonder if aspects such as the clients' imagination abilities and levels of cognitive avoidance, although sometimes problematic in *in virtuo* exposure, might be a bigger problem with *in imago* exposure. After all, clients participating in *in imago* exposure have to create all aspects of the exposure stimuli by themselves, which is not the case with virtual reality. In addition, propensity to seek treatment might also differ for clients, when given the choice between the two techniques. One study did compare *in imago* desensitization with *in virtuo* exposure (Wiederhold, Gervirtz, & Spira, 2001). The authors randomly assigned 30 participants suffering from a fear of flying to either imagery desensitization treatment or virtual reality treatment with or without physiological feedback. Interestingly, although all participants reported a significant anxiety rise during exposure (which was supported by physiological data), only 20% of the participants in the imagery desensitization group flew after treatment, 80% of the participants in the *in virtuo* exposure without physiological feedback group did, and 100% of the *in virtuo* exposure group with physiological feedback flew after treatment.

Interestingly, what seems to be a common therapeutic tool in both *in imago* and *in virtuo* exposure is the feeling of presence. This phenomenon is defined as the subjective experience of "being there" that is felt in an environment, even if the individual is physically in another environment (Draper, Kaber & Usher, 1998; Witmer & Singer, 1998). Some conditions appear to be associated with the development of the feeling of presence: implication (the capacity to concentrate or to focus) and immersion tendency (the perception to be surrounded by the environment). According to Witmer and Singer (1998), these two conditions are necessary to experience the feeling of presence. Other elements such as the feeling of being in control, sensory factors, distraction and realism also appear to contribute to the feeling of presence. For a good review of available studies on the nature of presence, the results of presence, the measures of presence and the causes of presence, see Schuemie, van der Straaten, Krijn and van der Mast (2001).

Presence's role in therapeutic outcome is beginning to be documented. One study comparing 13 non-phobic to 13 phobic participants demonstrated that phobic participants feel a higher level of presence in virtual environments addressing their fear (Robillard, Bouchard, Fournier and Renaud, 2003). They compared participants' reactions in parts of environments that were considered "safe" by the participants (with low possibility of encountering fear-related cues) to parts of environments that were considered threatening. Robillard and colleagues' results suggest that low-cost game-derived virtual environments can induce anxiety in phobic participants. In addition, these environments can induce mid-range levels of anxiety that can be useful in therapy.

Group difference analyses between phobic and non-phobic participants showed that anxiety is associated with presence both before and after immersion in virtual environments. Before they were immersed, phobic participants showed a higher tendency to feel anxious and a greater tendency to experience presence in virtual environments (as measured by anxiety and presence questionnaires; see study for details). After their immersion, phobic participants reported a higher level of fear (verbal ratings) and of presence (verbal ratings and self-report questionnaire). The authors concluded that a high anxiety level is associated with a high level of presence. Further analyses revealed that anxiety during *in virtuo* exposure is the best predictor of the level of presence.

In their study on aviophobia, Price and Anderson (2007) found a significant and linear relationship between anxiety (measured during immersion) and presence. This relationship remained significant after controlling statistically for pre-treatment scores on measures of fear of flying. These results are congruent with other studies that measured the relationship between presence and emotion (Regenbrecht, Schubert & Friedman, 1998; Renaud, Bouchard & Proulx, 2002; Riva et al., 2007). Moreover, Bouchard, Robillard and Dumoulin (2006) used residualized change scores in multiple regression analyses and showed that age, immersive tendencies assessed at pre-treatment, and presence assessed regularly during therapy sessions significantly predicted treatment outcome on the Fear of Flying Questionnaire (Adj $R2 = .58$, $p < 0.001$) and the Questionnaires on Attitudes towards Flying (Adj $R2 = .61$, $p < 0.001$).

In virtuo exposure's efficacy

In virtuo exposure in the treatment of phobias is still evolving, and only a few studies are currently available to demonstrate its efficacy. A literature search was done with PsychInfo and Medline (key words: virtual reality and phobia) and from references included in scientific articles and books. Because the object of the present review was specific phobias, studies using *in virtuo* exposure for other disorders were eliminated. Similarly, studies that used exposure techniques that were non-immersive (e.g., computer-assisted modelling) were not considered virtual reality and were also eliminated. One study (Huang, Himle & Alessi, 2000) comparing one exposure session in *in vivo* versus *in virtuo* was eliminated because the study focused more on the virtual experience's intensity than on treatment *per se*. Therefore, the literature search traced 39 studies that are reported in Table 1. The information included in this table summarizes the basic methodological details of each study. The studies presented in the table will then be discussed in regard to their contribution to the field and the importance of their scientific validity. General comments will be made first, and then case and small sample studies will be discussed, followed by uncontrolled studies, comparison studies and controlled comparison studies.

The very first obvious conclusion to be drawn is that the field is still in its infancy. In general, studies have small samples and participants are generally in the same age range (e.g., studies with children and the elderly are very rare). Diagnosis criteria were generally not strict and the use of semi-structured interviews (such as the SCID-IV) is rare. Many studies do not have control groups, which makes efficacy conclusions more hazardous. The most commonly found type of *in virtuo* exposure equipment is the "Head Mounted Display system," which makes studies' equipment choice rather homogenous. Virtual environments were mainly created specifically for each study, although a few studies used lower cost resources, such as computer games, to create virtual environments that appeared to produce significant results all the same.

Indeed, it is interesting to note that Bouchard, Côté, Robillard, St-Jacques and Renaud (2006) used virtual environments that are different than those used by most studies published thus far. Instead of using original virtual environments, they used virtual environments that were created using 3D video games to treat 11 people suffering from arachnophobia in three sessions of *in virtuo* exposure. Results on self-report and objective outcome data revealed significant clinical and statistical improvement between pre-test and post-test results on a Behavioral Avoidance Test (BAT), on the Spider Beliefs Questionnaire (SBQ), and on perceived self-efficacy. Participants showed sufficient levels of presence in the virtual environments, as demonstrated by their subjective ratings of anxiety during exposure, which showed intra-session and inter-session habituation. These promising results suggest that therapy using *in virtuo* exposure via a modified computer game is useful in the treatment of specific phobias. This is supported by other studies (Bouchard, St-Jacques, Côté et al., 2003; Bouchard, St-Jacques, Robillard et al., 2003). The same type of virtual environment was used for *in virtuo* exposure with children (Bouchard, St-Jacques & Renaud, 2007) and also yielded clinically and statistically significant results.

The percentage of available case or small sample studies ($N < 10$) is 56%. A few studies produced unclear results, mainly because of their treatment protocol, which included other types of treatment used before *in virtuo* exposure

Table 1
Efficacy studies for the treatment of specific phobias using in virtuo exposure
Virtual reality efficacy studies for specific phobias

Authors and year	**Phobia**	**N**	**Type of VR**
Bouchard et al., 2003	Acrophobia	7	HMD
Bullinger, 2005	Acrophobia	213	HMD and CAVE-like HMD
Choi et al., 2001	Acrophobia	1	HMD
Emmelkamp et al., 2001	Acrophobia	10	HMD
Emmelkamp et al., 2002	Acrophobia	33	CAVE
Lamson, 1997	Acrophobia	32	HMD
Rothbaum et al., 1995	Acrophobia	1	HMD
Rothbaum et al., 1995	Acrophobia	20	HMD
Schuemie et al., 2000	Acrophobia	10	HMD
Bouchard et al., (submitted)	Arachnophobia	11	HMD
Carlin et al., 1997	Arachnophobia	1	HMD
Garcia-Palacios et al., 2002	Arachnophobia	23	HMD
Hoffman et al., 2003	Arachnophobia	8	HMD
Bouchard et al., (in preparation)	Arachnophobia	9	HMD
Botella et al., 1998	Claustrophobia	1	HMD
Botella et al., 1999	Claustrophobia	1	HMD
Botella et al., 2000	Claustrophobia	4	HMD
Bouchard et al., 2003	Claustrophobia	2	HMD
Wald et al., 2003	Fear of driving	1	HMD
Wald et al., 2003	Fear of driving	5	HMD
Walshe et al., 2003	Fear of driving following a motor vehicle accident	7	HMD and screen
Wiederhold et al., 2000	Fear of driving	3	HMD

Control group	Efficacy variables	VR effect	Comments
No	Questionnaires BAT	+	Uses modified 3D games 6 month follow-up still significant
Yes In vivo Waiting list	Questionnaires BAT Psychophysiology	+	VR environments are exact replicas of *in vivo* situations Both treatments superior to waiting list Results are maintained at six-month follow-up
No	Questionnaires SUDS Psychophysiology	+	The patient tried in vivo exposure before the end of the study
No	Questionnaires	+	The therapist controlled the VR VR sessions are followed by *in vivo* sessions
Yes *In vivo*	Questionnaires BAT	+	VR as efficacious as *in vivo* VR environments are exact replicas of in vivo situations Gains maintained at 6 month follow-up
No	BAT Clinical impressions	+	One-session treatment Results were maintained at three-month follow-up
No	Questionnaires BAT	+	Sessions were held twice weekly
Yes Waiting list	Questionnaires Clinical impressions	+	Some participants took the initiative to expose themselves *in vivo* between VR sessions
No	Questionnaires	+	The environments were evaluated by other participants in phase 1
No	Questionnaires BAT	+	Uses modified 3D games
No	Questionnaires Clinical impressions	+	A tactile dimension was added with a fur toy
Yes Waiting list	Questionnaire BAT Clinical impressions	+	Tactile dimension added by a virtual glove Unlimited number of sessions
Yes Waiting list	Questionnaires BAT	+	Used a toy spider to add a tactile dimension, which was associated with greater progress
No	Questionnaires BAT	+	Multiple baseline design with children
No	Questionnaires SUDS	+	Underwent her CT scan after the 6th session with low anxiety
No	Questionnaires BAT	+	Gains maintained at 3 month follow-up and generalized to other situations
No	Questionnaires BAT SUDS	+	Sample consisted of one claustrophobic and three people with panic disorder and agoraphobia
No	Questionnaires BAT	NS	Clinically significant change only Uses modified 3D games
No	SUDS Behavioral measure	+	Multiple baseline 3 sessions treatment 1, 3 and 7 month follow-up *In vivo* exposure for homework
No	Questionnaires SUDS Behavioral measure	+/NS	Improvement in 3/5 Ss Negligible change in driving frequency Some gains were lost at follow-up
No	Questionnaires SUDS Heart rate	+	Participants were chosen according to their immersion capacities (7/14) Use of modified 3D games
No	Questionnaires SUDS, Physiology	+	*In vivo* exposure was used between and some times during sessions

Authors and year	Phobia	N	Type of VR
Botella et al., 2004	Fear of flying	9	HMD
Kahan et al., 2000	Fear of flying	31	HMD
Klein, 1998	Fear of flying	1	HMD
Klein, 1999	Fear of flying	3	HMD
Klein, 2000	Fear of flying	1	HMD
Maltby et al., 2002	Fear of flying	45	HMD
Mühlberger et al., 2001	Fear of flying	30	HMD
Mühlberger et al., 2003	Fear of flying	45	HMD
North et al., 1997	Fear of flying	1	HMD
Rothbaum et al., 1996	Fear of flying	1	HMD
Rothbaum et al., 2000	Fear of flying	49	HMD
Rothbaum et al., 2002	Fear of flying	24	HMD
Rothbaum et al., (in press)	Fear of flying	75	HMD
Smith et al., 1999	Fear of flying	1	HMD
Wiederhold et al., 1998	Fear of flying	1	HMD
Wiederhold et al., 2001	Fear of flying	30	HMD
Wiederhold et al., 2003	Fear of flying	30	HMD

Note

VR type: *HMD = Head Mounted Display, Screen = Computer screen only, CAVE = C-Automated virtual environment*

Behavioral measure: *A recording of the occurrence of a behavior that the participants willingly decides to do or not, without a specific scale like for the BAT (e.g., booking a flight reservation and take that flight after treatment).*

VR effect: *A + indicates that VR therapy's impact was significant, NS indicates that the effect was non-significant*

Control group	Efficacy variables	VR effect	Comments
No	Questionnaires Behavioral measure	+	Multiple baseline design All participants flew after treatment Results maintained at 1-year follow-up
No	Questionnaires Behavioral measure	+	Confounding phobic comorbidity was accepted in the sample 68% flew after treatment 8 month follow-up participants flew, but with anxiety
No	Questionnaires SUDS Behavioral measure	+	Client flew with little anxiety after treatment
No	Questionnaires SUDS Behavioral measure	+	Anxiety decreased for all participants, 1 flew after treatment
No	SUDS Behavioral measure Clinical impressions	+	Client flew with little anxiety after treatment
Yes Placebo	Questionnaires BAT SUDS	+	Both groups showed significant improvement at post-test, but VR was superior at 6 month follow-up
Yes Placebo	Questionnaires BAT SUDS	+	Sessions are 180 mins. long (4 exposures) Test flight is in VR
Yes Cognitive treatment	Questionnaires Behavioral measure	+	VR exposure with or without motion simulation are equally significant A one session treatment can be effective (6 month follow-up) VR and cognitive condition did not differ on behavioral avoidance after treatment and on follow-up
No	Anecdotal reports Behavioral measure	+	Participant flew several times with little anxiety after treatment Exposure was done with a helicopter
No	Questionnaires Behavioral measure	+(?)	Specific impact of VR unclear; anxiety management techniques used before VR exposure produced therapeutic change
Yes *In vivo* and Waiting list	Questionnaires Clinical impressions Behavioral measure	+	VR is as effective as *in vivo*
Yes *In vivo* and Waiting list	Questionnaires Clinical impressions Behavioral measure	+	VR is still as effective as *in vivo* at 6 and 12 73% of VR participants reported using alcohol or drugs during a subsequent flight
Yes *In vivo* and Waiting list	Questionnaires Clinical impressions Behavioral measure	+	Replication of their previous study VR is still as effective as *in vivo* and differences from those two treatments are not significant
No	Questionnaires Clinical impressions	+(?)	Specific impact of VR unclear; anxiety management techniques used before VR exposure produced therapeutic change
No	SUDS Psychophysiology	+	Participant reported a decrease in subjective distress
Yes *In imago*	Psychophysiology BAT SUDS Questionnaires	+	20% of participants in *in imago* flew after treatment 80% of participants in VR exposure without physiological feedback flew after treatment 100% of participants in VR exposure with physiological feedback flew after treatment
Yes *In imago*	Questionnaires Psychophysiology Behavioral measure	+	3 year follow-up: Gains are the same in VR with physiological feedback and in imago groups; 2 participants in VR without physiological feedback group had lost their gains

(Rothbaum, Hodges, Watson, Kessler & Opdyke, 1996; Smith, Rothbaum & Hodges, 1999) or between *in virtuo* exposure sessions (Choi, Jang, Ku, Shin & Kim, 2001; Wald & Taylor, 2003; Wiederhold, Wiederhold, Jang & Kim, 2000). Other studies reported satisfying results, but mainly relied on subjective reports of anxiety (Botella, Osma, Garcia-Palacios, Quero & Banos, 2004; Botella et al., 1998; Carlin, Hoffman & Weghorst, 1997; Hoffman, Garcia-Palacios, Carlin & Botella-Arbona, 2003; Klein, 1998; Klein, 1999; North, North & Coble, 1997; Wiederhold, Gevirtz & Wiederhold, 1998) after treatment or during a test situation (e.g., a test flight for aviophobia). On the other hand, some studies relied principally on objective measures and reported a clinical and statistical difference after *in virtuo* exposure treatment (Botella, Villa, Banos, Perpiña & Garcia-Palacios, 1999; Bouchard et al., 2003), which was maintained at follow-up. Finally, only one study used a control condition (waiting list) and found a statistically significant difference between groups of patients suffering from arachnophobia (Hoffman et al., 2003).

Other studies used larger samples (N > 10), but had a control condition (Botella, Banos, Villa, Perpina & Garcia-Palacios, 2000; Bouchard et al., 2003; Bouchard et al., 2006; Emmelkamp, Bruynzeel, Drost & van der Mast, 2001; Kahan, Tanzer, Darvin & Borer, 2000; Lamson, 1996; Schuemie et al., 2000) and account for approximately 13% of available studies. All reported significant results after treatment, except for one study. In that study (Wald & Taylor, 2003), improvements were present, but only clinically (not statistically) significant and only for three participants out of five. Participants were evaluated on their *in vivo* driving frequency during treatment, which suggests that some *in vivo* exposure did take place during treatment, blurring the results about a possible specific impact of *in virtuo* exposure.

Another set of studies used comparison or control conditions, the most common being the waiting list (Garcia-Palacios, Hoffman, Carlin, Furness & Botella, 2002; Hoffman, Garcia-Palacios, Carlin & Botella-Arbona, 2003; Mühlberger, Wiedemann & Pauli, 2003; Rothbaum et al., 1995). These account for approximately 31% of available studies. All obtained significant results. For example, Garcia-Palacios and colleagues (2002) randomly assigned 23 participants to either an *in virtuo* exposure treatment with tactile feedback (provided by a virtual glove) or to a waiting list. Participants could receive an unlimited number of sessions, but the average treatment length was four sessions (of 60 minutes). In this study, outcome measures included self-reports, a BAT and severity ratings made by the therapist and an independent assessor. The *in virtuo* exposure treatment group showed improvement on all measures in a proportion of 83%, while the waiting list showed none. In addition, no patient dropped out of the study, which is seen by the authors as an encouraging sign that *in virtuo* exposure may increase chances that participants complete treatment.

One other interesting example of this type of study is that of Mühlberger and colleagues (2003) who assigned 45 people suffering from a fear of flying to either a cognitive treatment plus *in virtuo* exposure with motion simulation, a cognitive treatment with *in virtuo* exposure without motion simulation, a cognitive treatment alone or a waiting list with treatment offered later. Participants showed a significant statistical and clinical improvement after a one-session *in virtuo* treatment; results showed that the VR groups differed significantly from the cognitive-only and wait-list control groups on most measures of anxiety immediately after treatment and at six-month follow-up.

However, there were no significant group differences in rates of flying between groups at post-treatment and at six-month follow-up. Although somewhat surprising, the outcome results in the control condition (cognitive treatment) might be explained by results from Hunt, Fenton, Goldbert and Tran (2005) who showed that cognitive restructuring could be effective in the treatment of specific phobias. Those results were consistent with an earlier study by Mühlberger, Hermann, Wiedemann, Ellgring and Pauli (2001), who found greater reduction in subjective and physiological measures of anxiety for a group of participants suffering from the same phobia and who completed a virtual intervention than for participants who completed a relaxation training session. In that study, however, the difference between the two conditions remained statistically significant at three-month follow-up.

In the same vein, Hoffman and colleagues (2003) published another study, more specifically about the use of tactile augmentation in the *in virtuo* exposure treatment for arachnophobia. In their study, eight clinically arachnophobic students were randomly assigned to either a waiting list or three sessions of *in virtuo* exposure treatment with or without tactile cues. They were matched with 28 non-clinically phobic students, more specifically, students who scored one standard deviation above the mean on the Fear of Spiders Questionnaire (FSQ) (Szymanski & O'Donohue, 1995) but did not meet the DSM-IV-TR criteria for specific phobia (American Psychiatric Association, 2000). Authors reported that participants in the two *in virtuo* exposure groups showed a significant drop in behavioral avoidance and subjective anxiety, while the participants who did not receive treatment showed little or no drop in behavioral avoidance and subjective anxiety. However, participants in the *in virtuo* exposure group with tactile cues showed the greatest improvement. They also reported a higher level of presence in the virtual environments.

Four studies used either a placebo condition (Maltby, Kirsch, Mayers & Allen, 2002; Mühlberger et al., 2001), or an *in imago* condition (Wiederhold et al., 2001; Wiederhold & Wiederhold, 2003) for the treatment of aviophobia. Maltby and colleagues (2002) provided a group treatment about the mechanics of flying and the sharing of personal experiences with flights, while participants in the placebo condition in Mühlberger and colleagues' study (2001) received relaxation training.

All studies reported that participants who received *in virtuo* treatments showed more improvement on their phobia symptoms, which was maintained at follow-up. One particularity of the Maltby et al., (2002) study is that 65% of the *in virtuo* exposure group was able to complete a post-treatment flight at the six-month follow-up, but 57% of the placebo group completed it as well. Mean Subjective Units of Discomfort Scales (SUDS) ratings of in-flight anxiety did not differ between groups. Since the post-treatment flight was conducted using a small aircraft and accompanied by a therapist (albeit not the one treating the patients), some participants in the placebo condition might have felt confident enough to try the graduation flight at six-month follow-up. This successful behavioral experiment at post-treatment could also have a positive impact on their fear, explaining why statistical differences on questionnaires completed at post-treatment disappear at follow-up.

Until now, six studies have directly compared *in vivo* exposure's efficacy with *in virtuo* exposure. Gilroy, Kirkby, Daniels, Menzies and Montgomery (2000) treated 45 people suffering from arachnophobia with modeling exposure therapy with a computer (participants looked at a person interacting with spiders), *in vivo* therapy, or a placebo (relaxation therapy) and reported significant results in both treatment groups. However, this study used a non-immersive virtual environment (only a computer screen), which is not considered *in virtuo* exposure per se.

On the other hand, Emmelkamp and colleagues (2001) treated ten individuals suffering from acrophobia in a within-group design with two sessions of *in virtuo* exposure, followed by two sessions of *in vivo* exposure. *In virtuo* exposure was mostly controlled by the therapists who decided, based on SUDS and heart rate readings, when to increase exposure intensity. Assessment was made at pre-treatment, post *in virtuo* exposure and post *in vivo* exposure, with questionnaires assessing phobia symptoms, presence and general symptoms. Results showed that *in virtuo* exposure was at least as effective as *in vivo* exposure in decreasing anxiety and avoidance. Although its contribution was original, the limitations of this study are important. The authors did not balance the treatment groups, expecting a ceiling effect of *in vivo* exposure. In addition, they had a relatively small sample and did not use more objective outcome measures such as the BAT.

Fortunately, in a second study, the same team randomly assigned 33 participants suffering from acrophobia to either *in vivo* and *in virtuo* exposure treatment groups (Emmelkamp, Krijn, Hulsbosch, de Vries, Schuemie & Van der Mast, 2002). On an interesting note, the virtual environments were the exact replicas of the *in vivo* situations that were used for exposure.

The authors' results are congruent with those of Rothbaum, Hodges, Smith, Lee and Price (2000). Participants improved significantly on both self-report and objective measures of anxiety and avoidance (questionnaires and BAT). Moreover, they took special care to replicate, as exactly as possible, the *in vivo* situations in the virtual environments, in order to strengthen the comparative validity of their group design. Analyses revealed that *in virtuo* therapy was as efficient as traditional *in vivo* exposure. Participants' gains were maintained at 6 month follow-up.

Rothbaum and colleagues (2000) randomly assigned 49 participants suffering from fear of flying (aviophobia) to either a treatment condition with *in virtuo* exposure, to *in vivo* exposure or to a waiting list. Their results suggest that therapy with *in virtuo* exposure was as effective as therapy with *in vivo* exposure. Those two groups had an equivalent success rate on the BAT after treatment. At six month follow-up, 93% of participants in both *in virtuo* exposure and *in vivo* exposure groups had flown, either at their post-treatment flight or afterwards. In a second article reporting a 12-month follow-up, Rothbaum, Hodges, Anderson, Price and Smith (2002) reported that *in virtuo* exposure was still considered as effective as *in vivo* exposure. However, they reported a higher use of substances and alcohol during test flights for participants in the virtual reality group, which suggests caution in the interpretation of their efficacy results for this group.

In a replication and extension of their previous study, Rothbaum et al. (2006) reported on the results from a sample of 75 participants (25 completers per condition). With a new and larger sample than in their previous publications, they demonstrated once more that: (a) both traditional exposure and *in virtuo* exposure are superior to the waiting list and (b) the differences between the two active treatments are not significant, and effect sizes were extremely low. Once participants on the waiting list were reassigned to the experimental conditions and treated, the comparisons between the treatment involving *in virtuo* and *in vivo* exposure were conducted with 42 and 40 patients in each condition respectively, and both treatments were still found to be equally effective. Participants' gains were maintained at follow-up. For example, 71% and 76% of participants in the *in virtuo* and *in vivo* conditions respectively, did not meet the diagnostic criteria for specific aviophobia at six-month follow-up. Finally, there was no evidence of differences in anxiety during the post-treatment flight, as self-rated anxiety was rather low and similar in both treatment conditions. Wiederhold and Wiederhold (2003) reported even longer gains maintained at a three-year follow-up for fear of flying.

In the study with the largest sample so far, Bullinger (2005) recruited 213 adults suffering from acrophobia that were randomly assigned to *in virtuo* exposure (74 using HMD technology and 40 using a highly immersive system similar to a CAVE), to *in vivo* exposure (n = 52) or to a waiting list (n = 47). Participants received three sessions of exposure, completed questionnaires, and their physiological measures were recorded (heart rate, salivary cortisol, etc.). At six-month follow-up, participants performed a *BAT* in which they were invited to climb to the top of the bell tower of the Münster of Basel and look down. As was the case in the Emmelkamp et al. (2002) study, the virtual environment was a replica of the physical environment used for *in vivo* exposure. Results showed that *in virtuo* exposure was as effective as *in vivo* exposure, both of which were superior to the waiting list. There was no significant difference between the two technologies that were used to immerse the patients (HMD vs. CAVE).

Discussion

This review of the use of *in virtuo* exposure in the treatment of specific phobias examined 37 articles. The case studies that have been published so far tend to conclude that *in virtuo* exposure is a potentially efficacious treatment for various specific phobias. Unfortunately, these studies suffer from methodological limitations that render firm conclusions difficult. Larger sample studies also provide evidence of the general efficacy of *in virtuo* exposure. Most importantly, comparable findings were obtained in studies using control groups (placebo and/or waiting list) or comparison groups (*in vivo* or *in imago*), and the treatment gains were usually maintained at follow-up, even as long as after three years (Wiederhold & Wiederhold, 2003).

Clinicians considering using *in virtuo* exposure should take under advisement the following points: studies assessing *in virtuo* exposure efficacy in the treatment of specific phobias tend to demonstrate that it constitutes an interesting alternative to *in vivo* treatment, as it is at least equally efficacious and presents advantages that *in vivo* does not possess, as mentioned before; *in virtuo* exposure uses the cognitive-behavioral model and technique by gradually exposing patients to their fear following a pre-determined hierarchy in a flexible time frame until their anxiety decreases significantly and their avoidance behaviors subside. In sum, the therapeutic part of the treatment is the same, except for the exposure stimuli, which are computer-generated rather than "real." Therefore, the similarity between the two allows *in virtuo* exposure to be in continuity with a well-known and empirically supported therapeutic approach.

Clinicians using *in virtuo* exposure will wonder what parameters determine treatment success, as therapeutic stimuli differ. A common misconception about VR relates to the level of pictorial realism. Many virtual environments that are used in the studies described in this review look cartoonish, and none of the environments are an excellent replica of physical reality, but participants' subjective anxiety reached therapeutic levels all the same during treatment. Some studies reduced realism or graphic quality to a minimum and observed that their participants, although not even suffering from specific phobia, experienced anxiety all the same (Herbelin, Riquier, Vexo & Thalmann, 2002; Zimmons, 2005). These are only a few examples reminding us that emotions are not logical and that anxiety can be triggered by the simple perception of a threat, even if the stimuli are virtual, cartoonish and not dangerous.

Similarly, some researchers have tested the level of technical sophistication that is needed to achieve therapeutic success (e.g., adding tactile or auditory stimuli, using CAVE systems instead of HMDs). In the case of spider phobia, studies tend to suggest that the addition of tactile stimuli is useful in the treatment of spider phobia (Carlin, 1997; Garcia-Palacios et al., 2002; Hoffman et al., 2003). However, using a CAVE instead of an HMD does not seem to bring greater therapeutic success, even if it is associated with increased presence (Bullinger, 2005). Finally, adding motion simulation during exposure for people suffering from a fear of flying did not trigger greater therapeutic success either (Mühlberger et al., 2003).

In sum, clinicians considering VR as an option should choose it to palliate to the disadvantages of using *in vivo* exposure without having to change the structure or theoretical background of their interventions.
From a research point of view, uniformity in outcome measures is observed across studies. In general, participants show clinically and statistically significant improvement after *in virtuo* exposure treatment and maintain their gains at follow-up.

Richard and Lauterbach (2005) affirm that the conclusions coming from the existing controlled comparison studies are premature. They argue that the authors who compared *in virtuo* to *in vivo* misused the null hypothesis by assuming that failure to reject the null hypothesis is the same as determination of equivalence. For Richard and Lauterbach (2005), the null hypothesis simply cannot be used that way to support that kind of evidence. Secondly, they argue that these studies have sample sizes that are too small, which gives them insufficient power to detect significant treatment differences between the two techniques.

Therefore, evidence for an equal efficacy of *in vivo* and *in virtuo* exposure is still a work in progress. Nevertheless, the current studies' need for improvement should not make their contribution useless or non-significant, as studies on *in virtuo* exposure's specific contributions and advantages are not limited to its efficacy when compared to *in vivo*.

Additional studies, statistically and methodologically sounder, with larger sample sizes and, ideally, placebo treatment groups (e.g., relaxation training, attention-control treatment) are still needed to provide better empirical support in the comparison between *in virtuo* exposure and traditional *in vivo* exposure. However, the focus should not only be on that one goal.

One should always keep in mind that researchers did not develop *in virtuo* exposure in order to find an exposure treatment that would be better than *in vivo*; it was rather developed to address *in vivo*'s limitations, such as the need to use *in imago* exposure because anxiety-provoking stimuli are not accessible, or because of cost issues in some cases (e.g., renting a plane to treat aviophobia), etc. After all, *in vivo* exposure's efficaciousness had already accumulated a respectable amount of empirical support over the last decades, along with cognitive-behavioral techniques' rise in popularity and use. Researchers developed *in virtuo* exposure treatments to take advantage of the impressive technological progress that characterizes this time in history. This progress, among other things, has made it possible to address some of *in vivo* exposure's practical weaknesses. And the studies about *in virtuo* exposure do show that researchers have succeeded in that matter. With this in mind, it becomes easier to see the clinical and scientific potential of these studies. So far, tangible evidence is available about *in virtuo* exposure's impact on specific phobia symptoms.

Nevertheless, although studies have attempted so far to examine *in virtuo* exposure treatment's global efficacy, none has looked deeper into the process, at a micro-level. One could wonder why virtual environments are capable of producing fear per se, referring to the concept of presence. After all, participants are perfectly aware that the stimuli that are used during *in virtuo* exposure are all computer-based and not "physical reality-based." One could also go further and wonder why and how virtual environments are capable of producing a level of fear that has positive therapeutic impacts. After all, systematic desensitization has long been believed to be efficacious because of a possible pairing between relaxation and a feared situation or stimulus, when in fact, some studies highlighted that the active ingredient in systematic desensitization was its exposure component (Marks, 1984). Similarly, one could wonder if the observed efficacy for *in virtuo* exposure could be attributed to a conditioning effect (changes in information processing) or to an increased sense of competence (perceived self-efficacy).

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VIRTUAL REALITY IN THE TREATMENT OF PAIN*

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Many medical procedures produce acute pain that in most cases is quite disturbing for the individual. Medication is the treatment of choice for acute pain. However, given the involvement of psychological aspects in the experience of pain, psychological techniques are being used as an effective adjunct to alleviate pain related to medical procedures. In the last years a new technology is demonstrating an enormous potential in this field: Virtual Reality (VR) distraction. In this article we review studies that explore the efficacy of immersive VR distraction in reducing pain related to different medical procedures. We include clinical studies and analogue studies with healthy participants. We discuss the results achieved by these studies and recommend future directions of VR pain control research.

Introduction

Until recently in the history of medicine, pain was understood in terms of a simple connection between a pain stimulus and a hypothetical pain center in the brain. The intensity of pain was thought to be directly related to the magnitude of the tissue damage. The emotional, attentional, behavioral and cognitive aspects were thought to be mere reactions to the pain process.

The theory by Melzack and Wall (1965) constituted a revolution in the understanding of pain. They proposed the concept of modulation. From this perspective, a pain signal does not follow a fixed pathway from the pain receptor (e.g. in the skin) to the brain. The pain signal can be controlled, modified or inhibited on its way to the brain by messages coming from other sources in the brain. Higher order thought processes can change the way incoming pain signals are interpreted as they are processed by the brain, and can even change the intensity of incoming pain signals that make it into the brain (like a gate). According to Melzack and Wall, pain perception involves a balance of activity within the whole system. Pain involves the interaction of several neural networks, including parts of the nervous system involved in the sensory component of pain, but also parts involved in other processes like attention, emotion or memory. Psychological factors such as stress, depression and anxiety can alter the central and autonomic nervous systems and increase the amount of pain experienced. Other psychological factors like relaxation or distraction can diminish the experience of pain.

Melzack and Wall (1965) distinguished three main dimensions related to the experience of pain: a) Sensory-discriminative dimension, related to the mechanism that discriminates the sensory signals of pain; b) Motivational-affective

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dimension, related to the qualitative aspects of the pain experienced like anxiety, depression, suffering, aversiveness, etc., and c) Cognitive-evaluative dimension, related to past experiences related to pain, expectations, beliefs, etc.
In summary, pain is a complex and multidimensional construct that involves sensory, emotional and cognitive processes that can modulate the experience of pain. Melzack and Wall's model widened the understanding of pain, moving the field from a unidimensional view to a multidimensional framework, and opening the doors of pain research and pain management not only to medicine, but to many other disciplines, like psychology (Craig & Rollman, 1999).

From this perspective, psychological techniques like distraction, cognitive reappraisal, preliminary information, behavioral modification, and hypnosis have been used for pain control (Patterson, 1992). Distraction is one of the most commonly used techniques for acute pain control. Its use is based on the assumption that the amount of attention paid to pain stimuli modulates the perception of pain. Attentional resources are limited. If the individual can draw attention away from pain by focusing attention to other stimuli, the perception of pain diminishes. The role of attention in pain is being studied (i.e. Eccleston & Crombez, 1999). The characteristics of a good distractor include multiple sensory modalities, emotional involvement, and participation of the individual (Wismeijer & Vingerhoets, 2005). These features made researchers in the field pay attention to a new technology with a high potential as a good distractor: virtual reality (VR).

Immersive VR gives patients the illusion of "going into" a 3-D computer-generated environment. In this human-computer interaction, the user is no longer just an outsider watching a screen. They become active participants inside a three-dimensional virtual world. A number of factors contribute to the strength of the illusion of presence in a virtual world. The field-of-view or amount of peripheral vision permitted by the VR helmet or HMD and the clarity of what is seen helps, as do stereo visual images. Converging evidence from sounds and sometimes touch and taste, in synchrony with what the users see as they interact with the virtual world also helps strengthen the illusion of presence in the virtual world. Electromagnetic head position tracking can influence presence. When users move their heads up in the real world, what they see in the virtual world changes accordingly. The computer quickly updates the virtual environment presented to the user by changing the viewpoint in VR when the user moves his/her head. VR has the capacity to create many different and dynamic environments in the user's mind, where a very wide pattern of responses can be evoked.

Virtual reality pain control is a new psychological distraction technique that has recently been applied to acute pain. In the next section we summarize the studies exploring the utility of VR for acute pain control.

VR and acute pain control

In this review we will summarize the studies exploring the efficacy of VR for acute pain control in clinical populations. We will also review experimental studies with non-clinical populations. It is not our aim to conduct an exhaustive review. We will focus only in studies using immersive VR and not other similar techniques like non-immersive VR.

There are other reviews that we recommend (Wiederhold & Wiederhold, 2007; Wismeijer & Vingerhoets, 2005).
VR for acute pain has been studied mainly in two populations: burn patients and cancer patients. The pioneer work of the use of immersive VR distraction was published by Hoffman, Doctor, Patterson, Carrougher, and Furness, a research group from the University of Washington, in 2000. These authors presented two case reports providing the first evidence of the effectiveness of VR as a powerful adjunctive non-pharmalogical analgesic for acute pain in burn patients. They compared the analgesia of two distraction procedures, playing a video game vs. going into VR. The

patients were two adolescent males. One of them had a severe gasoline burn on 5% of his body and the second patient had deep flash burns on 33.5% of his body surface. They spent 3 minutes in VR and 3 minutes playing a video game while going through wound care. The order of administering the treatments was randomized and counterbalanced. The effectiveness was measured using subjective presence and pain ratings in 100-mm Visual Analogue Scales. Patients were asked to rate their Worst pain, Average pain, Anxiety, Unpleasantness, Bothersomeness, and Time spent thinking about their pain/burn wound during the relevant wound care. They were also asked to rate how much nausea (if any) they experienced while in each condition. They were asked to what extent they felt they went into the computer-generated environment and how real the objects in the virtual world seemed to them. The virtual world used was SpiderWorld. For the video game condition, Wave Race 64 and Mario Kart 64 Nintendo 64 games were used. Results showed that VR was more effective in reducing pain than the video game in both cases and in all measures of pain.

Since the publication of these case reports, the research team led by Drs. Hoffman and Patterson has conducted several studies to explore the efficacy of VR distraction in pain control related to medical procedures like wound care and physical therapy in burn patients. Hoffman, Patterson, and Carrougher (2000) explored the use of VR to distract patients from pain during physical therapy. Twelve patients performed physical therapy with no distraction for three minutes and physical therapy in VR for three minutes. All patients reported statistically significantly lower pain and less time thinking about pain when in VR, compared to no distraction. In these two studies, patients received only a single short VR session. One of the concerns of the researchers was that that the amount of pain reduction may diminish with repeated use of VR. The novelty of the virtual environment would decrease with repeated VR sessions.

In a case study (Hoffman, Patterson, Carrougher, Nakamura, Moore, Garcia-Palacios, & Furness, 2001) and a within subject design study (Hoffman, Patterson, Carrougher, & Sharar, 2001) this group explored whether immersive virtual reality continues to work when used more than once. In the second of these studies seven patients performed physical therapy while being immersed in SnowWorld, a virtual environment that depicts an icy 3-D virtual canyon with a river and waterfalls where the patients can shoot snowballs at snowmen and igloos. Each patient participated in the VR condition on at least three separate days. As before, they received VR for part of their physical therapy, and no distraction during another part. Condition order was randomized and counterbalanced. Pain ratings were statistically lower when patients were in VR, and the magnitude of VR pain reduction did not diminish with repeated use of VR. Although the small sample size is a limitation of this work, the results suggest that VR retains its analgesic properties with multiple treatments. This finding is encouraging for the wound care field, given the fact that burn patients usually need multiple wound care and physical therapy sessions during their recovery. Hoffman and Patterson's team has also designed specific devices for the delivery of VR for specific procedures. They developed a water-friendly HMD in order to apply VR distraction to burn patients who were going through wound care in a water tank (Hoffman, Patterson, & Magula et al., 2004).

Das, Grimmer, Sparnon, McRae, and Thomas (2005) used VR games in children with burn injuries, finding strong support for the use of VR distraction for acute pain in children. A recent paper by Chang, Chung, Wong, Lien and Yang (2007) exploring the use of VR for reducing pain during burn wound care in children in Taiwan found that VR reduced anxiety, suggesting that using VR before the children develop conditioned anxiety regarding pain during wound care would be a useful intervention in this field. In another study van Twillert, Bremer and Faber (2007) comparing VR to no distraction and to other distraction methods like television, did find significant reductions in pain but did not find significant reductions in anxiety ratings. Anticipatory anxiety regarding painful medical procedures is an area of research that could also benefit from VR interventions. More research is needed regarding this issue.

VR pain distraction has been used also in cancer patients in order to reduce pain and distress related to chemotherapy. Gershon, Zimand, Lemos, Rothbaum and Hodges (2003) showed promising findings using immersive VR distraction vs. non-VR distraction vs. no distraction in a 8-year old boy undergoing port access for chemotherapy. They used a virtual environment called Virtual Gorilla. Pain ratings given by the child, his parents and the nurse were lower in the VR condition. His heart rate also decreased in VR. These authors conducted another similar study with a larger sample, 59 cancer patients ranging in age from 7 to 19 years (Gershon, Zimand, Pickering, Rothbaum & Hodges, 2004). They randomly assigned the patients to three conditions, VR distraction, non-VR distraction and no distraction. The results showed lower pain ratings from the children and the nurses and lower pulse rates in the VR distraction condition.

Another interesting study is the one conducted by Schneider, Prince-Paul, Allen, Silverman and Talaba (2004). They randomly assigned 20 women suffering from cancer and going through chemotherapy to VR distraction vs. no distraction. VR significantly reduced chemotherapy symptom distress. Also, both the patients and the nurses were satisfied with VR. In a second study Schneider (2005) evaluated 123 participants in order to explore if the effects of VR lasted for a period of two days. 86% of the participants were satisfied with VR and 82% reported willingness to use it again. An interesting result was that the patients estimated the time of the chemotherapy session to be less than the actual time. However, there were no differences in symptom distress one or two days after the chemotherapy session. VR has also been used in pain control related to dental procedures. Hoffman, Garcia-Palacios, Patterson, Jensen, Furness, and Ammons (2001) reported the results of a study where two patients with periodontitis underwent periodontal scaling and root planing under three conditions: VR distraction, movie distraction, and no distraction. Condition order was randomized and counterbalanced. Both patients reported lower pain ratings in the VR distraction condition; they also reported higher presence in the VR distraction condition than in the movie condition. Wiederhold and Rizzo (2006) recently reported data from a study in which 10 patients undergoing different dental procedures reported less pain and discomfort while being in VR. They also reported physiological correlates of analgesia. As in the Schneider (2005) study, patients estimated the time of the dental procedure to be less than the actual time. Patients and dental staff reported a positive experience using the VR equipment and the use of VR did not cause a significant addition of time or interfere with the dental procedure.

There have been other studies exploring the use of VR distraction in different medical procedures. For example, Steele et al. (2003) applied VR distraction vs. no distraction to a 16-year old patient with cerebral palsy undergoing physical therapy after surgery. Pain ratings were lower in VR. In another study, Wright, Hoffman and Sweet (2005) found support to VR distraction analgesia during transurethral microwave thermotherapy in a case report. Murray et al. (2007) showed preliminary data of the utility of VR for reducing phantom limb pain in three cases. Gold, Kim, Kant, Joseph and Rizzo (2006) found encouraging results in decreasing pain and anxiety in twenty children undergoing IV placement for MRI/CT.

There are two interesting studies combining hypnosis and VR. Patterson, Tininenko, Schmidt, and Sharar (2004) used VR to induce hypnosis in a burn patient, achieving important reductions in pain during burn care. In a more recent study, Patterson, Wiechman, Jensen and Sharar (2006) showed reductions in pain and anxiety in thirteen patients undergoing burn care. These results showed that VR hypnosis could be a promising technique for acute pain control. We have reviewed clinical studies so far. Other works have been conducted with normal samples in order to advance the study of specific aspects of VR analgesia or the mechanism underlying VR analgesia. Hoffman, Garcia-Palacios, Kapa, Beecher and Sharar (2003) replicated VR analgesia in normal participants. Pain was induced via blood pressure cuff ischemia. Using a within subject design, participants reported high levels of analgesia when immersed in VR compared with no distraction. In this same experiment, participants went through a divided attention task while in VR. The results showed a reduction in accuracy in identifying pairs of odd numbers among random numbers when immersed in VR compared to being in the real world. These results support the idea that attentional distraction may be an important mechanism in VR analgesia. Hoffman, Sharar, Coda, Everett, Ciol, Richards, and Patterson (2004) also explored the relationship between VR analgesia and presence. This study found higher analgesia in a highly immersive VR condition compared to a less immersive VR condition (manipulating sound effects, quality of the images, and interaction). The sense of presence and analgesia was higher in the highly immersive VR condition. Magora, Cohen, Shochina and Dayan (2006) found that VR increased ischemic pain tolerance in 20 healthy volunteers. Mühlberger, Wieser, Kenntner-Mabiala, Pauli and Wiederhold (2007) conducted an interesting study exploring the effect of different virtual worlds in pain reduction. They induced pain with cold and warm stimuli and compared the reduction achieved by warm and cold virtual environments.

They also included a control condition in which the participants wore a HMD but they just saw a static picture. They found that VR was superior to the control condition, demonstrating that the distracting value of the VR environments was not achieved only by excluding perception of the real world. They also found that VR analgesia achieved by both virtual environments was similar, that is, the content of the VR environment was not important for reducing pain induced by cold or hot stimuli.

There is an important work in VR distraction literature conducted by Hoffman, Richards, Coda, Bills, Blough, Richards, and Sharar (2004). The study examines brain activity related to VR analgesia. Some of the clinical studies previously mentioned (Gershon et al., 2004; Wiederhold & Rizzo, 2006) found a reduction in physiological measures like pulse rate related to VR analgesia. Hoffman et al. induced pain by thermal stimulation to eight healthy participants and studied brain activity (fMRI) while the participants went through VR distraction vs. no distraction. As in other studies, pain ratings were significantly lower in the VR condition. Also, VR significantly reduced pain-related activity in five brain regions: insula, thalamus, anterior cingulated cortex, and primary and secondary somatosensory cortex.

This is the first study showing the analgesia-related brain activity of VR analgesia. In a recent work Hoffman et al. (2007) explored the efficacy of VR analgesia both alone and combined with opioids using self-report and fMRI. Nine healthy volunteers were randomly assigned to four conditions: control, opioids alone, VR alone, and VR plus opioids. The results indicated that both VR and opioids alone were effective in reducing pain perception and pain-related brain activity. However, the combination of VR and opioids produced the highest reduction in pain ratings. These results, though preliminary, support the idea of the potential of combining pharmacologic and nonpharmacologic procedures for acute pain control. The neurobiology of virtual pain analgesia has been discussed in a recent paper (Gold, Belmont & Thomas, 2007). These authors link the neurobiology of pain to VR pain control and suggest some areas of research to study the mechanisms of VR analgesia like exploring the role of endogenous opiodergic signaling during VR analgesia using an opioid receptor antagonist like naloxone. They also recommend studying different issues to enhance VR analgesia, like customizing the VR environments to match patient characteristics or exploring the role of interaction in the efficacy of VR for pain reduction.

We mentioned a case report using VR hypnosis. Patterson, Hoffman, Garcia-Palacios and Jensen (2006) conducted a study with 103 healthy volunteers to explore the efficacy of VR and hypnosis in acute pain control. Participants were assigned to posthypnotic suggestions vs. no posthypnotic suggestion, then pain was induced using thermal pain stimulation, and then they underwent VR distraction vs. non VR distraction. Results indicated that posthypnotic analgesia was mediated by hypnotizability whereas VR distraction was not. The analgesia achieved by hypnosis was specific for highly hypnotizable individuals while VR analgesia was effective independent of hypnotizability. For those with high hypnotizability, the combination of hypnosis and VR was the most effective condition. This study offers support for the possibility of combining different pain control procedures to enhance analgesia.

Conclusions and future directions

All of the studies reviewed in the former section show that VR distraction is a promising technique for acute pain control related to medical procedures. The findings indicated that perception of pain decreases significantly with VR as well as other variables related to pain like unpleasantness, discomfort, distress, or anxiety. It seems that VR distraction can be used in a large number of medical procedures like wound care, physical therapy, chemotherapy, dental procedures, etc. It is important to notice that in the clinical studies, reviewed side effects were not a problem. Most of the studies measured cybersickness and did not report high levels of nausea or other cybersickness symptoms. Also, VR procedures were well-accepted by both the patients and the medical staff.

The studies exploring VR analgesia and brain activity offer preliminary data of reduction in pain-related brain activity. In psychology we have a wide and lasting history of developing and validating subjective measures which are a way to measure treatment efficacy. However, VR analgesia is used mainly in medical settings for pain related to medical procedures. In medicine, the effects of treatments are measured with objective measures. It is important to conduct studies using both subjective and also objective measures for VR analgesia. This will strengthen the efficacy data and the acceptance of this technique by the medical community.

It is important to note the limitations of the research reviewed. Most of the studies conducted so far offer methodological limitations that suggest caution when drawing conclusions. It is necessary to conduct controlled studies with larger clinical samples to strengthen VR pain control research. The results to date are promising and come from different research teams. We have results from subjective and objective measures that show that VR is able to produce analgesia.

Future research should study mechanisms underlying the efficacy of VR. Attention seems to be the cognitive process involved in the efficacy of VR distraction. Experimental research in the role of attention in VR analgesia is needed. Other psychological aspects like individual differences in personality traits or the role of emotions like anxiety in the experience of pain could shed light on the understanding of VR analgesia and the development of VR environments. There are no indications about the features that a virtual environment needs to have to produce analgesia. There are already VR worlds that are demonstrating their efficacy. Studying the features of the VR worlds that already exist and doing research to explore the specific elements that produce analgesia would be helpful to the researchers in this area. Finally, there is an emerging line of research in VR pain control related to using this technology in the treatment of chronic pain. The literature in this field recommends a multidisciplinary and multidimensional approach in the treatment of chronic pain conditions (i.e. Morley, Eccleston & Williams, 1999). VR can help to enhance the efficacy of techniques used in multicomponent programs for chronic pain like relaxation, mindfulness, distraction or cognitive reappraisal. There are some studies supporting the idea that VR can be a useful tool in the management of chronic pain conditions like fibromyalgia (Garcia-Palacios et al., 2006; Wiederhold & Wiederhold, 2007). However, these studies have so far reported only very preliminary data.

VR is a technology with enormous potential in many areas related to mental and physical health. In recent years VR has appeared as a promising distraction technique for acute pain that is producing a growing library of scientific literature and is contributing to the alleviation of pain in many people who are suffering. In the near future we predict that the VR community will work to develop and test VR procedures for chronic pain, a complex area that constitutes an important and growing health problem which needs better treatments. The birth of *Journal of CyberTherapy & Rehabilitation* will constitute an important source of support for the stimulation and dissemination of this research.

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VIRTUAL REALITY APPLICATIONS FOR PATIENTS WITH SCHIZOPHRENIA

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Schizophrenia is a brain disorder that is characterized by disturbances in general cognition, such as abnormal expressions of emotion and ways of thinking, mental derangement, regression from reality, strange language or behavior, and delusion or illusion. Family-based interventions, cognitive behavioral therapy, symptom-focused interventions, and social skills training are required for schizophrenic patients to return to normal life. Virtual reality is a medium that can present social and emotional situations via effective human-computer interactions that provide more realistic stimuli than the pictures or movies that are used in existing psychiatric therapy. Using conventional cognitive-behavioral therapy, it is difficult to obtain objective measurements. In addition, it is difficult to provide emotional or social situations. Virtual reality techniques can computerize various parameters so that objective measurements are possible; they can also provide emotional or social situations. Recently, virtual reality techniques have been used in the psychiatric field for effective training and objective assessment, such as in cognitive-behavioral therapy, social skills training, and medication training. In this paper, we describe the potential applications of virtual reality for patients with schizophrenia. More interactive and effective applications for patients with schizophrenia will emerge as virtual reality techniques continue to evolve.

Introduction

Virtual reality (VR) is the technology that can be used to design and build various applications. This technology consists of human-computer interactions that are used to present multimodal information and sense the virtual world, as well as the hardware and software used to generate the virtual environment. It also includes the techniques and electromechanical systems used in telerobotics, which can be transferred to the design of VR systems, as well as communication networks that can be used to transform VR systems into shared virtual worlds (Stanney, 2002). Various interfaces are used such as head mounted display (HMD), cave automatic virtual environment (CAVE), and wide-degree screen (Tichon & Banks, 2006) so that the human user can realistically perceive the environment. Human-computer interactions consist of multimodal devices that are used to present information to VR users. Computer generation of VR requires very large physical memories, high-speed processors, high-bandwidth mass storage capacity, and high-speed interface ports for input/output devices (Durlach & Mavor, 1995).

VR technology has been actively used to treat several types of phobias and other psychiatric disorders, as well as for applications in industry and for entertainment. VR therapy is an innovative paradigm in psychotherapy. Conventional intervention methods, including family-based interventions, cognitive-behavioral therapy, symptom-focused interven-

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tions, social skills training, medication training, and vocational rehabilitation, are aimed at returning patients to normal life (Glynn, 2003; Lysaker, Bond, Davis, Bryson, & Bell, 2005); these methods still use simple stimuli such as pictures or movies.

Cognitive-behavioral therapy is better known for the treatment of depression; some of the earliest literature on this therapy pertains to the treatment of schizophrenia (Turkington, Kingdon, & Weiden, 2006). During the 1970s and 1980s, when interest in cognitive-behavioral therapy in the United States primarily focused on depression, case reports arising from the United Kingdom described successful outcomes using cognitive-behavioral therapy along with antipsychotic medications for the persistent symptoms of schizophrenia (Tarrier, Harwood, & Yussof, 1990; Chadwick & Lowe, 1990; Kingdon & Turkington, 1991; Milton, Patwa, & Hafner, 1978).

Moreover, social skills training helps patients with schizophrenia communicate their own personal emotions or express their desire to achieve success in their personal relationships. Social skills include receiving social information, processing the information, and sending a response (Smith, Bellack, & Liberman, 1996). However, in conventional cognitive-behavioral therapy and social skills training, there are certain problems associated with non-objective assessment arising from a discrepancy in a therapist's ability to assess a patient's condition or training effectiveness (Popescu, Burdea, & Trefftz, 2002). In addition, it is difficult to provide emotional, social, or practical situations in the same manner for each training or assessment session.

VR techniques can overcome these shortcomings by composing diverse social situations with various backgrounds in the virtual environment, and by providing objective assessments based on parameters from specific social situations. In addition, VR provides interactive dynamic simulation in social and emotional situations, unlike passively watching movies and most computer programs.

VR has potential utility in training patients with mental disorders, and the application of VR technology to schizophrenia is being actively pursued by our research group. We have successfully conducted pilot experiments on the use of VR technologies for assessing the characteristics of patients with schizophrenia including cognition (Ku et al., 2003; Kim et al., 2005), behaviors (Park et al., 2005; Ku et al., 2005; Ku et al., 2006; Han et al., 2006; Han et al., 2006), and emotions (Ku et al., 2005; Ku et al., 2005; Jang et al., 2005). In addition, using VR technologies, we have developed several tasks for communication, social interaction, social cue perception, social problem solving, and expression of emotions (Kim et al., 2005; Kim et al., 2006; Kim et al., 2006; Kim et al., 2006). Furthermore, the measurement of brain activities using functional magnetic resonance imaging (fMRI) (Lee et al., 2006; Park et al., 2006) has also been investigated.

In this paper, therefore, we introduce some of the research relating to VR applications for patients with schizophrenia, particularly regarding the development of virtual reality simulators for cognitive behavioral therapy, social skills training, and medication training.

Applications of Virtual Reality

Cognitive Assessment

Schizophrenia is a serious psychiatric illness that can involve massive disruptions in thinking, perception, memory, and behavior. In the treatment of schizophrenia, atypical antipsychotic medications have several advantages over conventional neuroleptic agents. The atypical antipsychotic medications induce fewer extrapyramidal side effects and are better able to ameliorate the cognitive deficits of individuals with schizophrenia (Green et al., 1997). One psychosocial approach that may prove effective in the long-term management of schizophrenia is cognitive-behavioral therapy. Cognitive-behavioral therapy for schizophrenia addresses the dysfunctional information processing of individuals with this disorder (Pinto et al., 1999). However, there have been few cognition studies concerning perception, memory, and rehabilitation.

Perception

Receiving skills (social perception) are necessary for attending to and accurately perceiving the relevant social information embedded in a situation. According to Bellack et al., receiving skills can be divided into “attention to the interpretation of relevant cues” and “emotion recognition.” These authors suggest that this combination of attention, analysis, and knowledge is generally considered “social perception.” Schizophrenics appear to have particular difficulty in this area (Bellack, Mueser, Gingerich, & Agresta, 1997). Effective social perception requires a person to detect a rapidly changing series of facial expressions, verbal content with shifting intonation, and subtle gestural and postural changes (Bellack et al., 1997). These social cues can be divided into verbal and nonverbal social signals (Toomey et al., 2002). Another aspect of social perception involves the accurate perception of emotions such as happiness, sadness, and anger. According to Bellack et al., data on the perception of emotion are inconsistent. However, schizophrenics appear to have specific deficits in their ability to perceive emotions, particularly negative emotions such as anger and sadness (Bellack, Blanchard, & Mueser, 1996).

The VR task devised by Kim et al., (2007) consisted of an Interpretation of the Relevant Cue (IRC) and Emotional Recognition (ER) elements. The IRC comprises nonverbal and verbal social cues, and the ER comprises a happy, a sad, and an angry situation. In nonverbal social cue perception, physical gesture and social situation were selected because they could be used as virtual “avatars” and in a virtual “context.” The VR contents for verbal social cues consisted of a basic verbal component (e.g., a suitable or unsuitable greeting, or a polite or rude expression). Happy, sad, or angry emotion recognition contents were designed for the emotion recognition components. During the presentation of ER contents, the patients must recognize the emotion by examining the avatar’s facial expression and context. In this study, Smith et al. (1996) examined the potential for VR in social perception. They attempted to determine if VR can be used to measure social perception, and to determine which VR parameters are related to schizophrenic symptoms. Some of these results have clear clinical relevance, while other observations need further study (Kim et al., 2007).

Memory

Traditional tests of visual and verbal memory have been used to evaluate memory deficits in schizophrenia. Kraepelin, Barclay, and Robertson (1919) were convinced that schizophrenia involves brain abnormalities and speculated that hallucinations and thought disorder were related to damage to the temporal lobes (Kraepelin, Barclay, & Robertson, 1919). Neuropsychological assessment of hippocampal function in patients with schizophrenia has traditionally been conducted with visual and verbal memory tasks related to temporal-lobe function (Hanlon et al., 2006). Investigators have described the neuropsychological impairment observed in schizophrenia as a “generalized deficit” (Blanchard & Neale, 1994). Nevertheless, specific cognitive abilities, such as attention, executive function, and memory have been found to contribute substantially to this generalized deficit (Goldman, Axelrod, & Taylor, 1996). The studies of Saykin et al. have demonstrated particularly large memory impairments related to attention and executive function in unmedicated patients with schizophrenia (Saykin et al., 1991; Saykin et al., 1994). They determined that impaired visual and, particularly, verbal learning and memory distinguished patients from normal controls better than other neuropsychological variables, and they related these deficits to those found after temporal-hippocampal damage.

In the traditional hidden-platform version of the Morris water task (MWT), the platform is submerged just below the water surface in a large circular pool of opaque water, and a rat is released from one of the four cardinal compass points (Morris, 1981). The rat must learn to escape from the water by locating this hidden platform. Virtual navigation tasks consisting of a computer-generated display of a virtual MWT (VMWT) (Astur, Ortiz, & Sutherland, 1998; Chamizo, Aznar-Casanova, & Artigas, 2003; Hamilton, Driscoll, & Sutherland, 2002; Hamilton & Sutherland, 1999; Moffat & Resnick, 2002; Sandstrom, Kaufman, & Huettel, 1998) and a computer-generated circular arena (Jacobs, Laurance, & Thomas, 1997; Jacobs, Thomas, Laurance, & Nadel, 1998; Thomas, Hsu, Laurance, Nadel, & Jacobs, 2001) have been developed for human testing. When performing the species-relevant MWT, rats and humans with hippocampal damage are unable to use spatial cues in the environment to locate a hidden platform (allocentric spatial ability) as controls do (Astur, Taylor, Mamelak, Philpott, & Sutherland, 2002; Morris, Garrud, Rawlins, & O'Keefe, 1982; Sutherland, Kolb, & Whishaw, 1982; Sutherland, Whishaw, & Kolb, 1983). If the hidden platform is removed after training during a probe trial, the normal human and rat will persist in searching where the platform had been located (Hamilton & Sutherland, 1999; Astur et al., 2002; Morris, 1981), indicating that they had learned the spatial location of the hidden platform. In contrast, rats and humans with hippocampal damage do not exhibit a preference for a particular area of the pool during a probe trial, signifying that they have not learned the location of the platform, thus exhibiting an allocentric spatial deficit.

In the virtual MWT, human subjects navigate a computer-generated on-screen environment in order to escape from the “water” by locating a platform. Patients with schizophrenia and controls performed two versions of the virtual MWT: a hippocampal-dependent, hidden-platform version, relying on allocentric navigational abilities, and a non-hippocampal-dependent, visible-platform version, relying on cued-navigational abilities. Schizophrenic patients traveled further and took longer to find the hidden platform over training blocks and spent less time in the correct quadrant during a probe trial. There was no deficit in the visible-platform condition. These findings identified a behavioral impairment in schizophrenics assigned a hippocampal-dependent task and support using the MWT in testing animal models of schizophrenia (Hanlon et al., 2006).

In other studies on human memory, computer navigation through a virtual maze is used for working memory (Sorkin, Weinshall, Modai, & Peled, 2006). The simulated journey consisted of a series of rooms, each of which included three doors. Each door was characterized by three features (color, shape, and sound), and a single combination of features–the door-opening rule–was correct. Participants had to learn the rule and use it. This experiment concentrated on working memory; some of the measured variables showed significant correlations with standard measures of schizophrenia (based on personal interviews), leading us to hope that similar tests may be able to replace subjective interviews in future diagnosis of the disease.

Cognitive Rehabilitation

Patients with schizophrenia undergo cognitive rehabilitation that is required for treatment involving the use of medication. The use of VR applications in different fields of activity has experienced an increase in growth over recent years. The virtual environments based on this sophisticated technology have been tested in the clinical treatment of people with different mental health disorders (Costa & de Carvalho, 2004). Advances in this area could enhance the understanding and study of the human cognitive process (Pantelidis, 2007).

According to Jeste et al. (1996) and Silverstein, Schenkel, Valone, and Nuernberger (1998) the most consistently replicated deficits in schizophrenic patients have been observed in tasks measuring attention/information processing, learning/memory, and executive functions. Costa and de Carvalho (2004) examined how patients accept the technology and presented the development of an “Integrated Virtual Environment for Cognitive Rehabilitation” (Ambiente Virtual Integrado para Reabilitação Cognitiva, AVIRC) that has an associate cognitive and development model.

AVIRC presents a unified workspace: a city. It focuses on the cognitive processes of training, such as attention and concentration, and functional skills training, such as executive functioning in everyday life. AVIRC is composed of a square surrounded by streets and several types of constructions–houses, stores, a library, a church, small buildings and a supermarket–that can be freely visited by patients. This study presented a virtual environment development process–supported by a cognitive model based on an information processing model of human cognition–for the cognitive rehabilitation of patients with different types of mental health disorders.

Behavioral Characteristics

VR has the potential to provide a realistic three-dimensional world generated by computer graphics with which the user can interact, so that he or she can navigate within and manage the virtual world and obtain computerized objective scores. Moreover, technological advances have recently been made in avatars that enable computer-generated entities to mimic both the appearance and behavior of humans.

Several studies have been conducted in which human behavior characteristics in response to a virtual avatar (or a social situation populated with several avatars) were investigated (Bailenson, Blascovich, Beall, & Loomis, 2002; Blascovich et al., 2002). These studies support the idea that, in a virtual environment, an avatar could be a powerful tool to investigate human behavior in an interpersonal or social relationship (Blascovich et al., 2002).

Interpersonal Distance

Patients with schizophrenia have a negative effect on their partners in interpersonal or social interactions, and they suffer when living with others. Therefore, investigating the interpersonal behavioral characteristics of patients with schizophrenia is necessary in order to understand and treat them. However, there are few objective methods for assessing patients' interpersonal behavioral characteristics in a social setting.

Ku et al. (2006) developed a method for assessing the interpersonal behavioral characteristics of patients with schizophrenia using VR technology. This study examined whether a virtual avatar could be perceived as a real human by patients with mental disease, particularly schizophrenia, as well as whether a virtual avatar could be applied to acquiring patients' behavioral characteristics in a short conversation situation. A virtual avatar, standing in a virtual room, was designed for this study. A task to approach, initiate a conversation, and answer the avatar's questions was assigned to the schizophrenic patients.

This study provided evidence that the patients behave as if the virtual avatar is really standing in front of them and talks to them. This finding is supported by the observation that patients' behavior toward a virtual avatar varied depending upon their symptoms and that this behavior is the same as that displayed toward a real person. This suggests that applying a VR technique to the schizophrenic patients is possible and that an avatar in a virtual environment could be used for interacting with patients with schizophrenia (Ku et al., 2006).

Head Gaze (Eye Gaze)

Patients with schizophrenia exhibit less eye contact during their interactions with others. That patients with schizophrenia exhibit less eye contact could be coincidental with the fact that these patients apply suppression or defense mechanisms because they have negative perceptions that give rise to a feeling of uneasiness, and also that they have an anxiety disorder that is characterized by a fear of negative evaluation in social situations (Kaye, Lea, Craig, & Evian, 2003).

Expression training is one of the cognitive-behavioral therapies used for patients with schizophrenia, autism, and other mental diseases. Some psychopathic patients have a deficit in expression that needs to be improved before they can return to normal life. In general, expression training is used to help psychopathic patients attain their goals in interpersonal relationships. According to a study on the components of assertive behavior by Eisler, Miller, and Hersen (1973), two components can be used to measure these characteristics: nonverbal behavior (duration of looking and smiling) and speech characteristics (duration of reply, latency of response, loudness of speech, and fluency of speech). In addition, the duration of looking is also considered one of the most important components of expression (Aronov, 1981).

Using VR, Han et al. (2007) developed expression characteristics in emotional situations. The VR tasks were composed of positive and negative situations. These contained various situations involving family, friends, and coworkers in various environments, such as at home, at a café, at a bakery, and in the street. The system measured head gaze using a head-mounted display and tracker.

People tend to have more eye contact in order to reduce stress during social interaction under negative and stressful situations. One of the most striking observations in clinical studies of social phobia is the avoidance of eye contact in social interactions, which may be a consequence of the fear of negative evaluation in social interaction (Greist, 1995; Marks, 1969; Ohman, 1986).

Social Skills Training

Schizophrenia is a brain disorder that is characterized by disturbances in general cognition such as abnormal expressions of emotion and ways of thinking, mental derangement, regression from reality, strange language or behavior, and delusion or illusion (Lee, et al., 1998). Moreover, schizophrenia is disease that represents a great social burden; it is a disease that strikes in adolescence, has a low complete recovery rate, and is a handicap in daily life or personal relations even in those who are treated. Family-based interventions, cognitive therapy, symptom-focused interventions, social skills training, and vocational rehabilitation are required for schizophrenic patients to return to normal life (Glynn, 2003).

From among these, Social Skills Training (SST) helps schizophrenic patients to communicate their personal emotions or their desire to achieve success in personal relationships. Social skills training is a process that involves receiving social information (Social Perception), processing the information (Social Problem Solving), and sending a response (Assertiveness) (Smith, et al., 1996).

Social skills training is vital for patients with schizophrenia and other mental conditions as these conditions are governed by negative symptoms, leading to incongruent behavior and emotions, along with unreasonable thinking. Typical approaches to social skills training are based on social learning theory (Bahn, 2001). Many therapists add role-playing to training programs designed to develop social skills. However, there are also certain problems with regard to nonobjective assessment in conventional social skills training due to the dependence on the therapist’s ability to assess a patient’s state, or in conducting social skills training effectively (Popescu, Burdea, & Trefftz, 2002). In addition, conventional methods are limited by time and space.

VR techniques can overcome the shortcomings of conventional studies by providing a method that can deliver exact and objective measurements. These techniques can provide emotional and social situations in interpersonal relationships using dynamic interactions with avatars. VR is the latest technique that can provide an immersive environment, a presence using three-dimensional rendering, and interpersonal parameters. Moreover, VR can provide a standard method that is based on computerized parameters to perform an assessment objectively. Virtual reality can also provide a safe experimental environment, and can overcome time and space limitations in conducting training or assessing tasks. VR techniques have the advantage of providing emotional and social stimuli.

Conversation Skills Training

In a study examining social skills training, Ku et al. (2007) proposed a conversation skills training system as implemented by the developed VR technique. This system contains a conversational scenario based on the theory of social skills training. Patients evaluated this program positively after the clinical experiment had been conducted. The overall positive reports indicated that schizophrenic patients underwent the virtual conversation program without problems and that the virtual conversation situations populated by virtual avatars could be presented effectively to patients with schizophrenia. These findings support the notion that a VR-based conversational training system could be used for conventional social skills training.

Social Problem Solving

The D`Zurilla and Goldfried social problem-solving model is comprised of the following five processes: define the problem, generate alternative solutions, choose the best solution, make a plan and execute it, and evaluate the outcome (Smith, 1996). Most of the current social problem-solving ability training for schizophrenics in psychiatric wards is based on the D'Zurilla and Goldfried social problem-solving model. One type of training is performed using video recordings. After showing the video recording, the patient is asked a set of questions relating to each social problem situation. The rater, who is a therapist, then assesses the patients' social problem-solving abilities.

Smith et al. (1996) developed a social problem-solving training and objective assessment system using VR based on the D`Zurilla and Goldfried model. Participants confronted with a social problem situation were asked to resolve the problem based on information derived from a VR system that was developed. Using this social problem-solving system, the authors demonstrated that social problem situations can be contained in a virtual environment and can thereby be utilized for social problem-solving ability training and assessment

Assertiveness (Emotional Expression) Skills Training

Emotional expression is the expression of one's feelings toward another person; such expression is necessary for establishing and managing relationships with other people. According to Wolpe (1958) and Wolpe and Lazarus (1968), assertiveness is defined as "one's suitable emotion expression without anxiety from another person" and assertiveness is not only "one's right of demand" but also "another person's right of protection." According to Fensterheim and Baer (1975), assertiveness is defined as "action what informing one's sort of man," "action what doing as feeling or thinking", and "action what positive approaching in one's life than passive approaching."

That is to say, emotional expression is directly and frankly expressing to another person one's feelings, rights, desires, and thoughts in an interpersonal relationship while respecting the other person's opinions or thoughts without impinging upon that person's authority. Effective emotional expression is necessary so that people can establish positive personal relationships and decrease or avoid tension. Emotional expression is one of the basic abilities individuals require to live a normal daily life. Further, emotional expression is necessary to establish and manage relationships with other people. Therefore, social skills are one of the important abilities required to maintain a self-supporting life.

Han et al. (2007) developed an emotional expression skill measurement system using VR for the objective measurement of emotional expression characteristics and provided emotional, social, and conversational situations. In this sys-

tem, VR tasks consist of positive and negative situations in various places with various avatars.
Moreover, participants could express their opinions, thoughts, and emotions during conversation with a virtual avatar in a given emotional situation. These authors identified emotional expression characteristic differences in positive and negative situations. Moreover, the emotional expression characteristics of normal control subjects and patients with schizophrenia were also compared. It was suggested that the developed VR system could offer controllable emotional, social, and conversational situations, and that the parameters from the VR system indicate emotional expression characteristics.

Medication Training

As many as 70% of schizophrenic patients have neurocognitive deficits (Palmer, Heaton, Kuck, & Braff, 1997), and some recent estimates suggest that the majority of patients with schizophrenia are noncompliant with regard to their antipsychotic medication (Lieberman et al., 2005). One area of instrumental role function in patients with schizophrenia that has received increasing attention in recent years is medication management abilities. This interest has been stimulated by both the importance of optimal pharmacotherapy for the management of symptoms and the frequency with which patients fail to adhere to their prescribed medication regimens.

Estimates from the extant literature suggest that oral antipsychotic medication adherence rates in patients with psychotic disorders range widely, with the divergent findings being related to the method used for assessing adherence and the sample characteristics (Fenton, Blyler, & Heinssen, 1997). Poor medication adherence leads to an increased frequency of relapse, emergency room visits, and re-hospitalization (Moore, Sellwood, & Stirling, 2000; Weiden & Olfson, 1995).

Patterson et al. (2002) validated a performance-based tool for the medication management of patients with schizophrenia. In this study, patients with schizophrenia and healthy controls completed a performance-based assessment of medication management, the Medication Management Ability Assessment (MMAA), as well as a variety of clinical scales. While the MMAA includes a variety of elements crucial to a more ecologically valid assessment of medication management skills in schizophrenic patients, including a delay between the presentation of the medication regimen and the time to take medications, and the availability of medication labels to help patients sequence their medication regimen correctly, it does not simulate the variety of environmental distractions or environmental prosthetics (e.g., written notes or the use of a clock) in a patient's natural environment that may influence adherence.

Recently, a VR performance-based instrument for the assessment of medication management skills in patients with schizophrenia, called the Virtual Reality Apartment Medication Management Assessment (VRAMMA) was developed (Baker, Kurtz, & Astur, 2006; Kurtz, Baker, Pearlson, & Astur, 2007). This instrument consists of a mock medication regimen and an apartment that the participant must navigate in order to take the appropriate type and dosage of medication at the appropriate time. The advantages of a VR instrument relative to interview-based and paper-and-pencil assessments of medication management skills are that, (1) it dynamically engages a broad range of neurocognitive functions via a complex multimodal environment that more closely approximates how neurocognitive skills are utilized in a patient's natural environment, including common environmental distractions; that (2) in so doing, it may provide a closer estimate of the actual community performance of medication management skills than that provided by clinic-administered capacity measures of such skills; and that (3) it allows for careful measurement of how performance of this medication management task may break down by quantifying patterns of behavior within the virtual apartment.

VR technology, as the present study clearly demonstrates, may thus be used effectively for the assessment of both neurocognitive and instrumental role functioning skills in patients with schizophrenia.

Conclusion

In this paper various VR applications for patients with schizophrenia are presented–cognitive-behavioral assessment, social skills training, and medication training. The systems designed in the studies described can overcome the difficulties associated with conventional methods by providing a sufficient variety of social and emotional situations for objective assessment or training. The application of VR could lead to better results than those obtained using pictures or videos in cognitive-behavioral therapy and social skills training because VR can provide more realistic social and emotional situations. In addition, VR techniques can computerize various parameters so that objective measurements are possible. Moreover, these techniques can overcome the limitations associated with existing methods such as objective measurement, time and space limitations, and sufficiently realistic social and emotional situations. The VR systems developed in these studies provide immersive reality, dynamic interaction, social and emotional situations, and interpersonal parameters. Furthermore, the presented parameters indicate the cognitive and behavioral characteristics of patients with schizophrenia. VR has many potential applications for patients with schizophrenia. Many ongoing studies are currently investigating the correlation between brain mechanism and cognitive processes and symptom diagnosis or education. Yellowlees and Cook (2006), for example, have looked at hallucination from an educational perspective using an internet virtual reality system (second life). More interactive and effective applications for patients with schizophrenia will no doubt emerge, including the use of haptic devices, networks, portable devices, and motion capture, as VR technologies continue to evolve.

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CYBERFOCUS

New technologies are developing at a rapid pace. To help you stay abreast of the latest trends in advanced technologies and healthcare, this feature showcases upcoming events which will provide you with the opportunity to connect with leading experts worldwide and remain on the cutting edge of the most recent developments.

The CyberFocus column welcomes your contributions. To supply relevant information for this feature, please send an e-mail to: office@vrphobia.eu.

CyberTherapy 13
June 22–June 25, 2008
San Diego, California, USA
www.interactivemediainstitute.com

The Journal of CyberTherapy & Rehabilitation is the official journal of the CyberTherapy Conference. The 13th Annual International CyberTherapy Conference (CT13) brings together researchers, clinicians, policy makers and funding agencies to share and discuss advancements in the growing discipline of CyberTherapy & Rehabilitation, which includes training, education, prevention, rehabilitation, and therapy. The Conference acknowledges the transformative effect that technology has had and will have on the healthcare field. Technologies featured at the conference include VR simulations, videogames, telehealth, the Internet, robotics, brain-computer interfaces, and non-invasive physiological monitoring devices. Conference attendees have the opportunity to play a role in designing the future of mental healthcare. Interactive exhibits at the Cyberarium allow participants to experience the technologies firsthand.

The 4th International Conference On Technology, Knowledge And Society
January 18-20, 2008
Northeastern University, Boston, USA
www.Technology-Conference.com

The Technology Conference is held annually and examines the nature of new technologies, their connection with the community, their use as tools for learning, and their place in a ‘knowledge society’. The perspectives range from big picture analyses that address global and universal concerns, to detailed case studies that speak of localized social applications of technology. Main speakers of the conference include some of the leading thinkers in these areas, as well as numerous paper, colloquium and workshop presentations.

Australasian User Interface Conference 2008
January 22-25, 2008
Wollongong, Australia
www.se.auckland.ac.nz/conferences/auic2008/

The Australasian User Interface Conference is part of the Australasian Computer Science Week. It is a technology-focused forum for user interface researchers and practitioners from Australia and New Zealand and throughout the world, which provides an opportunity for workers in the areas of HCI, CSCW, and pervasive computing to meet with other experts in the broader computer science community.

Stereoscopic Displays and Applications XIX
January 28-30, 2008
San Jose Convention Center, San Jose, California USA
www.stereoscopic.org/2008/register.html

Stereoscopic Displays and Applications is a part of IS&T/SPIE's International Symposium on Electronic Imaging: Science and Technology. Main topics of this year's meeting include: Stereoscopic Image Quality and Image Processing, Volumetric Display, Stereoscopic Human Factors, Multiview 3D Content, Autostereoscopic Displays, Digital 3D Stereoscopic Entertainment, Medical Application of Stereoscopy and Integral 3D Displays.

Medicine Meets Virtual Reality 16
January 29-February 1, 2008
The Hyatt Regency Long Beach
Long Beach, California, USA
www.nextmed.com/mmvr_virtual_reality.html

Medicine Meets Virtual Reality (MMVR) is the conference on emerging data-centered technologies for medical care and education. This year's conference puts emphasis on collaboration among specialists involved in designing medical technology. MMVR is an interdisciplinary community of computer scientists, engineers, physicians, medical educators, students, military medicine specialists and biomedical futurists.

16th International Conference in Central Europe on
Computer Graphics, Visualization and Computer Vision 2008
February 4-7, 2008
University of West Bohemia, Plzen, Czech Republic
http://wscg.zcu.cz/wscg2008/wscg2008.htm

This conference is organized by the Center of Computer Graphics and Data Visualization at the Department of Computer Science and Engineering at the University of West Bohemia in Plzen. The Center is focused especially on design and verification of algorithms for computer, algorithms for data visualization and algorithms of computational geometry.

5th IASTED International Conference on Signal Processing,
Pattern Recognition and Applications: SPPRA 2008

February 13–15, 2008
Innsbruck, Austria
www.iasted.org/conferences/home-599.html

6th IASTED International Conference on Biomedical Engineering: BioMED 2008
February 13–15, 2008
Innsbruck, Austria
www.iasted.org/conferences/home-601.html

10th IASTED International Conference on Computer Graphics and Imaging: CGIM 2008
February 13–15, 2008
Innsbruck, Austria
www.iasted.org/conferences/home-600.html

The International Association of Science and Technology for Development (IASTED) promotes economic and cultural advancement and organizes multidisciplinary conferences for academics and professionals, mainly in the fields of engineering, science and education.

SPIE Medical Imaging
February 16–21, 2008
Town & Country Resort and Convention Center
San Diego, California, USA
http://spie.org/medical-imaging.xml

The Society of Photographic Instrumentation Engineers (SPIE) is an international society advancing an interdisciplinary approach to science and the application of light. Individuals involved with SPIE conduct research and apply discoveries to the design and development of such technologies as semiconductor manufacturing, robotics, medical imaging, next-generation displays, battlefield technologies, entertainment, biometric security, image processing, communications, astronomy and much more.

IEEE Virtual Reality 2008
March 8-12, 2008
Reno, Nevada, USA
http://conferences.computer.org/vr

IEEEVR provides the opportunity to mix with researchers in VR and closely related disciplines. Organized by IEEE, this year's conference is co-located with the IEEE 3DUI Symposium. Topics include mixed reality, user interfaces, augmented reality, and advanced display technologies.

10th International General Online Research Conference: GOR 08
March10-12, 2008

Hamburg University, Germany
www.gor.de/gor08/index.php

GOR 08 is organized by the German Society for Online Research, which supports Online Research and Internet Service. Conference topics include theories, methods and findings related to social and business aspects of the Internet and mobile communication.

23rd Annual Association for Computing Machinery Symposium on Applied Computing
March 16-20, 2008
Fortaleza, Ceará, Brazil
www.acm.org/conferences/sac/sac2008/

This conference is a forum for applied computer scientists, engineers, software engineers and application developers from around the world to interact and present their work.

The IEEE 22nd International Conference on
Advanced Information Networking and Applications: AINA-08
March 25-28, 2008
Ginowan, Okinawa, Japan
www.c-lab.de/rls/socne08/

The conference encourages communication and exchange of ideas between industrial and academic researchers in the field of service oriented architectures, their design and engineering process as well as their deployment in application prototypes. The main areas of interest are: Service Oriented Architectures, Quality of Service, Service Platforms and Frameworks, Autonomic Services Management, Services, Applications and Prototypes.

CHI Conference 2008
April 5-10, 2008
Florence, Italy
HYPERLINK "http://www.chi2008.org" www.chi2008.org

CHI is the venue to present innovations in human computer interaction. CHI 2008 underlines the balance between art and science, design and research, practical motivation and innovative excellence. This year's conference features a specialized workshop on "Technology in Mental Health".

10th Virtual Reality International Conference: VRIC 2008
April 9-11, 2008
Laval, France
www.laval-virtual.org

Virtual Laval is a European Virtual Reality convention. This year's conference focuses on three themes: Agriculture and sustainable development, Alzheimer's disease and crisis management.

Eurographics 2008
April 14-18, 2008
Crete, Greece
www.ics.forth.gr/eg2008/home.php

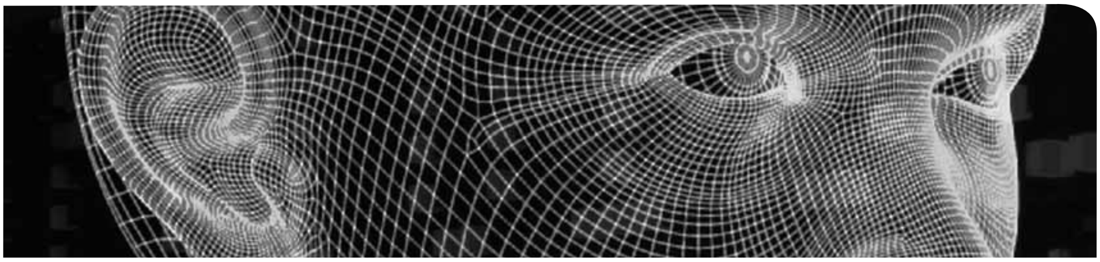
Eurographics 2008 is the 29th annual conference of the European Association for Computer Graphics, hosted by the Foundation for Research and Technology – Hellas (FORTH). The conference is devoted to computer graphics and all related visual and interactive domains.

Med-e-Tel 2008
April 16-18, 2008
Luxembourg

Med-e-Tel brings together speakers from around the world to present on a wide variety of e-health and telemedicine topics. The educational and information program includes interactive seminars on ICT applications in medicine and healthcare. This three-day meeting provides the opportunity to network with leading specialists who will present recent developments in the field. Exhibits offer the ability to experience some of the technologies.

17th International World Wide Web Conference: WWW2008
April 21-25, 2008
Beijing, China
www2008.org/CFP/RP-rich_media.html

The World Wide Web Conference is a global event bringing together researchers, innovators, decision-makers, technologists and businesses to shape the Web. The main theme of the conference is "One World, One Web". The conference will explore how Web access is moving from the desktop to mobile phones and TV screens, and how users are moving from passive browsing on the Internet to active participation in building Web communities.



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