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Virtual reality: an experiential tool for clinical psychology

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Several Virtual Reality (VR) applications for the understanding, assessment and treatment of mental health problems have been developed in the last 15 years. Typically, in VR the patient learns to manipulate problematic situations related to his/her problem. In fact, VR can be described as an advanced form of human–computer interface that is able to induce a feeling of 'presence' in the computer-generated world experienced by the user. This feature transforms VR in an 'empowering environment', a sheltered setting where patients can start to explore and act without feeling threatened. With such assurance, they can freely explore, experiment, feel, live out and experience feelings and/or thoughts. The paper presents the current state of clinical research in this area. Furthermore, the open source 'NeuroVR' system and its potential clinical applications are presented and discussed.

Keywords: virtual reality; psychotherapy; 3D modelling; open-source software

Introduction

A Virtual Reality (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. The virtual world may be either a model of a real-world object, such as a house, or 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 in a completely imaginary world.

Typically, a VR system comprises (Burdea & Coiffet, 2003):

- the *graphic rendering system* that generates, at 20–30 frames per second, the virtual environment;
- the *database construction and virtual object modelling software* for building and maintaining detailed and realistic models of the virtual world. In particular, the software handles the geometry, texture, intelligent behaviour and physical

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modelling of hardness, inertia and surface plasticity of any object included in the virtual world;

- the *input tools* (trackers, gloves or mice) that continually report the position and movements of the users;
- the *output tools* (visual, aural and haptic) that immerse the user in the virtual environment.

According to the hardware and software included in a VR system, it is possible to distinguish between:

- *Fully Immersive VR*: with this type of solution the user appears to be fully inserted in the computer-generated environment. This illusion is produced by providing immersive output devices (head-mounted display, force feedback robotic arms, etc.) and a system of head/body tracking to guarantee the exact correspondence and co-ordination of users' movements with the feedback of the environment.
- *CAVE*: this is a small room where a computer-generated world is projected on the walls. The projection is made on both front and side walls. This solution is particularly suitable for collective VR experiences because it allows different people to share the same experience at the same time.
- *Telepresence*: users can influence and operate in a world that is real but in a different location. The users can observe the current situation with remote cameras and achieve actions via robotic and electronic arms.
- *Augmented*: the user's view of the world is supplemented with virtual objects, usually to provide information about the real environment. For instance, in military applications vision performance is enhanced by pictograms that anticipate the presence of other entities out of sight.
- *Desktop VR*: uses subjective immersion on a standard PC screen. The feeling of immersion can be improved through stereoscopic vision. Interaction with the virtual world can be made via mouse, joystick or typical VR peripherals such as a data glove.

VR in clinical psychology

Several VR applications for the understanding, assessment and treatment of mental health problems have been developed in the last 5 years (Riva, 2005). 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 exposure therapy (VRE) has been proposed as a new medium for exposure therapy (Gorini & Riva, 2008) that is safer, less embarrassing and less costly than reproducing the 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 it reduces the anxiety through the processes of habituation and extinction. VRE offers a number of advantages over *in vivo* or imaginal exposure. Firstly, VRE can be administered in traditional therapeutic settings. This means VRE may be more convenient, controlled, and cost-effective than *in vivo* exposure. Secondly, it can also isolate fear components more efficiently than *in vivo* exposure.

For instance, in treating fear of flying, if landing is the most fearful part of the experience, landing can be repeated as often as necessary without having to wait for AQ1 the airplane to take off. Finally, the immersive nature of VRE provides a real-like 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 AQ2 desensitisation (Riva, 2005). As noted by Glantz et al. (1997, p. 2), 'VR technology may create enough capabilities to profoundly influence the shape of therapy'. In fact, 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).

On the one hand, it can be described as an advanced form of human–computer interface that allows the user to interact with and become immersed in a computer-generated environment in a naturalistic fashion. On the other, VR can also be considered as an advanced imaginal system, a medium that is as effective as reality in inducing emotional responses. This is achieved through its ability to induce a feeling of 'presence' in the computer-generated world experienced by the user (Riva, 2007; Riva, Gaggioli, & Mantovani, 2008; Riva et al., 2007).

These features transform VR into an 'empowering environment', a special, sheltered setting where patients can start to explore and act without feeling actually threatened (Botella et al., 2007). Nothing the patient fears can 'really' happen to them in VR. With such assurance, they can freely explore, experiment, feel, live and experience feelings and/or thoughts. VR thus becomes a very useful intermediate step between the therapist's office and the real world (Botella et al., 2004).

Emerging applications of VR in psychotherapy include post-traumatic stress disorder (Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001), sexual disorders (Optale, 2003), pain management (Hoffman, 2004), stress management (Villani, Riva, & Riva, 2007) and eating disorders and obesity (Riva, Bacchetta, Cesa, Conti, & Molinari, 2003; Riva et al., 2006).

In fact, immersive VR can be considered an 'embodied technology' for its effects on body perceptions (Lambrey & Berthoz, 2003; Riva, 2008; Vidal, Amorim, & Berthoz, 2004; Vidal, Lipshits, McIntyre, & Berthoz, 2003). VR users become aware of their bodies during navigation: e.g. 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).

For example, 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. The results of this approach are very promising. As showed by different experimental research, VR is effective in producing fast changes in body experience (Murray & Gordon, 2001; Riva, 1998) and in body dissatisfaction (Perpiña, Botella, & Baños, 2003; Riva, Bacchetta, Baruffi, Cirillo, & Molinari, 2000; Riva, Bacchetta, Baruffi, & Molinari, 2002; Riva, Bacchetta, Baruffi, Rinaldi, & Molinari, 1998; Riva et al., AQ3 2004, 2006).

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 the subjects changing their perceptive strategy, i.e. re-weighting (top-down processes).

Viaud-Delmon et al. (2002, 2000) showed that subjects with high trait anxiety, such as 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.

Another medical field in which VR has been successfully applied is neuropsychological testing and rehabilitation. Here, the advantage of VR over traditional assessment and intervention is provided by three key features: the capacity to deliver interactive 3D stimuli within an immersive environment in a variety of forms and sensory modalities; the possibility of designing safe testing and training environments; and the provision of 'cueing' stimuli or visualisation strategies designed to help guide successful performance to support an error-free learning approach (Morganti, 2004; Rizzo, Schultheis, Kerns, & Mateer, 2004; Schultheis, Himelstein, & Rizzo, 2002).

Future VR clinical applications will also include online virtual worlds (such as Second Life, There or Active Worlds): computer-based simulated environments characterised by the simultaneous presence of multiple users within the same simulated space, who inhabit and interact via avatars (Gorini, Gaggioli, & Riva, 2007). Online virtual worlds can be considered as 3D social networks, where people can collaboratively create and edit objects, besides meeting each other and interacting with existing objects. Over the last few years the number of virtual worlds' users has dramatically increased and today Second Life, the largest 3D online digital world, counts about 12 million subscribers.

Beyond clinical applications, VR has been revealed to be a powerful tool for behavioural neuroscience research. Using VR, researchers can carry out experiments in an ecologically valid situation, while still maintaining control over all potential intervening variables. Moreover, VR allows us to measure and monitor a wide variety of responses made by the subject (Tarr & Warren, 2002).

VR in clinical psychology: from theory to practice

Although it is undisputable that VR has come of age for clinical and research applications, the majority of them are still in the laboratory or investigation stage. In a recent review, Riva (2005) identified four major issues that limit the use of VR in psychotherapy:

- the lack of standardisation in VR hardware and software and the limited possibility of tailoring the virtual environments (VEs) to the specific requirements of the clinical or the experimental setting;
- the low availability of standardised protocols that can be shared by the community of researchers;
- the high costs (up to US$ 200,000) required for designing and testing a clinical VR application;
- VEs in use today not being user-friendly, as expensive technical support or continual maintenance are often required.

To address these challenges, we have designed and developed NeuroVR (http://www.neurovr.org), a cost-free virtual reality platform based on open-source software, that allows non-expert users to easily modify a virtual environment (VE) and to visualise it using either an immersive or non-immersive system.

The NeuroVR platform is implemented using open-source components that provide advanced features; this includes an interactive rendering system based on OpenGL, which allows for high quality images. The NeuroVR Editor is realised by customising the user interface of Blender, an integrated suite of 3D creation tools available on all major operating systems; this implies that the program can be distributed even with the complete source code. Thanks to these features, clinicians and researchers have the freedom to run, copy, distribute, study, change and improve the NeuroVR Editor software, so that the whole VR community benefits.

The NeuroVR Editor

The majority of existing VEs for psychotherapy are proprietary and have closed source code, meaning they cannot be tailored from the ground up to fit specific needs of different clinical applications (Riva, 2005). NeuroVR addresses these issues by providing the clinical professional with a cost-free VE editor, which allows non-expert users to easily modify a virtual scene to best suit the needs of the clinical setting.

Using the NeuroVR Editor (see Figure 1), the psychological stimuli/stressors appropriate for any given scenario can be chosen from a rich database of 2D and 3D objects and easily placed into the pre-designed virtual scenario by using an icon-based interface (no programming skills are required). In addition to static objects, the NeuroVR Editor allows us to combine a video with the 3D background to create the appearance of partial transparency (known as alpha compositing).

The editing of the scene is performed in real time and effects of changes can be checked from different views (frontal, lateral and top).

The NeuroVR Editor is built using a custom Graphical User Interface (GUI) for Blender. The GUI allows hiding of all the richness and complexity of the Blender

Figure 1. A screenshot taken from the NeuroVR Editor.

suite, so as to expose only the controls needed to customise existing scenes and to create the proper files to be viewed in the player.

Currently, the NeuroVR library includes different pre-designed virtual scenes, representing typical real-life situations, e.g. the supermarket, the apartment, the park. These VEs have been designed, developed and assessed in the past 10 years by a multidisciplinary research team in several clinical trials, which have involved over 400 patients (Riva et al., 2004). On the basis of this experience, only the most effective VEs have been selected for inclusion in the NeuroVR library.

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An interesting feature of the NeuroVR Editor is the possibility to add new objects to the database. This feature allows the therapist to enhance the patient's feeling of familiarity and intimacy with the virtual scene, i.e., by using photos of objects/people that are part of the patient's daily life, thereby improving the efficacy of the exposure (Riva et al., 2004). Future releases of the NeuroVR Editor software may also include interactive 3D animations. A VRML/X3D exporter and a player for PocketPC PDAs are planned Blender features, too.

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The NeuroVR Player

The second main component of NeuroVR is the Player, which allows the user to navigate and interact with the VEs created using the NeuroVR Editor.

NeuroVR Player leverages two major open-source projects in the VR field: Delta3D (http://www.delta3d.org) and OpenSceneGraph (http://www.openscenegraph.org). Both are building components that the NeuroVR player integrates with ad-hoc code to handle the simulations.

The whole player is developed in C++ language, targeted for the Microsoft Windows platform but fully portable to other systems if needed. When running simulations, the system offers a set of standard features that contribute to increase the realism of the simulated scene. These include collision detection to control movements in the environment, realistic walk-style motion, advanced lighting techniques for enhanced image quality and streaming of video textures using alpha channel for transparency.

The player can be configured for two basic visualisation modalities: immersive and non-immersive. The immersive modality allows the scene to be visualised using a head-mounted display, either in stereoscopic or in mono-mode; compatibility with a head-tracking sensor is also provided. In the non-immersive modality, the virtual environment can be displayed using a desktop monitor or a wall projector. The user can interact with the virtual environment using either keyboard commands, a mouse or a joypad, depending on the hardware configuration chosen.

Conclusions

The basis for the VR idea is that a computer can synthesise a 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.

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). 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 (Gorini, Gaggioli, Vigna, & Riva, 2008; Riva, 1997).

Even if the potential impact of VR in clinical psychology is high, the majority of the existing clinical VR applications are still in the laboratory or investigation stage. To address the challenges outlined in this paper, we have designed and developed NeuroVR (http://www.neurovr.org), a cost-free virtual reality platform based on open-source software, that allows non-expert users to easily modify a virtual environment and to visualise it using either an immersive or non-immersive system.

Currently, the NeuroVR library includes a limited number of VEs addressing specific phobias (e.g. fear of public speaking, agoraphobia) and eating disorders. However, these pre-designed environments can be easily adapted for targeting other clinical applications. Moreover, it is envisioned that the 250,000-strong worldwide Blender user community will contribute to extend the NeuroVR library, developing new VEs that can be tailored by the clinical professionals for a range of clinical and experimental needs.

A future goal is also to provide software compatibility with instruments that allow collection and analysis of behavioural data, such as eye-tracking devices and sensors for psychophysiological monitoring. Beyond clinical applications, NeuroVR provides the VR research community with a cost-free, open-source 'VR lab', which allows the creation of highly controlled experimental simulations for a variety of behavioural, clinical and neuroscience applications.

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