A Free Virtual Reality Platform for Clinical Psychology and Behavioral Neurosciences: The NeuroVR Project

Giuseppe RIVA 1-2, Andrea GAGGIOLI 1-2, Daniela VILLANI 1, Alessandra PREZIOSA 1, Francesca MORGANTI 1, Riccardo CORSI 3, Gianluca FALETTI 3, Luca VEZZADINI 3

1 Applied Technology for Neuro-Psychology Lab, Istituto Auxologico Italiano, Milan, Italy
2 ICE-NET, Università Cattolica del Sacro Cuore, Milan, Italy
3 VR Department, Virtual Reality & Multi-Media Park, Turin, Italy

Abstract. Virtual reality (VR) can be considered an embodied technology whose potential is wider than the simple reproduction of real worlds. By designing meaningful embodied activities, VR may be used to facilitate cognitive modelling and change. However, the diffusion of this approach is still limited by three main issues: poor usability, lack of technical expertise among clinical professionals, and high costs. To address these challenges, we introduce NeuroVR (http://www.neurovr.org – http://www.neurotiv.org), a cost-free virtual reality platform based on open-source software, that allows non-expert users to adapt the content of a pre-designed virtual environment to meet the specific needs of the clinical or experimental setting. Using the NeuroVR Editor, the user can choose the appropriate psychological stimuli/stressors from a database of objects (both 2D and 3D) and videos, and easily place them into the virtual environment. The edited scene can then be visualized in the NeuroVR Player using either immersive or non-immersive displays. Currently, the NeuroVR library includes different virtual scenes (apartment, office, square, supermarket, park, classroom, etc.), covering two of the most studied clinical applications of VR: specific phobias and eating disorders. The NeuroVR Editor is based on Blender (http://www.blender.org), the open source, cross-platform suite of tools for 3D creation, and is available as a completely free resource. 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 or movies of objects/people that are part of the patient’s daily life, thereby improving the efficacy of the exposure. The NeuroVR platform runs on standard personal computers with Microsoft Windows; the only requirement for the hardware is related to the graphics card, which must support OpenGL.

1. Introduction

The basis of virtual reality (VR) 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; 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 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 20-30 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, or surface plasticity, of any object included in the virtual world.

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 a user's movements with the feedback of the environment.

- **Desktop VR**: Uses subjective immersion. 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 Dataglove.

- **CAVE**: A CAVE 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.

### 2. VR in medicine and behavioral neurosciences

The use of virtual reality (VR) in medicine and behavioral neurosciences has become widespread (Riva & Wiederhold, 2006). According to a recent market analysis, in 2003 the medical sector contributed $8.7 billion to worldwide visual simulation/virtual reality systems; in the same year, psychotherapy and medical research were rated among the top ten applications of VR. The growing interest in medical applications of VR is also highlighted by the increasing number of scientific articles published each year on this topic; searching Medline with the keyword “virtual reality”, we found that the total number of publications has increased from 45 in 1995 to 246 in 2005, showing an average annual growth rate of nearly 14 percent (see Figure 1).

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 exposure therapy – VRE), i.e., fear of heights, fear of flying, and fear of public speaking (Wiederhold & Rizzo, 2005; Wiederhold & Wiederhold, 2003). In VR exposure therapy, the patient is gradually confronted with the virtual simulation of 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 (Wiederhold et al., 2002). 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 also isolate fear components more efficiently than in vivo exposure (Choi et al., 2005). 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 the airplane to take-off. Finally, the immersive nature of VRE provides a realistic experience that may be more emotionally engaging than imaginal exposure.

In VR exposure therapy, the patient is gradually confronted with the virtual simulation of feared stimuli while allowing the anxiety to attenuate. The main advantage of VR exposure over conventional “in vivo” exposure is that using VR, the therapist can control and grade the feared situations with a high degree of safety for the patient (Wiederhold & Rizzo, 2005).

Riva and his group (Riva et al., 2006a) have recently conducted the largest randomised controlled trial to date with 211 morbidly obese patients. This trial compared Experiential Cognitive Therapy (CT) - a VR-based treatment for obesity - with nutritional and cognitive-behavioral approaches along with waiting list controls. At the 6 month follow up, experiential CT, in contrast to the other approaches, resulted in improvements in both the level of body image, satisfaction and self-efficacy; and in the maintenance of weight loss. Riva and colleagues’ experiential CT has also been used in the treatment of Anorexia, Bulimia and Binge Eating (Riva et al., 2002; Riva et al., 1999; Riva et al., 2003). A similar approach was presented and tested by Perpiña and colleagues (Perpiña et al., 2002; Perpiña et al., 1999; Perpiña et al., 2003). A similar approach was presented and tested by Perpiña and colleagues (Perpiña et al., 2002; Perpiña et al., 1999; Perpiña et al., 2003).

Further applications of VR in psychotherapy include, 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).

![Figure 1. Trend in publications on VR in medicine](Source: Medline; keyword: “virtual reality”; accessed: June 30, 2006)

Another medical field in which VR has been fruitfully 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 visualization strategies designed
to help guide successful performance to support an error-free learning approach (Morganti, 2004; Riva et al., 2006b; Schultheis & Rizzo, 2001).

Beyond clinical applications, VR has been revealed to be a powerful tool for behavioral 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 the measurement and monitoring of a wide variety of responses made by the subject (Tarr & Warren, 2002).

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 (Wiederhold & Wiederhold, 2004). In a recent review, Riva identified four major issues that limit the use of VR in psychotherapy and behavioral neuroscience (Riva, 2005):

- the lack of standardization 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 standardized protocols that can be shared by the community of researchers;
- the high costs (up to $200,000 US) required for designing and testing a clinical VR application;
- most VEs in use today are not user-friendly; 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 visualize 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 realized by customizing the User Interface of Blender, an integrated suite of 3D creation tools available on all major operating systems, under the GNU General Public License; this implies that the program can be distributed 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.

3. The NeuroVR Editor

The majority of existing VEs for psychotherapy are proprietary and closed source, meaning they cannot be tailored from the ground up to fit the specific needs of different clinical applications (Riva, 2005). NeuroVR addresses these issues by providing the clinical professional with a cost-free VE editor that 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 2), 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 an overlay on the 3D scene video composited with a transparent alpha channel.
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 Python scripts that create a custom graphical user interface (GUI) for Blender. The Python-based GUI allows the clinician to hide all the richness and complexity of the Blender suite, exposing only the controls needed to customize 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, i.e., the supermarket, an apartment, the park.

These VEs have been designed, developed and assessed in the past ten 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.

An interesting feature of the NeuroVR Editor is the ability 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, e.g., 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 controlled at runtime. A VRML/X3D exporter and a player for PocketPC PDAs are planned Blender features, too.

4. The NeuroVR Player

The second main component of NeuroVR is the Player, which allows navigation and interaction 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 a simulation, the system offers a set of standard features that contribute to increasing 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 the alpha channel for transparency.

The player can be configured for two basic visualization modalities: immersive and non-immersive. The immersive modality allows the scene to be visualized using a head-mounted display, either in stereoscopic or in mono-mode; compatibility with 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.
4. Conclusions

In this paper, we have introduced NeuroVR, an advanced platform designed for the creation and customization of highly flexible VEs for clinical psychology and behavioral neurosciences. Currently, the NeuroVR library includes a limited number of VEs addressing specific phobias (i.e. 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 person worldwide Blender user community will contribute to extend the NeuroVR library, developing new VEs which 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 behavioral 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 behavioral, clinical and neuroscience applications.

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6. References


