Abstract
Virtual Reality (VR) is more than a fancy technology: recent studies support its possible use in clinical assessment and therapy. On one side, VR 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 side, VR can also be considered as an advanced imaginal system: an experiential form of imagery that is as effective as reality in inducing emotional responses. The paper outlines the current state of research in this area. In particular, it focuses its analysis on the main applications of VR in clinical psychology: anxiety disorders, eating disorders and obesity, pain reduction. The open source “NeuroVR” VR system (http://www.neurovr.org) and its potential clinical applications are also introduced.

Keywords
Virtual Reality, Cybertherapy, Open Source Software
ACM Classification Keywords
H5.m. Information interfaces and presentation; J.3 Life And Medical Sciences; D.2.6 Programming Environments

Introduction
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; 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 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 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.

Virtual Reality as Experiential Tool
The use of virtual reality (VR) in clinical psychology has become more widespread [1, 2]. 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 [3].

On one side, 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 side VR can also be considered as an advanced imaginal system [4]: an experiential form of imagery that is effective as reality in inducing emotional responses. As recently showed by two different meta-analysis by Parsons & Rizzo [5] and by Powers & Emmelkamp [6] virtual reality exposure therapy was as effective as in vivo exposure in treating anxiety. Even, there was a small effect size favoring virtual reality over in vivo conditions [6]: Cohen's d = 0.35 (S.E. = 0.15, 95% CI: 0.05–0.65). Apparently, Virtual Reality is able to induce “presence” [4, 7, 8]: the feeling of “being inside” the simulated world.

These features transform VR in an “empowering environment”, a special, sheltered setting where patients can start to explore and act without feeling threatened [9, 10]. 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 [11].

Typically, in VR the patient learns to cope with 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 [12], i.e., fear of heights, fear of flying, and fear of public speaking [13-15].
Indeed, VR exposure therapy (VRE) has been proposed as a new medium for exposure therapy [1] 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 [12]. First, VRE can be administered in traditional therapeutic settings. This makes VRE may be more convenient, controlled, and cost-effective than in vivo exposure. Second, 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 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 desensitisation [1]. As noted by Glantz and colleagues [16], "VR technology may create enough capabilities to profoundly influence the shape of therapy." (p.92). Emerging applications of VR in psychotherapy include eating disorders and obesity [17, 18], posttraumatic stress disorder [19], sexual disorders [20], and pain management [21].

In fact, immersive VR can be considered an "embodied technology" for its effects on body perceptions [22-24]. First, VR users become aware of their bodies during navigation: their head movements alter what they saw. 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 is very promising.

Riva and his group [17] have recently conducted the largest randomised controlled trial to date with 211 morbidly obese patients (Fig. 1). 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 months 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 also in the treatment of Anorexia, Bulimia and Binge Eating [18, 25, 26]. A similar approach was presented and tested by Perpiña and colleagues [27] in the treatment of eating disorders.

Apparently, a similar approach may be used in other pathologies. Lambrey and Berthoz [24] 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 and colleagues [28, 29] 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 are interpreted and in which the subject would remained 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 fruitfully applied is neuropsychological testing and rehabilitation. Here, the advantage of VR on 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 of 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 [30-32].

Beyond clinical applications, VR has 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 to measure and monitor a wide variety of responses made by the subject [33].

The NeuroVR Software

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 [1] identified four major issues that limit the use of VR in psychotherapy:

- 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 (last downloadable version: 1.5), 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 was developed 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 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.

Figure 1. A Screenshot of the NeuroVR Editor. It allows the customization of the available interactive scenes: it is possible to create a completely new scene starting from a model, or the editor can be used to make changes to an existing scene. NeuroVR includes different predefined scenes:

Currently, the NeuroVR library includes a number of VEs addressing specific phobias (i.e. fear of public speaking, agoraphobia), obesity and eating disorders. Each of these pre-designed environments can be easily
adapted for targeting other clinical applications. Specifically, the therapist can add audio, 3D and video objects (Chroma Key is supported) to the pre-defined scenario using a simple point-and-click interface (see Figure 1). 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 videos of objects/people that are part of the patient’s daily life - thereby improving the efficacy of the exposure. More, the audio and video objects can be activated both by the therapist using a keyboard, or by the user through a collision detection algorithm. The edited scene can then be visualized in the NeuroVR Player using either immersive or non-immersive 3D displays.

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 to create highly-controlled experimental simulations for a variety of behavioral, clinical and neuroscience applications.

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Example citations