Guest Editorial: Introduction to the Special Issue on Virtual Reality Environments in Behavioral Sciences

***Abstract*—Virtual reality (VR) is usually described in biology and in medicine as a collection of technologies that allow people to interact efficiently with three-dimensional (3-D) computerized databases in real time using their natural senses. This definition lacks any reference to head-mounted displays (HMDs) and instrumented clothing such as gloves or suits. In fact, less than 10% of VR healthcare applications in medicine are actually using any immersive equipment. However, if we focus our attention on behavioral sciences, where immersion is used by more than 50% of the applications, VR is described as an advanced form of human– computer interface that allows the user to interact with and become immersed in a computer–generated environment. This difference outlines a different vision of VR shared by psychologists, psychotherapists, and neuropsychologists: 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 3-D virtual world. This special issue investigates this vision, presenting some of the most interesting applications actually developed in the area. Moreover, it discusses the clinical principles, human factors, and technological issues associated with the use of VR in the behavioral sciences.**

***Index Terms*—Behavioral sciences, clinical psychology, virtual reality (VR).**

I. Vision of Virtual Reality (VR) in Healthcare

RECENTLY, Rubino *et al.* [1], McCloy and Stone [2], and Székely and Satava [3] reviewed the situation of VR applications in healthcare. All these researchers share a common vision of what VR is: "a collection of technologies that allow people to interact efficiently with three-dimensional (3-D) computerized databases in real time using their natural senses and skills" [2]. This definition lacks any reference to head-mounted displays (HMDs) and instrumented clothing such as gloves or suits. In fact, less than 10% of VR healthcare applications in medicine are actually using any immersive equipment.

However, if we focus our attention on behavioral sciences, where immersion is used by more than 50% of the applications, VR is 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" [4].

These two definitions underline two different visions of VR. For physicians and surgeons, the ultimate goal of VR is the presentation of virtual objects to all of the human senses in a way identical to their natural counterpart [3]. As noted by Satava and Jones [5], as more and more of the medical technologies become information-based, it will be possible to represent a patient with higher fidelity to a point that the image may become a surrogate for the patient—the medical avatar. In this sense, an effective VR system should offer real-like body parts or avatars that interact with external devices such as surgical instruments as near as possible to their real models.

For clinical psychologists and rehabilitators the ultimate goal is radically different [6], [7]. They use VR to provide a new human–computer interaction paradigm in which users are no longer simply external observers of images on a computer screen but are active participants within a computer–generated 3-D virtual world. The key characteristics of virtual environments (VEs) for these professionals are both the high level of control of the interaction with the tool without the constraints usually found in computer systems, and the enriched experience provided to the patient [4].

VEs are highly flexible and programmable. They enable the therapist to present a wide variety of controlled stimuli and to measure and monitor a wide variety of responses made by the user. This flexibility can be used to provide systematic restorative training that optimize the degree of transfer of training or generalization of learning to the person's real-world environment [8].

Moreover, VR systems open the input channel to the full range of human gestures: it is possible to monitor movements or actions from any body part or many body parts at the same time. On the other side, feedbacks and prompts can be translated into alternate and/or multiple senses [9].

The main goal of this special issue is to investigate more in depth how psychologists and psychotherapists are actually using virtual reality in their clinical practice. In particular, it discusses the clinical principles, human factors, and technological issues associated with the use of virtual reality in behavioral sciences.

II. VR in Clinical Psychology

As information technology has advanced and costs have declined over the past decade, there has been a steady growth in the use of VR in behavioral sciences. If we check the leading psychological database, PSYCINFO, using the "virtual reality" keyword we can find 569 papers listed (accessed 6 Dec 2001).

These data seem to indicate that VR is starting to play an important role in clinical psychology [10], [11]. One of the main advantages of a VE is that it can be used in a medical facility, thus avoiding the need to venture into public situations. In fact, in most of the previous studies, VEs are used to simulate the real world and to assure the researcher full control of all the parameters implied. VR constitutes a highly flexible tool, which makes it possible to program an enormous variety of procedures of intervention on psychological distress. The possibility of struc-

Publisher Item Identifier 10.1109/TITB.2002.802369.

turing a large amount of controlled stimuli and, simultaneously, of monitoring the possible responses generated by the user of the virtual world offers a considerable increase in the likelihood of therapeutic effectiveness, as compared with traditional procedures [12]. In particular, a key advantage offered by VR is the possibility for the patient to manage successfully a problematic situation related to his/her disturbance. Using VR in this way, the patient is more likely not only to gain an awareness of his/her need to do something to create change but also to experience a greater sense of personal efficacy.

In general, these techniques are used as triggers for a broader empowerment process. In psychological literature *empowerment* is considered a multifaceted construct reflecting the different dimensions of being psychologically enabled, and is conceived of as a positive additive function of the following three dimensions [13].

- *Perceived control*: includes beliefs about authority, decision-making latitude, availability of resources, autonomy in the scheduling and performance of work, etc.
- *Perceived competence*: reflects role-mastery, which besides requiring the skillful accomplishment of one or more assigned tasks, also requires successful coping with non-routine role-related situations.
- *Goal internalization*: this dimension captures the energizing property of a worthy cause or exciting vision provided by the organizational leadership.

VR can be considered the preferred environment for the empowerment process, since it is a special, sheltered setting where patients can start to explore and act without feeling threatened. In this sense, the virtual experience is an "empowering environment" that therapy provides for patients. As noted by Botella [14], 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.

Even if the clinical rationale behind the use of VR is now clear, much of this research growth, however, has been in the form of feasibility studies and pilot trials. As a result, there is little convincing evidence coming from controlled studies, of the clinical and economical advantages of this approach. In Table I, the only controlled clinical trials in the clinical psychology area that included ten or more patients, which have been published in scientific journals as of January 2002, are listed.

TABLE I
CONTROLLED CLINICAL TRIALS WITH MORE THAN TEN PATIENTS

Authors	Paper	Sample
Emmelkamp, P.M.G., Bruynzeel, M., Drost, L., & van der Mast, C.A.P.G.	(2001) Virtual reality treatment in acrophobia: A comparison with exposure in Vivo, *Cyberpsychol Behav, 4*(3), 335-339.	10 acrophobia patients
Emmelkamp, P.M.G., Krijn, M., Hulsbosch, A.M., de Vries, S., Schuemie, M.J., van der Mast, C.A.P.G.	(2002) Virtual reality treatment versus exposure in vivo: a comparative evaluation in acrophobia, *Behav Res Ther*, 40, 509–516.	33 acrophobia patients
Hoffman, H. G., Patterson, D. R., & Carrougher, G. J.	(2000). Use of virtual reality for adjunctive treatment of adult burn pain during physical therapy: a controlled study. *Clin J Pain, 16*(3), 244-250.	12 burn patients
Riva, G., Bacchetta, M., Baruffi, M., & Molinari, E.	(2001). Virtual reality-based multidimensional therapy for the treatment of body image disturbances in obesity: a controlled study. *Cyberpsychol Behav, 4*(4), 511-526.	28 obese patients
Riva, G., Bacchetta, M., Baruffi, M., & Molinari, E.	Virtual reality-based multidimensional therapy for the treatment of body image disturbances in binge eating disorders: A preliminary controlled study *IEEE Transactions on Information Technology in Biomedicine*, ***this issue.***	20 binge eating patients
Rothbaum, B. O., Hodges, L. F., Kooper, R., Opdyke, D., & et al.	(1995). Effectiveness of computer-generated (virtual reality) graded exposure in the treatment of acrophobia. *American Journal of Psychiatry, 152*(4), 626-628.	17 college students
Rothbaum, B. O., Hodges, L., Smith, S., Lee, J. H., & Price, L.	(2000). A controlled study of virtual reality exposure therapy for the fear of flying. *J Consult Clin Psychol, 68*(6), 1020-1026.	49 fear of flying patients
Wiederhold, B.K., Jang, D.P., Kim, S.I., & Wiederhold, M.D.	(2002). Physiological monitoring as an objective tool in virtual reality therapy, *Cyberpsychol Behav. 5*(1) 77-82.	36 fear of flying patients, 22 non-phobics
Wiederhold, B.K., Jang, D.P., Kim, S.I., & Wiederhold, M.D.	(2002). A controlled trial comparing physiological responses during virtual reality exposure and imaginal exposure in flight phobics. *IEEE Transactions on Information Technology in Biomedicine*, ***this issue.***	30 fear of flying patients

III. CONTENTS OF THE SPECIAL ISSUE

To create successful clinical applications with today's virtual environments, we must begin by asking: *what are they good at?* This special issue tries to offer an answer to its possible readers—physicians, psychologists, technicians, programmers, and healthcare providers—by presenting an overview of the current research in this field. The issue contains a collection of papers from researchers who have pioneered the ideas and the technology associated with virtual reality. Moreover, this special issue discusses the clinical principles, human factors, and technological issues associated with the use of VR for assessment and treatment in the behavioral sciences.

It should be noted that technical characteristics of virtual worlds change very rapidly; but what will not change is the user of a VE. Thus, to ensure that the contents of this special issue are not quickly outdated, all the contributors have made a great effort to identify possible constraints in the use of this technology and to indicate how they can be faced and solved. The key issue was to integrate knowledge of clinical therapy and psychological principles related to human factors into the design of VEs.

The opening paper by Riva *et al.* discusses the qualities that make VR reliable and particularly useful in the practice of assessment and rehabilitation in clinical psychology. According to the presented theoretical framework, VR constitutes a 3-D interface that puts the interacting subject in a condition of active exchange with a world recreated via the computer. In a VE, the patient is not simply an external observer of pictures or one who passively experiences the reality created by the computer, but on the contrary, may actively modify the 3-D world in which he is acting, in a condition of complete sensorial immersion. The paper also discusses how this new situation modifies the interaction between patient and therapist outlining pros and cons for the clinical practice.

The remaining papers present different applications of VR in clinical treatment. The second paper by Baños *et al.* details the possible role of VR therapy in the treatment of flying phobia. In particular, the paper analyzes the different scenarios designed by the team for the VR treatment of flying phobia, presenting actual clinical results, coming from a multiple baseline study, supporting the effectiveness of this approach in the treatment of this phobia.

In the third paper, Jang *et al.* present the development and preliminary case study of an inexpensive PC-based VE used for acrophobia therapy. The effectiveness of the VR environment was evaluated through the clinical treatment of a subject who was suffering from a fear of heights.

In the fourth paper, Wiederhold *et al.* review the physiological responses of 30 fear-of-flying participants in a controlled study involving three groups: VR exposure with physiological feedback, VR exposure with no physiological feedback, and imaginal exposure (patient visualization). This approach allows us to begin to objectify findings in treatment outcome using virtual worlds and physiological data.

In the fifth paper, Riva *et al.* evaluated the efficacy of a VR-based multidimensional approach in the treatment of body image attitudes. In particular, they tested the proposed approach in a controlled study involving 20 female binge-eating disordered patients involved in a residential weight control treatment. The presented results indicate that, at least in the short-term, the VR treatment was more effective than the traditional cognitive–behavioral psychonutritional groups in improving the overall psychological state of the patients.

In the final paper of this issue, Renaud and Bouchard use the ecological psychology concept of *affordance* to analyze the behavior dynamics of phobic patients experiencing a fearful stimulus in VR. The results showed the efficacy of the proposed approach and supported the use of behavior dynamics for more precise and dynamic diagnoses. In particular, by monitoring online phase transitions in behavior dynamics as treatment progresses, mental health practitioners will resort to VR as a kind visualization tool opening new windows to behavior as it is dynamically linked to clinically relevant virtual affordances.

IV. VR Hardware and Software

All the VR applications included in this special issue are built around a low-cost PC system. In fact, the significant advances in PC hardware that have been made over the last five years, transformed PC-based VR into a reality. While the cost of a basic desktop VR system has only gone down by a few thousand dollars since that time, the functionality has improved dramatically, both in terms of graphics processing power and VR hardware such as HMDs. A simple VR system now costs less than $6000 (see Table II).

The availability of powerful PC engines based on such computing workhorses as Intel's Pentium IV Xeon and IBM G4/G5 processors, and the emergence of reasonably priced, Direct 3D and OpenGL-based 3D accelerator cards allow high-end PCs to process and display 3-D simulations in real time.

While a standard Celeron/Duron processor with as little as 64 MB of RAM can provide sufficient processing power for a simple VR simulation, a fast Pentium IV/Athlon XP-based PC (2 Ghz or faster) with 256 MB of RAM, can transport users to a convincing virtual environment, while a dual Pentium IV configuration with 512 MB of RAM OpenGL acceleration and 128 MB of video RAM (VRAM) running Windows XP Pro rivals the horsepower of a graphics workstation.

TABLE II
PC-Based VR System

PC	Suggested Price (as 01 Apr 02)
Pentium IV or Athlon XP branded PC with 2.2 Ghz processor, 512 Mb Ram, 80 GB Hard Disk and 17" monitor	1800 $
Graphic card	
GeForce 4 TI 4600 128 MB Vram AGP	400 $
Radeon 8500 128 MB Vram AGP	350 $
Tracking system	
PC Bird of Flick	2200 $
Intertrax 2	1100 $
3D Shutter Glasses	
StereoEyes Wireless	320 $
Elsa 3D Revelator IR	180 $
VRex Cordless	100 $
Head Mounted Display	
Olympus Eye-Trek FMD-700 (SVGA resolution)	1300 $
Daeyang I-Visor DH4400 VP (SVGA resolution)	1000 $
Olympus Eyetrek 250 W (Video output only)	600 $
Sony Glasstron PLM-A35 (Video output only)	500 $
VR Gloves	
Pinch Glove	2000 $
5DT Right Hand	550 $

The graphics card landscape, too, is evolving quickly. In particular, three advancements are interesting for VR users: the inclusion of a VGA-to-TV converter and tuner, the accelerated graphics port (AGP) and the new faster 3-D chips (GeForce 4, Radeon 8500) with 128 MB of dedicated VRAM.

- *AGP:* The AGP is a high-speed point-to-point connection between the system chip set and the graphics chip. AGP provides a high-speed pipeline between the graphics accelerator and the PC's system memory: using an AGP connection, a graphics chip is able to access system memory directly through the system chip set at memory-bus speeds, reducing latency and substantially increasing performance versus standard PCI-memory transfers. The graphics card gains access to system RAM to store and execute texture bitmaps, which allows more detailed textures of unlimited size while speeding 3-D rendering. When textures are large, AGP can make the difference between a smooth or choppy frame rates in 3-D rendering.
- *Faster 3-D chips:* In VR, performance is critical. VEs gave mainstream 3-D acceleration its start, and developers have been adding a sense of realistic depth to their creations for years. However, the addition of a z-axis in rendering, as opposed to simply drawing on an x–y coordinate plane, requires more sophisticated horsepower. In addition, VR applications contain more complex objects and complex *textures*: bitmap renderings of detailed surfaces (bricks, sand, or transparent water) that heighten realism. To exploit this potential a fast graphic card is a must. Happily, the new chip sets (GeForce 4 TI and Radeon 8500) *more than triple the 3-D acceleration* allowed by the first generation of chips (GeForce and Radeon VE) for a price tag of less than $500.
- *VGA-to-TV converter and tuner:* One welcome feature of the new graphics cards is the inclusion of a VGA-to-TV (NTSC or PAL) converter and TV tuner right on the card.

> This feature lets you display computer data on a standard television without the need for an external scan converter (usually $100 or more). Business users can then give PC-based presentations with TVs as large-screen monitors, and home users can play computer games on their TV sets. However, this feature is also useful for VR users: thanks to the converter it *is possible to use*— without any extra hardware—*the new low-cost HMDs* from $599 or Sony (Glasstron PLM-A35, $499).

On the software side, an interesting low-cost solution is the use of 3-D engines included in commercial 3-D games for developing simple VEs. Many 3-D games ($50 each), such as Quake 3 or Unreal, include level editors that allow the user to customize the environments and the avatars. Moreover, Discreet has released free software, *gmax*, that allows a professional customization of 3-D games. Intended to be a fully capable 3-D level editing, modeling, animation, and texture mapping tool, *gmax* ships with a full suite of professional 3-D content and animation features. Discreet approved game developers can publish *gmax* "game packs," which customize the downloadable version of *gmax* into a fully featured level editor for supported game titles. Using this software, it is possible to edit and create 3-D environments, materials, 3-D objects, weapons, images, and lights.

Obviously, level editing does not allow full control of the environment. In particular, the user interaction with the 3-D objects is usually very limited. To overcome this limitation, now there are different VR development toolkits available for PCs, ranging from high-end authoring toolkits that require significant programming experience to simple "hobbyist" packages. Despite the differences in the types of virtual worlds these products can deliver, the various tools are based on the same VR-development model: they allow users to create or import 3-D objects, to apply behavioral attributes such as weight and gravity to the objects, and to program the objects to respond to the user via visual and or audio events. Ranging in price from free (http://www.alice.org) to $5000 (Virtools Dev 2.1 or Sense 8 WorldUp R5), the toolkits are the most functional of the available VR software options. While some of them rely exclusively on C or C++ programming to build a virtual world, others offer simpler point-and-click operations to develop a simulation. Using VR toolkits, it is also possible to bring in files from a wide array of software packages, such as Wavefront, 3D Studio, EDS Unigraphics, Pro Engineer, and Intergraph EMS, and they can also import VRML and Multigen databases as well as animation scripts and sounds.

V. CONCLUSION

In general, the contents of this special issue show that VR can be considered a useful tool for assessment and treatment in the behavioral sciences. However, several barriers still remain. The PC-based systems, while inexpensive and easy-to-use, still suffer from a lack of flexibility and capabilities necessary to individualize environments for each patient [15]. On the other hand, in most circumstances the clinical skills of the therapist remain the most important factor in the successful use of VR systems. It is clear that building new and additional VEs is important so therapists will continue to investigate applying these tools in their day-to-day clinical practice [16].

Possible future scenarios will involve multidisciplinary teams of engineers, computer programmers, and therapists working in concert to attack specific clinical problems. Information on advances in VR technology must be made available to the mental health community in a format that is easy-to-understand and invites participation [17].

In conclusion, it is important that the technical-oriented members of the team understand the aims, requirements, and scope of the therapeutic intervention so they may effectively bring advanced computing tools that specifically address the problem. It is hoped that by bringing together this community of experts, further stimulation of interest from granting agencies will be accelerated. Future potential applications of VR are really only limited by the imaginations of talented individuals.

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ACKNOWLEDGMENT

This work was supported by the Commission of the European Communities (CEC), in particular by the IST programme (Project VEPSY UPDATED, IST-2000-25323, http://www.psicologia.net).

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