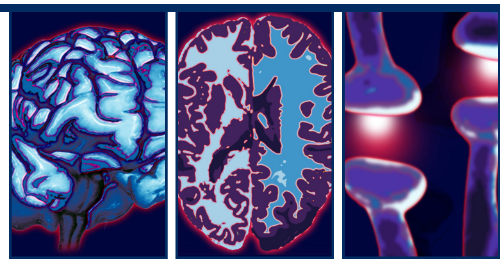
SPECIAL REPORT



# From virtual reality to interreality in the treatment of anxiety disorders

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## Practice points

- In the field of the treatment of anxiety disorder, a new tool has recently emerged that will allow implementation of exposure-based virtual reality programs.
- Virtual reality exposure treatments (VRET) present several advantages when compared with the traditional treatments carried out by both *in vivo* and imagination techniques.
- The flexibility of virtual environments makes VRET interactive, controllable, safe, confidential, time saving and cost saving.
- Many studies investigating the efficacy of VRET in reducing anxiety symptoms have demonstrated that it is useful for treating different anxiety disorders: specific phobias, panic disorder, post-traumatic stress disorder, social anxiety and public speaking.
- The new frontier that extends the clinical setting to a hybrid environment, bridging the physical and virtual world is interreality.
- The bridging of mobile phones with online virtual reality worlds is the final goal of the interreality paradigm.
- One of the first attempts to use interreality in a clinical context has been made by the INTREPID project, targeted to treat generalized anxiety disorders.

**SUMMARY** A virtual reality system is a combination of technological devices that allows users to create, explore and interact with 3D environments. In recent years, virtual reality has been increasingly employed in the treatment of anxiety disorders, since it offers the opportunity to carry out exposure-based programs that bypass the limitations that occur during both *in vivo* exposure and imaginal exposure. The introduction of a new therapeutic approach called interreality has brought us one step further towards e-health. If virtual worlds are considered as 'closed' experiences, separated from thoughts and emotions experienced by the patient in the real life, interreality, conversely, is an advanced technological tool whose main novelty is the creation of a hybrid, closed-loop, empowering experience bridging both the physical and virtual worlds. This article will discuss the use of virtual reality and interreality for clinical purposes, and will present the outcomes of different clinical trials that applied these tools in the field of anxiety disorders.

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Anxiety is a typically human emotion that requires a complex cognitive system to be experienced: the ability to represent and to think about one's self in the past and future is needed [1]. When anxiety is directed to a specific event, increases in intensity and its activation is episodic, then we refer to this emotion as fear. Fear is easily recognizable even in animals, and has a strong evolutionary basis, since it triggers escaping behaviors in case of danger, allowing survival. However, anxiety and fear share the same emotional features to the extent that they can be counted as two sides of the same coin. Furthermore, depending on the range of their intensity, they may be considered normal emotional reactions to the context or the core symptom of many psychiatric diseases. The former are adaptive emotions that belong to the experience of each human being; the latter are maladaptive since they prevent people from conducting a normal life.

We will refer to the second situation as anxiety disorders. These disorders are very common worldwide [2,3], and strongly impact personal and occupational life. Usual activities such as taking a plane, traveling on the subway, meeting friends and colleagues, and staying in crowded places become very stressful to the extent that, if not treated, the disorder may lead to avoidance of the feared situation. As time progresses, avoidance behaviors tend to worsen and then they start a vicious circle: in terms of conditioning paradigms, avoidance behaviors serve as negative reinforcements, since they stop the occurrence of an aversive symptom (anxiety); but, on the other hand, they also contribute to maintaining the link between the conditioned and unconditioned stimulus, preventing the extinction phenomenon.

Many different kinds of treatment for anxiety disorders are now available: behavioral treatments, cognitive psychotherapy, medication and biofeedback are among the most used. Different research studies investigating the effectiveness of the different treatments have demonstrated that exposure-based therapies are more suitable and effective then others [4–12].

Exposure is a process in which the patient is progressively exposed to the feared stimulus or the situation that provokes anxiety. Exposure alone, without relaxation training, is documented to be effective in treating a number of anxiety disorders and phobias, such as panic disorder with agoraphobia [9], social phobia [13] and obsessive–compulsive disorder [12]. However, one of the most influential exposure techniques is the procedure of systematic desensitization developed by Wolpe [14], in which exposure is applied during relaxation, an emotional and physiological state considered incompatible with anxiety and fear [15]. In these protocols, the patient learns to manage anxiety symptoms by replacing emotional maladaptive activation with relaxation and having the opportunity to monitor his/her thoughts and beliefs with a therapist while experiencing anxiety, he/she can downsize his/her cognitive attributions. This process, repeated over time, helps people to face their fears and break off the vicious circle of avoidance.

Traditionally, exposure may be achieved in two manners: *in vivo*, with direct contact with the stimulus, or by imagery. However, despite its effectiveness, both types of exposure present some limitations: some patients report difficulties when asked to imagine the feared situation, because of poor abilities in creating mental images and in getting inside a specific situation. Furthermore, emotions have been shown to modulate visual imagery and perception [16] and, in particular, fear seems to impair visualization of detailed scenes, making the mental reconstruction of the stimulus, to some extent, biased and inaccurate. By contrast, *in vivo* exposure bypasses this limitation but poses other critical issues. First, many patients are rather unwilling to expose themselves to the real situation, since it is conceived too frightening; second, the real situation is not fully under the control of the therapist; third, it requires a high effort in terms of money and time expenditure, since usually the therapist and the patient meet each other outside the therapist's office to work together on the stimulus target.

For these reasons, clinicians are showing an increasing interest for a novel tool to treat anxiety symptoms that overcomes most of these limitations: virtual reality (VR).

## VR: a new way of being there

A VR system is a combination of technological devices that allows users to create, explore and interact with 3D environments. This capability is made possible by the use of input tools (e.g., trackers, gloves and mice), which send the position and the movement of the user to the computer in real time, graphic rendering, which changes the environment coherently with the information acquired, and output devices (e.g., visual, aural and haptic), which return a feedback of the interaction to the user. The integration of these devices gives the user the opportunity to be immersed in the environment and to experience the sense of presence in a computer-generated world. Presence is defined as a 'sense of being there' [17] or as 'the feeling of being in a world that exists outside the self' [18,19].

Thanks to these features, VR has been considered a useful tool to carry out exposure-based programs that better fit the needs of the patients [20]. In effect, VR exposure treatments (VRET) present several advantages when compared with the traditional treatments carried out by both *in vivo* and imagination techniques. Many of the problems encountered with *in vivo* exposure are easily bypassed by the use of VRET: first, it is completely controllable by the therapist, who can grade the intensity of the stimulus in relation to the personal needs of each patient and eventually stop the session in case of excessive emotional activation (which is, indeed, extremely rare). In this way, the patient feels less uncomfortable about the treatment and his/her motivation increases. Furthermore, a portion of a more complex event can be selected and repeated, in order to practice exactly the critical stimulus instead of wasting time with all other concomitant aspects [21]. Compared with imagination, VRET offers the possibility to visualize a realistic environment and to interact with it, making the experience more immersive and thus increasing the personal involvement. This will result in a more effective treatment, in terms of number of sessions needed to obtain improvements and, therefore, of costs incurred.

There are also some caveats in the use of VRET, which have to be taken into account. First of all, some VR users report symptoms of sickness that target different areas (e.g., visual, vestibular, CNS and musculoskeletal). The risk of this 'cybersickness' could be decreased by a gradual introduction to virtual environments, but in people prone to these kind of symptoms it cannot be removed at all. Furthermore, there are some medical conditions that represent significant contraindications for the use of VR, such as migraine, headache and seizure disorder. Finally, when using VR with patients affected by psychosis or personality disorders, it should be noted that they are predisposed to become confused by real versus virtual worlds.

The main problem with the use of VRET is related to practical issues: to date, VR technology is not yet widespread between private clinicians, so only a small number of patients worldwide have the opportunity to undergo this kind of treatment. Even taking into account this consideration, in recent years there is an increasing interest in evaluating the capabilities of this tool, and many researchers have investigated the effects of VRET in reducing symptoms of anxiety disorders and specific phobias. A number of qualitative reviews of VRET have pointed out that it has a good potential for the treatment of specific phobias [22–26], since it produces better outcomes than imaginal exposure, and it is as effective as *in vivo* exposure, but it is pragmatically a much more attractive alternative.

Recently, even more powerful statistical analyses, such as quantitative meta-analyses, have been conducted on studies reporting VRET treatments. Parsons and Rizzo have collected data from 21 articles that evaluated anxiety and/or phobia before and after VRET [27]. The results revealed that VRET has a statistically large effect on all affective domains and, thus, is a relevant approach to reduce anxiety-related symptoms. Similarly, Powers and Emmelkamp provided effect size estimates for VR treatment in comparison to *in vivo* exposure and other control conditions [28]. They found a predictable larger effect of VRET compared with the control conditions; but more interestingly, VRET outperformed *in vivo* exposure.

Another line of research investigated the cognitive mechanisms underlying VRET and their weight in reducing symptoms [29]. The effectiveness of traditional cognitive behavioral treatments is usually justified following three major explanations: the information processing model, the perceived self-efficacy model and the cognitive/dysfunctional beliefs model. Even if all three mechanisms are involved in VRET, perceived self-efficacy and a change in dysfunctional beliefs are the best predictors of good outcome, and then should also be pursued when the stimuli are virtual in nature [30]. Table 1 summarizes the most recent studies that examined the effects of VRET for reducing anxiety disorders and phobias.

## From VR to interreality

Even if VRET demonstrated good capabilities in the treatment of anxiety disorders, there is still room for improvement. In VRET the virtual

Table 1. Summary of the most recent studies examining the effects of virtual reality exposure therapy for reducing anxiety disorders and phobias.

| Author (year) | Type of disorder | n | Experimental design | Condition(s) | Follow-up | Short-term outcome | Ref. |
|---|---|---|---|---|---|---|---|
| Beck (2007) | PTSD | 6 | Open clinical trial | VRET | – | Significant reductions in post-trauma symptoms involving re-experiencing, avoidance and emotional numbing | [50] |
| Botella (2010) | PTSD | 10 | Randomized between subject design | CBT<br>CBT + VRET | – | CBT + VRET was as effective as CBT | [51] |
| Difede (2007) | PTSD | 21 | Randomized between subject design | VRET<br>WL | – | VRET group showed a significant decline in PTSD scores compared with the WL group | [52] |
| Freedman (2010) | PTSD | 1 | Case study | EI + VRET | Gains maintained at 6 months | Large post-treatment reductions in PTSD symptoms | [53] |
| Gamito (2010) | PTSD | 10 | Randomized between subject design | VRET<br>EI<br>WL | – | Decrease on PTSD as well as on psychopathological symptoms in the VRET group when compared with EI and WL groups | [54] |
| Gerardi (2008) | PTSD | 1 | Case study | VRET | – | Improvement in PTSD symptoms | [55] |
| Krijn (2007) | Fear of flying | 86 | Between subject design | VRET<br>BIB<br>CBT | – | Treatment with VRET or CBT was more effective than BIB. No statistically significant difference between VRET and CBT | [56] |
| Krijn (2007) | Acrophobia | 26 | Randomized crossover | VRET<br>VRET + self-statements | At 6-month follow-up, most gains during treatment were not fully retained | VRET effectiveness not influenced by the addition of self-statements | [57] |
| Malbos (2008) | Claustrophobia | 6 | Open clinical trial | VRET | Gains maintained at 3 months | Significant reduction in fear towards the enclosed space and quality of life improvement | [58] |
| McLay (2010) | PTSD | 10 | Open clinical trial | VRET<br>IVE + EI | – | VR-based and traditional therapy were found to be safe and effective in the combat theater | [59] |
| Botella (2007) | Arachnophobia | 12 | Open clinical trial | VRET | The therapeutic gains were maintained at 3 months | Improvement in all clinical measures at post-treatment | [20] |

BIB: Bibliotherapy; CBT: Cognitive behavioral therapy; EI: Imaginal exposure; IVE: *In vivo* exposure; PTSD: Post-traumatic stress disorder; VR: Virtual reality; VRET: Virtual reality exposure therapy; WL: Waiting list.
Data taken from [20,50–67].

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|---|---|---|---|---|---|---|---|
| Pérez-Ara (2010) | Panic disorder and agoraphobia | 29 | Between subject design | VR<br>Interoceptive exposure simultaneous condition<br>Interoceptive exposure traditional condition | Results maintained or even improved at 3 months | Both treatment conditions significantly reduced the main clinical variables at post-treatment | [60] |
| Ready (2010) | PTSD | 9 | Randomized between subject design | VRET<br>Present-centered therapy | – | No significant differences emerged between treatments | [61] |
| Reger (2008) | PTSD | 1 | Case study | VRET | – | Self-reported PTSD symptoms and psychological distress were reduced at post-treatment relative to pretreatment reports | [62] |
| Rizzo (2009) | PTSD | 20 | Open clinical trial | Mixed clinical protocol including VRET, IVE, EI | – | 16 patients no longer met diagnostic criteria for PTSD at post-treatment | [63] |
| Robillard (2010) | Social anxiety | 45 | Randomized between subject design | VRET + IVE<br>IVE<br>WL | | Significant reduction of anxiety on all questionnaires as well as statistically significant interactions between both treatment groups and the WL | [64] |
| St-Jacques (2010) | Arachnophobia | 31 (children) | Between subject design | IVE<br>IVE + VRET | – | The use of VR did not increase motivation toward psychotherapy | [65] |
| Wallach (2009) | Fear of public speaking | 88 | Randomized between subject design | VRET<br>CBT<br>WL | – | VRET and CBT were significantly more effective than WL in anxiety reduction, but twice as many participants dropped out from CBT than from VRET | [66] |
| Wood (2009) | PTSD | 12 | Open clinical trial | VRET | – | The VRET participants' clinical levels of PTSD and depression significantly reduced | [67] |

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experience is a distinct realm, separate from the emotions and behaviors experienced by the patient in the real world: the behaviour of the patient in VR has no direct effects on the real life experience and the emotions and problems experienced by the patient in the real world are not directly addressed in VR exposure.

To overcome this limitation the interreality (IR) paradigm extends the clinical setting to a hybrid environment, bridging the physical and virtual world [31]. By bridging virtual experiences – which are fully controlled by the therapist, and used to learn coping skills and emotional regulation – with real experiences – which allow both the identification of any critical stressors and the assessment of what has been learned – using advanced technologies allows IR to offer a comprehensive clinical experience. The idea of a stricter link between real and virtual worlds is not new: the use of 'augmented reality' or 'mixed reality' technology blends virtual objects seamlessly into views of the real world. Nevertheless, all previous attempts of connecting virtual and real worlds tried to remove the boundaries between. The main outcome is a blurred experience that is neither virtual nor real. It seems that working in a blurred world, in which boundaries are not always clear, is more of a problem than an advantage: the lack of boundaries calls for new concepts of self, identity and community that have to be learned, managed and shared. Furthermore, it does not allow us to exploit the specific advantages that a virtual and the real world afford us. For instance, virtual worlds are designed to augment humans and provide them with the capability to manipulate information in ways that are not normally possible in the real world. But in blurred worlds, the level of augmentation is constrained by the features of the task/context in which the user is involved. The main goal of IR is the connection between virtual and real worlds without removing the boundaries that define them.

The interconnections between the virtual and real world are bidirectional. Behavior in the real world influences the virtual environment. For example, if emotional regulation is poor during the day, then some exercises in the virtual environment are unlocked in order to train this ability; behavior in the virtual world influences real life. For example, if I participate in a virtual support group I can interact with other participants during the day via SMS.

The link between the virtual and real world is made possible by the following technologies:

- 3D individual and/or shared virtual worlds: the individual is immersive (in the therapist's office) or not immersive (at home) in environments inhabited by motional avatars, representing other users. The immersivity is produced by providing immersive output devices (e.g., head-mounted display and force feedback robotic arms) and a system of head/body tracking to guarantee the exact correspondence and coordination of users' movements with the feedback of the environment. The user can interact with others users, socialize and participate in individual and group activities;
- Personal biomonitoring system (from the real to virtual world): made up of bio and activity sensors that monitor the emotional status of the patient and coherently modify the virtual environment. This link could be achieved in real time or not;
- Personal digital assistance and/or mobile phones (from the virtual to the real world): these devices offer the opportunity to always be connected with the virtual world, where the user can receive warning and feedback, perform homework assignments and meet other users in the context of social networks.

Compared with traditional cognitive behavioral therapy, IR presents some interesting advantages. First, IR allows the implementation of a clinical protocol targeted on the peculiar characteristic of the patient. Furthermore, in the context of IR, the patient is engaged in activities and processes that focus on relational changes and self-efficacy as well. Finally, by merging virtual and real worlds, IR gives the opportunity to address the emotions and fears experienced in real life during the training. **Boxes 1 & 2** summarize the clinical areas in which IR can improve the standard treatment for both patient and therapist, respectively.

Furthermore, from a clinical standpoint, IR offers some innovations to current VR protocols: objective and quantitative assessment of symptoms using biosensors, provision of warnings, and motivating feedbacks to improve compliance and long-term outcome. The limitations of this approach parallel those of VR. The most evident limitation is related to the availability of the equipment: the technological equipment

**Box 1. Advantages of the interreality approach (patient).**

**Acceptance**
- Through the virtual worlds, patients will meet both the critical situation and the relaxation area and they will learn to face stressful events.
- Through daily review of recorded critical situations first experienced with the therapist in the clinical session.
- Through participation in the social virtual world, under the therapist's guidance, patients will share their stressful experiences and they will learn news strategies to cope with them.

**Coping skills**
- Learning new coping skills (e.g., relaxation techniques) within the virtual worlds.
- Personal digital assistance/smartphone will be used as training/simulation devices to facilitate the real-world transfer of the knowledge acquired in the virtual world.
- Learning through the other's behavior and using them in the real world.

**Emotional regulation**
- Through frequent experiencing of feared situations in different safe environments within the virtual worlds.
- Through a mobile phone with an assistant that will intervene when patients show difficulties in real life displayed by biofeedback and recorded markers.
- Through social support within communities and outside them through the social links created in the virtual worlds.

**Cognitive restructuring**
- Getting information needed to succeed with daily tips and expert ideas.
- Through therapist support and restructuring during patients' exploration of the virtual worlds.
- Through community-shared experiences.

increases the costs of the intervention dramatically and make it unlikely to be used by private clinicians. The contribution of the patient in the management of the sessions outside the therapist's office requires a good level of familiarity with the technology and, therefore, could prevent some patients from being included in the protocol.

To date, there are a limited number of clinical trials assessing the usability and the effectiveness of the IR paradigm. Some pioneering applications of the technologies involved in IR protocols have been undertaken in the field of mental health, but never assembled together in the aforementioned manner.

As reviewed by Gorini *et al.*, many environments created specifically for therapeutic purposes are available within the platform of Second Life [32]. Most aim to help patients and caregivers dealing with psychiatric and neurological diseases: Brigadoon, for example, is a private island in which people suffering from Asperger's syndrome may meet each other and have the opportunity to practice their social skills [101]. With similar goals, Live2Give is designed for patients affected by cerebral palsy [102]. A third example of this application is targeted specifically for anxiety symptoms. Starting from a personal experience, Roberto Salvatierra, a medical student with agoraphobia, created a virtual environment to help other people suffering from the same disorder [103].

Recently, the capabilities of mobile phones as a tool for responding to a variety of clinical needs have been investigated [33]. The interest in this device is motivated by its wide diffusion: the population of mobile phones has rapidly increased in the last decades, to the extent that a large portion of the population in Europe and the USA own at least one. Furthermore, the advanced technology now available allows mobile phones to combine the use of traditional phones, such as calling someone, with broader communication capabilities, such as supporting 3D graphics, pictures, musical sounds and software programs.

Two studies based on the use of the mobile phones for anxiety management have been carried out. In the first experiment, stress inoculation training to reduce exam stress was applied. The results demonstrated that the combination of video and audio narratives administered via UMTS induced more relaxation compared with other experimental conditions (either video only or narratives only administered with alternative means, e.g., CD and Mp3 players). In the second study, the ability to relax was successfully trained in a sample of stressed patients by mobile narratives on mobile phones. The outcome of this research, taken together with other experimental studies on mobile phones, suggests that this technology is promising in the treatment of anxiety disorders, since it offers the opportunity to plug the gap between inpatient and outpatient sessions.

**Box 2. Advantages of interreality (therapist).**

**Better assessment**

- The following indexes help the therapist to redirect the therapy:
  - Indexes will be taken from biosensors that connect the stressful situation to changed physiological parameters and this will orientate the therapy.
  - Biosensors will track the emotional/heath status of the users.
  - Markers of stressful experiences will be recorded directly by the patient in the personal digital assistance/smartphone (e.g., by pressing a button) to orientate the therapy process.
  - Cognitive, emotional and behavioral feedback will be received from the virtual world, helping the therapist to conduct more effective, individually focused therapy.
  - Evaluative questionnaires and experiential tasks will be used to assess if patients have really attained the strategies they were taught.

**Decision support**

- For the session:
  - Biosensor, virtual reality and personal digital assistance outcomes will give information on emotional/heath status so the therapist will know the best direction to proceed with in therapy.
  - Cognitive and emotional responses and behavioral decisions taken in the virtual worlds will facilitate therapeutic steps.
- For the therapy:
  - The number of times the avatar steps in and intervenes will be an index of the learning and autonomy level of users. Then the therapist will submit patients to the exploration of new environments to further improve their coping skills.

**Repository of clinical cases**

- All the relevant data collected may be stored.
- In the virtual world, information will be saved in a database that will help the therapist to take information regarding users' cognitive, emotional and behavioral responses.
- Through evaluative questionnaires, the therapist will take information on patients' learned capabilities in using relaxation techniques.
- Through forms filled out in the clinical session, the therapist will have more information regarding users' appraisal and behavioral skills related to the feared situation.

## On the road to IR: the INTREPID project

The first attempt to combine VR, biofeedback and mobile phones in a protocol designed to reduce anxiety disorders has been made with the implementation of a new instrument for the treatment of generalized anxiety disorder: the INTREPID project [34–38]. INTREPID is an EU-funded research project (IST-2002–507464) aimed to improve the treatment of generalized anxiety disorder using some advanced technologies working together to make the patient experience an engaged, immersive and meaningful experience in which anxiety symptoms are monitored and replaced by relaxation.

What makes this approach unique is the possibility to combine virtual environments and biofeedback, so that the virtual world is directly modified by the physiological activation of the patient. Even if INTREPID cannot be considered an example of IR application, due to the lack of many of the features of IR programs, it deserves to be mentioned for its effort to carry the therapy out of the therapist's office. In fact, the element that INTREPID shares with the IR programs is the therapy's portability, that is, the possibility to undergo daily, in the real-life context of the patient, the session of treatment needed.

The hardware elements of the INTREPID system include:

- A wireless (Bluetooth) multisensor module: galvanic skin response (GSR)/heart rate sensor module including finger sensors that simultaneously measure heart rate and electrodermal activity (GSR);
- The Virtual Reality control unit: Asus G2S portable computer with Intel® Core™ 2 Extreme Processor X7800, Nvidia GeForce 8600 GT 256 MB DDR3 graphic card, Bluetooth support;
- A head-mounted display: Vuzix iWear VR920 with twin high-resolution 640 × 480 (920,000 pixels) LCD displays, iWear® 3D compliant;
- The therapist's netbook: (EEPC 100H–BK039X) used to control in real time the features of the virtual environment and to assess physiological parameters;
- A joystick (Xbox Controller);
- A crosscable between the portable computer and the therapist's netbook;
- A smartphone (HTC Touch Pro T7272) for relaxation homework.

The clinical protocol was programmed simultaneously inside and outside the therapist's office: the patients underwent eight sessions (two sessions per week) with the therapist and were then asked to perform the same exercises at home using the Homecare Scenario supplied by the smartphone.

The virtual environment is designed as a tropical island facing the ocean with a forest in its internal area. The patient arrives on the beach by a boat, and following a footpath reaches the starting point, where different panels are allocated to indicate the different clinical areas. In each of the clinical areas a relaxation exercise is arranged, in which an element of the environment is modified by the physiological parameters recorded in real time.

A Phase II controlled clinical trial conducted on 12 patients with generalized anxiety disorder [39] led to important considerations. The clinical use of the mobile phone to re-experience and anchor the contents of VR sessions at home is justified by the judgments of the users. When interviewed about the usefulness of this device, the majority of patients reported a high level of satisfaction, since it helped them to apply their abilities learned with the therapist in a real-life condition. The combination of VR and biofeedback seems to provide additional value to VR alone: psychological self-reported measures of anxiety decreased significantly more in the group using VR plus biofeedback than in the group using VR alone. The psychophysiological indexes, although not statistically significant, go in the same direction.

## Conclusion

In the past decade medical applications of VR technology have been rapidly developing, and the technology has changed from a research curiosity to a commercially and clinically important area of medical informatics technology [40,41]. However, there is growing recognition that VR can also play an important role in clinical psychology.

One of the main advantages of a virtual environment for clinical psychologists 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 existing applications, VR is used to simulate the real world and ensures that the researcher has 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 structuring a large amount of controlled stimuli, and simultaneously, monitoring the possible responses generated by the user of the program, offers a considerable increase in the likelihood of therapeutic effectiveness, as compared with traditional procedures.

Furthermore, the availability of low-cost hardware and software is opening the VR experience to individual clinicians. For instance, the NeuroVR platform [104] – a cost-free VR toolkit based on open-source software – allows nonexpert users to easily set up a clinical virtual environment and to visualize it using both immersive and non-immersive technologies [42,43]. Finally, the reduction in the distance between the virtual and real world allowed by the IR paradigm frames VR in a more contextualized experiential process [44].

Specifically, the clinical use of IR is based on a closed-loop concept that involves the use of technology for assessing, adjusting and/or modulating the behaviors and emotions of the patient in both real and virtual worlds [31,45]. On one hand, the patient is continuously assessed in the virtual and real worlds by tracking their behavioral and emotional status in the context of challenging tasks (customization of the therapy according to the characteristics of the patient). On the other hand, feedback is continuously provided to improve the skills of the patient through a conditioned association between performance and execution of assigned tasks (improvement of self-efficacy). In general, this closed-loop experience is used as a trigger 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 [46]:

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

On one hand, in the real world, the dynamic behavioral profile of the patient and his/her physiological response to events is collected and assessed through different sensors (e.g., GPS) and biosensors (e.g., heart rate, GSR). Using these data, both patient and therapist can identify the antecedents and the consequences of any crisis. Furthermore, it is even possible to forecast a possible anxiety attack and to provide, in real time, suggestions and feedback to the patient.

On the other hand, 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 [47]. In this sense, the virtual experience is an 'empowering environment' that therapy provides for patients.

Besides, it is unnecessary to wait for situations to happen in the real world because any situation can be modeled in a virtual environment, thus greatly increasing self-training possibilities [48]. In addition, VR allows the situation to be graded so the patient can start at the easiest level and progress to the most difficult. Gradually, because of the knowledge and control afforded by interaction in the virtual world, the patient will be able to face the real world.

## Future perspective

The future of health technology will probably include two main features: portability and IR. Portability refers to the use of portable devices (e.g., personal digital assistance and smartphones) to provide VR everywhere. Having the possibility to run a VR system on a pocket device will allow patients to practice the skills learned in therapist's office by themselves and without limitations.

Currently, the mobile phone supports advanced communicative features, such as real-time video communications, audio and the exchange of texts and videos. This innovation will increase in the next few years, so a new generation of hardware-accelerated mobile devices will soon be joined by a suite of emerging 3D software standards that give developers the ability to create interactive content and other applications that have not been possible before [33]. Furthermore, the creation of an open standard (Ant+ [105]) for connecting biosensors to mobile phones is pushing the development of personal sensors for advanced self-tracking.

This trend is also parallel to the development of online VR worlds, such as Second Life [106] or JustLeapIn [107]. Compared with the traditional VR worlds, these online worlds appear to have much to offer to exposure-based therapy. Since they allow multiplayer interactions, the therapist and the patient can share the same online virtual space. This means that the therapist can accompany the patient through a particular threatening experience just by logging onto a specific website and adopting a preferred avatar. The way of interaction as well as the surrounding environment can be easily modified on the basis of therapeutic needs. In the case of social phobia, for example, after practicing with the therapist within a closed environment (i.e., the therapist's virtual office), the patient can be taken to a virtual world populated by other avatars and asked to initiate a conversation and obtain feedback from them in real-time audio through the use of a microphone. Similarly, patients with agoraphobia can be exposed to a variety of unfamiliar worlds, different from those the clinician can provide in an office setting. These are just a few examples describing the promising potential of online virtual worlds in the field of psychological therapy. Recently the American company InWorld Solutions [108] launched 'InWorld', an online VR environment for therapy only, that provides a glimpse into the future of VR therapy.

InWorld is easy to use, even for those with minimal technological skills. With the click of a mouse, the clinician and patient can modify their avatars to represent themselves in movement, action and communication. With a few more clicks they transport into a selected virtual environment.

All interactions are natural – the avatars talk to each other – so there is no need to type. To move the avatar the patient uses the arrow keys or a controller. All interactions can be recorded and saved for review during the session or at a later date. Furthermore, because InWorld is internet-based, clinicians and healthcare organizations can provide therapy to clients remotely, including real-time crisis intervention.

The bridging of mobile phones with online VR worlds is the final goal of the IR paradigm. In the standard cognitive behavioral protocol for anxiety disorders "imagination and/or exposure evoke emotions and the meaning of the associated feelings can be changed through reflection and relaxation" [49]. IR provides an alternative: a controlled experience evokes emotions that result in meaningful new feelings, which can be reflected upon and eventually changed through reflection and relaxation [44].

On one side, the patient is continuously assessed in the virtual and real worlds by tracking the behavioral and emotional status in the context of challenging tasks (customization of the therapy according to the characteristics of the patient). On the other side, feedback is continuously provided to improve both the appraisal and the coping skills of the patient through a conditioned association between effective performance state and task execution behaviors (improvement of self efficacy). Overall, from the clinical viewpoint, the IR paradigm may offer the following innovations to the current protocol for anxiety disorders:

- Objective and quantitative assessment of symptoms using biosensors and behavioral analysis: monitoring of the patient's behavior and of his/her general and psychological status, early detection of symptoms of critical evolutions and timely activation of feedback in a closed-loop approach;
- Decision support for treatment planning: monitoring the response of the patient to the treatment, management of the treatment and support to the clinicians in their therapeutic decisions;
- Provision of warnings and motivating feedback to improve compliance and long-term outcome: the sense of 'presence' allowed by this approach affords the opportunity to deliver behavioral, emotional and physiological self-regulation training in an entertaining and motivating fashion.

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