Interreality: the Use of Advanced Technologies in the Assessment and Treatment of Psychological Stress

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Abstract

Stress and its related comorbid diseases are responsible for a large proportion of disability worldwide. In particular, chronic stress is the main responsible for the dramatic increase of premature mortality in the Western countries. However, advanced simulation and sensing technologies, such as virtual reality and mobile biosensors offer interesting opportunities for innovative personal health-care solutions to stress. In this work, we describe a technology-based approach to the assessment and treatment of stress that is based on the vision of Interreality. The main feature of interreality is the creation of a hybrid-augmented experience merging the physical and virtual world. This is achieved through: a) an extended sense of presence: in interreality advanced simulations (3-D virtual worlds) are used to transform health guidelines and provisions into experience; b) an extended sense of community (social presence): interreality uses hybrid social interaction and dynamics of group sessions to provide each user with targeted social support in both the physical and virtual world; c) real-time feedback between the physical and virtual worlds: interreality uses bio and activity sensors and devices (e.g. smartphones) to track both the behavior and the health status of the user in real time and to provide targeted suggestions and guidelines. The feedback activity is twofold: (1) behavior in physical world influences the experience in the virtual one, and (2) behavior in the virtual world influences the experience in the real one.

Keywords: stress monitoring, wearable sensors, interreality

1. Introduction

Repeated and early exposure to stress in persons with a particular genetic disposition may result in a decreased threshold for developing anxiety [1]. Over-excitation can influence the affective system and may induce changes in the emotional circuitry of the brain that can contribute to stress-related psychopathology [1]. As underlined by Cohen and colleagues [2], associations between psychological stress and disease have been established, particularly for depression, CVD, and HIV/AIDS. Other areas in which evidence for the role of stress is beginning to emerge include upper respiratory tract infections, asthma, herpes viral infections, autoimmune diseases, and wound healing. Stressful events influence the pathogenesis of physical disease by causing negative affective states (e.g. feelings of anxiety and depression), which in turn exert direct effects on biological processes (they activate the hypothalamic-pituitary-adrenocortical axis - HPA - and the sympathetic-adrenal-medullary - SAM - system) or behavioral patterns that influence disease risk. Exposures to chronic stress are considered the most toxic because they are most likely to result in long-term or permanent changes in the emotional, physiological, and behavioral responses that influence susceptibility to and course of disease. This includes stressful events that persist over an extended duration (e.g. caring for a spouse with dementia) or brief focal events that continue to be experienced as overwhelming long after they have ended (e.g. experiencing a sexual assault).

According to the Cochrane Database of Systematic Reviews [3], the best validated approach covering both stress management and stress treatment is the Cognitive Behavioral Therapy (CBT). Typically, this approach may include both individual and structured group

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interventions (10 to 15 sessions) interwoven with didactics. It includes in-session didactic material and experiential exercises and out-of-session assignments (practicing relaxation exercises and monitoring stress responses). The intervention focuses on learning to cope better with daily stressors (psychological stress) or traumatic events (post traumatic stress disorders) and optimizing the use of social resources. The intervention also uses group members and group leaders as role models (for positive social comparisons and social support); encourages emotional expression; replaces doubt appraisals with a sense of confidence by means of cognitive restructuring; and skills in anxiety reduction (by progressive muscle relaxation and relaxing imagery), interpersonal conflict resolution, and emotional expression (by means of assertion training). The CBT package thus includes both problem-focused (e.g., active coping and planning) and emotion-focused (e.g., relaxation training, use of emotional support) coping strategies.

This is why Cohen and colleague [2] on their JAMA review suggest: "The development of interventions that can reduce the behavioral and biological sequelae of psychological stress and the demonstrated efficacy of such interventions in randomized clinical trials would provide critical data on the clinical importance of this work." (p. 1686).

Two recent meta-analysis [4,5] demonstrated the efficacy of virtual reality (VR) in the treatment of stress-related disorders. Specifically, VR has been used to provide the exposure/experiential part of a Cognitive Behavioral Intervention. A good deal of research has shown that exposure therapy is effective for reducing negative affective symptoms [6]. Exposure to emotional situations and prolonged rehearsal result in the regular activation of cerebral metabolism in brain areas associated with inhibition of maladaptive associative processes [7]. Identical neural circuits have been found to be involved in affective regulation across affective disorders [8]. In Virtual Reality Exposure (VRE), users are immersed within a computer-generated simulation or virtual environment (VE). During exposure, the patient experience specific feared stimuli within a safe context that simulates real-life situations. VRE fits well the emotion-processing model, which holds that the fear network must be activated through confrontation with threatening stimuli and that new, incompatible information must be added into the emotional network [9].

2. Interreality for stress management

CBT has undergone a very large number of trials in research contexts. However, it has been less efficacious in clinical contexts and it has become obvious that CBT has some limitations when applied in general practice. The Interreality approach focuses on three major limitations of conventional CBT:

- the therapist is less relevant than the specific protocol used;
- the focus of the therapy is more on the top-down model of change than on the bottom-up;
- the protocol is not customized to the specific characteristics of the patient.

By creating a bridge between virtual and real worlds, Interreality allows a full-time closed-loop approach actually missing in conventional CBT regimens.

From the technological viewpoint Interreality is based on the below devices/platform:

- 3D Individual and/or Shared Virtual Worlds (They allow: Objective Assessment, Provision of Motivating Feedback)
- Personal Biomonitoring System (From the Real World to the Virtual One; It allows: Objective and Quantitative Assessment, Decision Support for Treatment):
- Personal Digital Assistants (PDAs) and/or Mobile Phones (From the Virtual World to the Real One; It allows: Objective Assessment, Provision of warnings and motivating feedbacks).

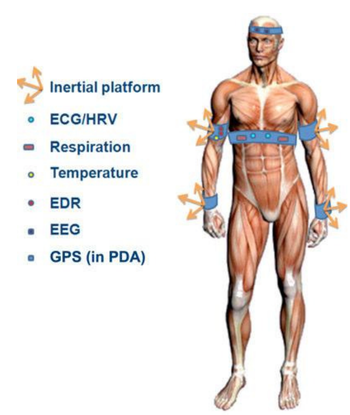

Figure 1 – Personal Biomonitoring System

These devices are integrated around two subsystems: the Clinical Platform (inpatient treatment, fully controlled by the therapist) and the Personal Mobile Platform (real world support, available to the patient and connected to the therapist) that allow:

- to monitor the patient behaviour and of his general and psychological status, early detection of

symptoms of critical evolutions and timely activation of feedback in a closed loop approach;
- to monitor the response of the patient to the treatment, management of the treatment and support to the doctors in their therapeutic decisions.

By creating a bridge between virtual and real worlds, Interreality allows a full-time closed-loop approach actually missing in current approaches to the assessment and treatment of psychological stress:

- the assessment is conducted continuously throughout the virtual and real experiences: it enables tracking of the individual's psycho-physiological status over time in the context of a realistic task challenge.
- the information is constantly used to improve both the appraisal and the coping skills of the patient: it creates a conditioned association between effective performance state and task execution behaviours.

In conclusion, the INTERSTRESS approach provides a two-fold feedback activity:

- Behaviour in the physical world influences the experience in the virtual world:
  - For example, if my emotional regulation during the day was poor, some new experiences in the virtual world will be unlocked to address this issue.
  - For example, if my emotional regulation was okay, the virtual experience will focus on a different issue.
- Behaviour in the virtual world influences the experience in the real world:
  - For example, if I participate in the virtual support group I can SMS during the day with the other participants.
  - For example, if my coping sklills in the virtual world were poor, the decision support system will increase the chance of possible warnings in real life and will provide additional homework assignments.

3. Method

Interreality allows a full-time closed-loop approach actually missing in current approaches to the assessment and treatment of psychological stress:

- the assessment is conducted continuously throughout the virtual and real experiences: it enables tracking of the individual's psycho-physiological status over time in the context of a realistic task challenge.
- the information is constantly used to improve both the appraisal and the coping skills of the patient: it creates an effective association between performance state and task execution behaviors.

The 3D Virtual Worlds (3DWs) are organized around three different but interconnected islands/areas: the "Learning Island", the "Community Island" and the "Experience Island".

The goal of the Learning Island is to use motivation provided by the virtual worlds to teach the users about how to improve their stress management skills. The Learning Island is organized around different learning areas both without and with teachers (classes). In this island the users:

a. Learn the main causes of stress and how to recognize stress symptoms;
b. Learn to become aware of and modify unhelful toughts and maladaptive thinking;
c. Learn some stress relieving exercises (e.g., relaxation training or diaphragmatic breathing, use of emotional support);
d. Get the information needed to succeed, with daily tips and expert ideas.

The goal of the Community Island is to use the strength of virtual communities to provide real-life insights aimed at reducing avoidance behaviors and unrealistic thinking. The Community Island is organized around different zones in which users discuss and share experiences between themselves with or without the supervision of an expert (physician, psychologist, therapist, etc.). In this island the users:

a. Enjoy support and guidance;
b. Learn successful and unsuccessful examples of problem-focused and emotion-focused coping strategies;
c. Benefit from the exchange of practical experiences and tips from other users.

Finally, the goal of the Experience Island is to use the feeling of presence provided by the virtual experience to practice controlled exposure, emotional/relational management; general decision-making and problem-solving skills. The island will include different zones presenting critical situations related to the maintaining/relapse mechanisms and two relaxation areas. Each of these environments is experienced under supervision only. In the critical situation areas the user:

is exposed to specific/general stressful situations and helped in developing specific strategies for coping with them. After the experience the therapist explores the patient's understanding of what happened in the virtual experience and the specific reactions – emotional and behavioural - to the different situations experienced. If needed, some new strategies for coping with the situations are presented and discussed. In the relaxation areas the users enjoy a very relaxing environment (beach, waterfall, lake) and learn some basic relaxation procedures following a narrative voice.

Figure 2 - 3D Virtual Worlds

In Interreality, the social and individual users' activity in the virtual world has a direct link with his/her life through a mobile phone/digital assistant. This link is at three levels:

1. Follow-up (warnings and/or feedbacks): it is possible to assess/improve the outcome of the virtual experience through the PDA/Phone, eventually also using the info coming from the bio and activity sensors.

o Example: if the real world outcome is poor after receiving a real time warning, the user will experience again the same virtual environment. If it is good, the user will receive in real time motivating feedback and will be able to share his/her experience with other users.

2. Training/Homework: thanks to the advanced graphic/communication capabilities now available on PDAs/Smarthphone, they can be used as training/simulation devices to facilitate the real-world transfer of the knowledge acquired in the virtual world.

o Example: The relaxation techniques learned in the virtual world can be experienced again in the real life context before or during stressful activities.

3. Community: the social links created in the virtual world can be continued in the real world even without revealing the real identity of the user.

o Example: I can SMS a virtual friend in my own real context to ask for support.

Wearable physiological and behavioural sensors are used to track the emotional/health status of the user allowing the decision support system to influence his/her experience. The wearable interface integrates sensors for the transduction of relevant parameter related to stress monitoring [10]. Such parameters include HRV, respiration rate, activity and GPS data, that will be obtained by means of the Personal Biomonitoring System and main value/parameters show to the user through the smartphone.
The interreality processing architecture consists of a framework divided in three sections: SensorDriver, WConnection and Decision Support.

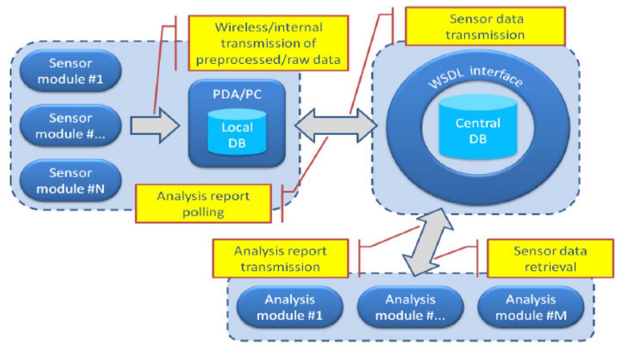

Figure 3 - The interreality framework

The interreality framework core will allow each single algorithm (data gathering and dispatching, data filtering, pre-processing, pattern recognition algorithms, i.e. artificial neural networks and fuzzy-rules knowledge-based models) to be executed as a parallel running process. The interreality framework core guarantees processes synchronization and connections, to gain time-space correlation, acquire information in event-based sampling (EBS), time-based sampling (TBS) and Combined Time-Event Based Sampling (CTEBS) modalities. The SensorDriver section allows multimodal information coming from different sensor technologies, context, localization and self-reports to be merged thanks to common framework protocols. SensorDriver libraries will enable the multimodal data buffering, the abstraction from the specific sensor and hardware interface technologies, data filtering and dedicated pre-processing algorithms. WConnection section will enable the connection between processes storing references of both sources and destination processes. In this section the artificial neural networks supervised training processes, as well as the self-reporting processes will be connected, synchronized and executed. In the Decision Support section a linguistic fuzzy-rules knowledge-based model will allow to analyze the different behavioural, mental and physiological classification states (outputs) of the artificial neural networks gaining a dedicated linguistic feed-back to the user.

The decision support system allows physiological and behavioural markers of stress, critical states and behaviours to be identified, as well as to help defining the treatment planning. The decision support system is a knowledge-based hierarchical, integrated, modular, predictive model able to combine cognitive behavioural therapy with events related to user's behaviour, physical state, mental state, context, communication and self-reports. All the control processes, data processing, pattern recognition algorithms, knowledge-based models, sensory interfaces and feed-backs are realized as interoperable single parallel running processes within a dedicated framework. The flow of multimodal information coming from different sensor technologies, context, localization and self-reports are used to identify the context and classify the user's behaviour, as well as physiological state, in order to unravel correlation between possible causes and effects following event-based sampling, time-based sampling and combined time-event based sampling strategies.

4. Interreality: The communication between real and virtual world

In interreality, the social and individual users' activity in the virtual world has a direct link with his/her life through a smartphone. This link is at three levels:

- Follow-up: it is possible to assess/improve the outcome of the virtual experience through the smartphone using the information coming from the wearable sensors.
- Training/Homework: thanks to the advanced graphic/communication capabilities now available on smarthphones, they are used as training/simulation devices to facilitate the real-world transfer of the knowledge acquired in the virtual world.
- Community: the social links created in the virtual world can be continued in the real one even without revealing the real identity of the user.

Conclusions

The Interreality approach has the potential to improve current limitations of cognitive-behavioral therapy. The specific advantages offered to PTSD treatment by the interreallity approach are:

• an extended sense of presence: interreality uses advanced simulations (virtual experiences) to transform health guidelines and provisions in experience. In interreality the patients do not receive abstract info but live meaningful experiences;

• an extended sense of community: interreality uses hybrid social interaction and dynamics of group sessions to provide each users with targeted – but also anonymous, if required - social support in both physical and virtual world.

• a real-time feedback between physical and virtual worlds: interreality uses bio and activity sensors and devices (PDAs, Mobile Phones, etc) both to track in real time the behavior and the health status of the user and to provide targeted suggestions and guidelines.

Our research strategy is based on a continuous and synergic interaction between: the medical and psychological expertise guiding the research and ensuring the medical consistency of the explored and developed solutions and providing the methods for the validation of the developed solutions; the ICT providing new and advanced tools able to open new horizons in monitoring, treatment and management of the disease with benefits for both the medical professionals (decision support in therapy planning) and for the patients (confidence, reassurance, quality of care).

Acknowledgments

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