A Virtual Reality Claustrophobia Therapy System – Implementation and Test

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ABSTRACT

Virtual reality exposure therapy (VRET) is becoming an increasing commonplace technique for the treatment of a wide range of psychological disorders, such as phobias. Effective virtual reality systems are suggested to invoke presence, which in term elicits an emotional response, helping to lead a successful treatment outcome. However, a number of problems are apparent: (1) the expense of traditional virtual reality systems hampers their widespread adoption; (2) the depth of research into several disorders is still limited in depth; and (3) the understanding of presence and its relation to delivery mechanism and treatment outcome is still not entirely understood. We implemented and experimentally investigated an immersive VRET prototype system for the treatment of claustrophobia, a system that combines affordability, robustness and practicality while providing presence and effectiveness in treatment. The prototype system was heuristically evaluated and a controlled treatment scenario experiment using a non-clinical sample was performed.

In the following, we describe the background, system concept and implementation, the tests and future directions.

KEYWORDS: Claustrophobia, Virtual Reality Exposure Therapy (VRET), XNA

INDEX TERMS: H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities, Evaluation/methodology; H.5.2 [User Interfaces]: Prototyping; H.1.2 [User/Machine Systems]: Software psychology.

1 INTRODUCTION AND RELATED WORK

The use of exposure therapy to treat psychological disorders such as phobias is a well-established technique. Exposure to feared situations is common across many psychotherapy treatments for anxiety [1], and has been shown in many clinical trials to be a highly efficacious treatment for obsessive-compulsive, anxiety, and phobic disorders [2]. Traditionally, this form of therapy has been conducted by exposure to either real stimuli (in vivo therapy), or to imagined stimuli (in imagino therapy); often, a course of therapy will utilise both techniques. The level of exposure to feared objects can be varied between flooding or gradual exposure. In the former, the patient is suddenly confronted with the most intense of anxiety-provoking stimuli; in gradual exposure, also known as systematic desensitization, the patient is exposed and moved through a carefully chosen hierarchy of stimuli.

The use of exposure therapy has been shown to be effective in the treatment of phobias [3]. Phobias, or pathological fears, are the most common of psychological disorders, with a study by [4] finding that 16.3% of Americans suffer from some form of agoraphobia, social phobia or specific phobia. A phobia is a strong, irrational, persistent fear of certain activities, situations, things, or people, which is generally regarded to be caused by a combination of external events and genetic predisposition [5]. However, regardless of how a phobia arises, a sufferer experiences the same symptoms [6], like feelings of panic, uncontrollable behavior, and escape and in particular avoidance behavior.

These symptoms lead to a "stimulus-response association between anxiety reduction and avoidance behavior (operant conditioning)" [7] that serves to reinforce phobic behavior. As such, a phobia can cause extreme disruption and interference to a sufferer's life.

The use of virtual reality exposure therapy, or VRET, in the treatment of psychological disorders is becoming increasingly established as a supplement for conventional therapy techniques, particularly in the treatment of phobias. This technique is a cognitive-behavioral approach that has roots in techniques of both systematic desensitization and exposure therapy. In VRET, a patient is immersed within a virtual environment, in which they are confronted with anxiety-provoking stimuli. As [8] notes, these stimuli "should provoke the same psychological and physiological reactions as the real world situation.". During therapy, the patient is gradually exposed to a hierarchy of stimuli, as in systematic desensitization.

Many studies show the effectiveness of VRET in different application areas, for instance in the treatment of fear of heights [9], fear of flying [10] or fear of spiders [11]. With respect to the scope of this paper, some preliminary work was done in the realm of treating the fear of small or closed spaces, or claustrophobia [12][13].

Almost all studies make use of rather specialized and expensive equipment not generally suitable for the introduction into a "standard" therapist's office. Because most of the practitioners work by themselves or with just a few partners, they can be considered as small businesses with limited resources. To eventually transfer a VRET system to practical use some requirements apply right from the beginning of (our) research. These requirements have been developed together with a practicing clinical psychologist and include aspects like affordability of hardware and software, customizability of the VRET environment regarding differences of patients and procedures, as well as degree of controllability, robustness and effectiveness. Of particular importance here is the provision of a sense of presence as a pre-requisite for a successful treatment while maintaining affordability and robustness.

Based on these assumptions we conceptually designed, implemented and tested a VRET system for treating claustrophobia

2 IMPLEMENTATION

An in-depth consideration of the requirements (in particular affordability, robustness and practicality while providing presence and effectiveness in treatment) led to a hardware and software framework favoring either a standard PC system (w/ high-end graphics and perhaps incorporating an inexpensive head-mounted display) or a game console system.

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2.1 Base system

2.1.1 Software framework

Microsoft's XNA framework (Game Studio 2.0) is a free of charge software solution for the development of computer games to be deployed to a game console device (Xbox360) or to be run as a Windows .NET application on a standard PC. With these properties it matched our requirements ideally. XNA provides a basic scenegraph API, 3D model loaders, (spatial) sound processing and display and I/O device handling (incl. game controller) amongst others. Besides this standard XNA API functionality we utilized Fabio Policarpo's BoxCollider (http://fabio.policarpo.nom.br/) for collision detection and samples provided by the XNA Creator's Club (http://creators.xna.com) for screen management and 3D audio generation. The system is implemented in C# using the Visual Studio Express 2005 IDE.

2.1.2 Hardware

We've implemented two different, though relatively affordable versions of the system to be tested against each other: a 32" monitor version (Samsung, 1360x768@60Hz) and a lightweight monoscopic head-mounted display (HMD) version (iVisor, 800x600@75Hz). Both versions utilize a standard Xbox360 gamepad controller (wired version). Figure 1 depicts the components used. We did not use the game console for the environment (yet), an affordable PC system is used instead (Pentium 4, 3.60GHz; 1.00GB of RAM, ATI FireGL V3100).

The HMD is tracked with an inexpensive OptiTrack FLEX:3 (http://www.naturalpoint.com/optitrack/products/flex-3/) system using retro-reflective markers on the HMD ("vector clip"). The OptiTrack SDK 1.3.035 was used to interface the tracker with the XNA environment.

Figure 1. Hardware at a glance

2.1.3 Virtual environment

The environment consists of four interconnected rooms with an increasing number of claustrophobic cues (see Figure 2). While the first room (see Figure 3) represents a rather normal, bright and spacious living room situation the fourth room (see Figure 6) is dark, small and window-less. The environment (including the collision meshes) was modeled with DeleD Pro 1.87 (http://www.delgine.com). Some interaction triggered animations have been added, i.e. after going through doors the doors close behind the users, locking him/her in gradually while progressing through the rooms.

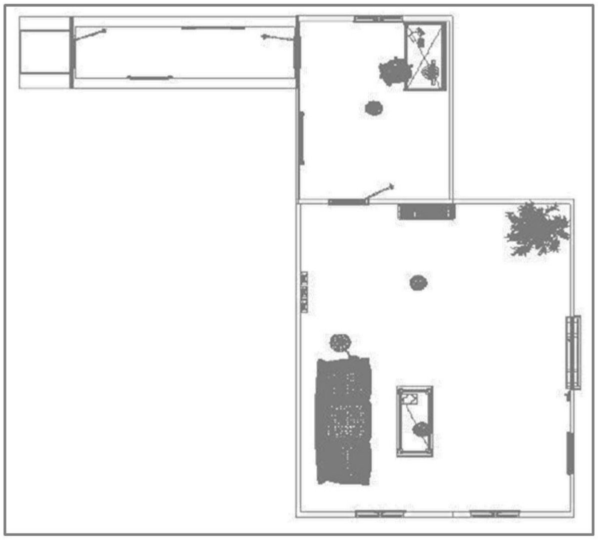

Figure 2. Floor plan: decreasing size and changing features

The navigation (travel) through these rooms is controlled with the Xbox360 controller, using "standard" button assignments: left thumb stick for walking and right thumb stick for looking around / turning. When the HMD is used this movement is augmented with view rotations of +/- 65 degrees horizontally and +/- 30 degrees vertically, restricted by the tracking volume of the OptiTrack. Figure 4 shows the HMD in use; the view into the virtual environment is not only rendered for the HMD but is also shown on the screen to monitor what the user is experiencing.

Figure 3. A user's view into the environment (room #1)

3 EVALUATION

We've incrementally tested the system: (1) according to its technical correctness, (2) with a heuristic expert evaluation and finally (3) with a laboratory experiment comparing the two hardware conditions.

3.1 Heuristic evaluation

Four heuristic evaluators were asked to use the first technical correct (bug-free) version of the system to find flaws to be rectified before the laboratory experiment. For example, the evaluators reported issues with the rendering (z-buffer, clipping), navigation rotation speed, lag in the HMD version, room size issues, and the lack of appropriate sound (doors closing, footsteps). All these findings have been addressed in the final, experimental version.

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Figure 4. HMD variant in use

3.2 Laboratory Experiment

The laboratory experiment should provide preliminary insight in addressing our main hypothesis, that an affordable, robust and practical system can provide appropriate levels of presence and effectiveness in the treatment of psychological disorders. An effective system should elicit presence scores not significantly different than those reported in other successful studies. The aforementioned two versions of the system (monitor, HMD) provided two (affordable) conditions to be investigated. For ethical reasons, only non-clinical subjects were targeted.

3.2.1 Participants

Eighteen participants (12 male and 6 female) with a mean age of 28.4 years (range 19 - 62) could be recruited for the experiment. Two had to be excluded at the beginning of the experiment because of reported levels of claustrophobia. The participants were "paid" with a chocolate bar. All participants had prior experience with computer systems, but not with the use of head-mounted displays. Most (14) had computer game experiences.

3.2.2 System and Apparatus

As shown in Figure 4 the entire system was placed on top of a desk. The participants experienced the system in a normal office environment, including seating position and height. The room light was dimmed to improve the immersion effect. The following main questionnaires have been used:

- CLQ – measuring trait claustrophobia [14] This instrument consists of 26 items, for instance: "How anxious would you feel in the following places or situations?: (9) Standing in the middle of the third row at a packed concert realizing that you will be unable to leave until the end."
- IPQ (14 items) and ITC-SOPI (44 items) measuring presence, negative effects, ecological validity and engagement [15][16], e.g. "How aware were you of the read world surrounding while navigating in the virtual world? (e.g. sounds, room temperature, other people)" or "I had the sensation that parts of the displayed environment (e.g. characters or objects) were responding to me", respectively.
- SUDS (4 items for the 4 rooms with 10 quality levels each and one additional item) – measuring the effect of the system on anxiety (discomfort and distress) [17], e.g. "During my exploration of the fourth room (the closet), the level of anxiety or distress I felt was (please circle the appropriate number): 1- No anxiety … 10 – Unbearable anxiety" and an additional item of: "At any time during your experience, did you feel trapped or suffocated? If so, please describe where and how in the environment this occurred."

3.2.3 Procedure

After the introduction into the experiment and assessing the participant's tendency towards clinical claustrophobia (where 2 have been excluded as a result) users were given the opportunity to make themselves briefly familiar with the use of the system. The order of the conditions (screen (1) vs. HMD (2)) has been randomized. Each participant experienced both conditions in one session (within-subject design). Then, the subjects got the task to proceed through the four rooms while exploring the environments to an extent to be able to report on as much detail as they can afterwards. Reaching the fourth and final room ends the task and the subjects were asked to fill in the questionnaires (SUDS, presence scales). Figure 3 shows the initial room; Figure 5 and Figure 6 show the following rooms with increasing claustrophobic features.

Figure 5. User's view into second room

The same procedure was repeated a week later with the same participants to control the so-called "wow effect" (first time exposure to new technology or environments) and learning and training effects.

3.2.4 Results & Discussion

The results indicate that both systems are effective in terms of providing a system that allows for the development of a sense of presence in the environment and for certain levels of discomfort (SUDS) indicating potential future use in therapeutic settings.

Both conditions reported similar scores across both sessions on the spatial presence (SP) factor ITC-SOPI. ($SP_{1,\,S1} = 2.88$; $SP_{2,\,S1} = 3.23$; $SP_{1,\,S2} = 3.10$; $SP_{2,\,S2} = 3.21$). The differences between these display devices were not significant, and were in line with the spatial presence reported by computer game users in [16]. Levels of presence reported were comparable to those reported by users of the treatment system detailed in [18]. Presence showed no significant "wow effect". Users of the system showed anxiety and arousal, with anxiety reported to increase as users moved between rooms, especially in the third and fourth rooms. The level of anxiety reported was more pronounced while using the HMD, with an average anxiety greater than zero experienced in all rooms; contrastingly, anxiety experienced by users of the monitor was only above zero in the final room. Reported anxiety decreased on the successive use of the system, suggesting habituation or familiarity with the system.

While users of the HMD reported the environment as having a higher level of ecological validity, and maintained a higher level of engagement, the level of negative effects experienced were reportedly slightly higher than those they experienced using the monitor. Evidence from a post-test interview suggested that preference between display mechanisms was equally split.

Figure 6. User's view into third and fourth room

4 CONCLUSION & FUTURE WORK

We've presented a Virtual Reality Exposure Therapy (VRET) system for the treatment of claustrophobia, which is affordable and potentially efficacious. The system was tested and effects could be shown with a small, non-clinical sample. Based on these findings we will further develop the system towards a productive prototype to be evaluated in a therapist's office. Based on our findings regarding anxiety elicitation, we will continue to develop both, the HMD and large monitor versions. This system also provides potential for application to other psychological disorders. Further work must establish the generalizability of this system to other disorders, such as agoraphobia.

The improved system will be tested in case studies with users actually suffering from claustrophobia. These studies will be performed in our partner's therapy office. Finally a version will be provided which can be used on a game console (MS Xbox360), allowing for an actually inexpensive, but effective exposure therapy treatment.

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