Collaborative Mixed Reality Exposure Therapy

Holger Regenbrecht[1] Daniel Wickeroth[1,2] Brian Dixon[3] Stefan Mueller[2]
[1]University of Otago, Information Science, New Zealand
[2]University of Koblenz, Computervisualistik, Germany
[3]University of Otago, Psychology, New Zealand
holger@infoscience.otago.ac.nz daniel.wickeroth@uni-koblenz.de brian@psy.otago.ac.nz Stefan.Mueller@uni-koblenz.de

Abstract

In addition to established methods, the treatment of mental disorders using Virtual Reality Exposure Therapy is becoming commonplace. We present an approach, which extends this concept in three ways: (1) the provision of maximum control for the therapist over the exposure environment, (2) the inclusion of different media and mediation elements in the virtuality continuum in Mixed Reality, and (3) support for co-located and remote collaboration between therapist and client.

This paper gives a brief overview of related work in the field, describes our conceptual approach and a first implementation, and highlights initial findings and issues. Empirical results of our work in progress will be presented at the conference.

1. Introduction

Many of us experience fear or try to avoid certain situations in different ways. We feel uncomfortable while standing at the edge of a cliff, do not really like to touch a hairy spider or simply do not like to travel in a 30 year old airplane. This feeling of discomfort is a normal reaction and is probably a result of evolutionary survival strategies.

With some people, these reactions of fear or avoidance are developed to an extent, where normal social behavior is negatively affected and therefore treatment is advisable or even necessary. In particular phobias, like the fear of heights, fear of flying, or the fear of public speaking, the problem can be a significant disadvantage for some persons in their private or business relationships and behavior.

Therapists in clinical psychology have developed several successful methods to treat these phobias. Clients (patients) are confronted with the fear-evoking stimuli either in reality (e.g. taking the client to a high bridge) or in letting the client imagine a fearful scenario, showing pictures or reading texts evoking a situation normally avoided by the client. The level of exposure to feared stimuli in these situations can be controlled by the therapist in terms of the approach adopted in the therapy from unexpected, sudden confrontation (flooding, implosion) to a carefully chosen, graduated exposure to images or situations (systematic desensitization). In any case, the client learns to cope with the fear evoking stimulus by experiencing the control of his/her avoidance / approach behavior.

In recent years, these methods, *in vivo* therapy (reality exposure) and *in imagino* therapy (imagined exposure), have been supplemented by a third method: *in virtu* therapy, thanks to the developments in interactive, three-dimensional computer technology (Virtual Reality – VR). [16] As proposed by North et al. [14] the virtual therapy environment should provoke the same psychological and physiological reactions as in the real world situation. Rothbaum et al. [19] laid the foundations in proving the empirical evidence of successfully applying Virtual Reality exposure therapy (VRET). They implemented a VRET system for the treatment of acrophobia (fear of heights) utilizing virtual lifts and bridges and could show, that the patients developed effects equivalent to the feared real-world situations. 20 students suffering from acrophobia were randomly assigned into a treatment group (12 subjects) and a waiting list condition (8 subjects). Subjects in the treatment group received 8 weekly sessions of VRET conducted by an advanced clinical psychology graduate student. While immersed in the VE, the subjects stood on a small platform surrounded by a railing they could hold on to. The results showed improvement on all measures for the treatment group, but not for the comparison group. The

Proceedings of the 2006 International Conference on Cyberworlds (CW'06)
0-7695-2671-3/06 $20.00 © 2006 IEEE

author's reported findings showed the potential of VRET, and supported the assumption, that VRET could also be successfully applied to other psychological disorders.

Another successful attempt to apply VRET to the treatment of fear of heights was undertaken by Choi et al. [5] in 2001. A steel tower was modeled after a bunjee jump location, known to the subject of the case study. To further enhance immersion the patient was isolated in a darkened room, where he could communicate with the therapist solely over microphone. Treatment consisted of four sessions of relaxation training, followed by VRET. Though originally 8 30-minute sessions of VRET were planned, the client felt so much improved after 6 sessions, that he deliberately moved on to in vivo exposure. The results showed a significant drop on all measures used, except the Body Sensation Questionnaire, which remained stable. Hodges et al. [10] and North & North [15] used VRET in the treatment of fear of flying. The main advantage in using this type of medium was seen in the range of control over the environment presented. A variety of parameters could be controlled by the therapists, including the weather, and the flight conditions and duration. The subjects of both case studies completed several actual flights after treatment. However, only the study by Hodges et. al. offered statistical data on the achieved improvement after the successful treatment and at one-month follow-up. Slater and colleagues [20] investigated the ability of a virtual audience to evoke fear in people suffering from public speaking anxiety. Therefore they introduced animated and partly interactively controlled 3D avatars as anxiety producing stimuli to gradually decrease the client's fear of speaking in front of other persons. Unfortunately the representation of the audience led to confusion amongst the clients, who perceived facial expressions of the avatars that were intended to be negative as positive. Nevertheless the authors found the results satisfying, since they allowed for the conclusion that "Higher perceived audience interest increases self-rating and reduces public speaking anxiety."

Anderson et al. [3] also implemented a VRET system for the treatment of fear of public speaking, but used a live video of actual people instead of 3D avatars. Two subjects were treated, each according to their specific needs. The first subject received treatment consisting of 12 weekly sessions, which made the setup comparable to other traditional treatment setups. The second subject came from out of town, and wanted to focus on exposure, since she only had a constrained amount of time to complete treatment. She received 8 sessions of treatment within 3 days, 5 of which solely consisted of VRET. Both subject's anxiety disorders were rated clinically significant improved after treatment. However, only the first subject completed the 8-month follow-up, which showed that her achievements remained stable.

Carlin et al. [4] enhanced the visual display of the stimulus by tactile augmentation in the treatment of arachnophobia (fear of spiders) using real world props exactly tracked and presented in position and orientation. In a kitchen environment, a table, a plate, and a toy spider were experienced visually and haptically at the same time, increasing the "realness" of the experience. Apparently the perceived distress of the subject of the conducted case study increased dramatically when she touched the so-called "mixed reality spider".

Edmans et. al. [7] developed a virtual reality system for the rehabilitation of stroke patients, which simulated the task of making a hot drink, an ability which is often lost after a stroke. The authors suspected that VR is (1) suitable for patients with physical impairments and (2) enjoyable and compulsive and thereby offers a high motivation to complete the task. They also wanted to take advantage of the strict control over learning processes potentially offered by virtual environments. In addition virtual hot drinks cannot burn the patient, which decreases risks during treatment. The authors found it very difficult to develop an interface suitable for stroke patients, which diminished the enjoyability of the virtual environment. Also, the huge variety of impairments complicated the development of an always fitting system. Alcañiz et. al. [1] presented an internet based tele-health system for the treatment of agoraphobia (fear of open places) in 2003. Their system is thought to complementary support treatment from the client's home. Exposure is achieved by the means of virtual reality, though no special VR-hardware (e.g. a HMD) is used. The application is installed on the client's PC in his home, but control over the progress of the treatment is assured, since the application can only be used while it is connected to an internet server. However, the therapist is not required to supervise these virtual reality sessions.

Virtual Reality depends on the sense of presence of the user within the virtual environment. In our case, the client should feel to be part of the virtual world to experience the fear intended. Unfortunately the client cannot be within the virtual world and the real world, where the therapist is, at the same time. So, every time, the therapist is, for instance giving instructions to the client, the illusion of presence is broken. In order to avoid interrupting the client's illusion of presence while maintaining the possibility of communication between the client and the therapist, we intend to overcome one main drawback of today's VRET systems : the de facto exclusion of the therapist from the virtual world.

Juan et al. (12) addressed this problem using a similar scenario as Carlin et al. treating the fear of animals, in this case cockroaches. But, they focused on the concept of visual augmentation to enhance the effect of the treatment and inherently allowing for the presence of the therapist in the same space as the client. An Augmented Reality system was used in combination with tangible user interfaces in their study. The clients operated in a real-world environment, while the virtual cockroaches are presented as overlaid, spatially placed, and animated stimuli. This way the client and the therapist could communicate in a natural way, without disturbing the client's perceived sense of presence.

The idea of Choi et al. [5] to isolate the client and allow communication via microphone only, also served the purpose of enhancing the sense of presence by supporting the clients concentration on the virtual environment. We believe that for the same reason including the therapist into the virtual environment is an effective way of increasing the sense of presence perceived by the client, which may lead to more efficient treatment.

All studies applying Virtual and Augmented Reality exposure therapy combined with *in vivo* or *in imagino* methods, and the most of the studies relying on the effect of VRET only reported success. In comparison to real-world treatments even some advantages can be extracted (see e.g. [9]):

VRET can save time for both the therapist and the client, because they do not have to travel to (several) *in vivo* locations, which sometimes also have to be prepared beforehand.

There is less risk involved, because virtual environments do not harm (physically).

The client is often rather willing to undergo a VRET in the therapist's office, because (1) there is no public exposure and therefore privacy and security is maintained and (2) the feared object/environment is a virtual one and with this in mind, it is easier for the client to approach it in the first instance.

The costs for the therapy can be decreased in most cases, not only because of the time saved, but also for less equipment needs to be hired (e.g. an airplane) and less organization is involved (e.g. hiring and preparing a lecture room).

The main advantage of VRET, in particular over *in vivo* therapy is the ability to control the environment in detail and in a pace according to the stage and progress of the therapy.

Finally, when following an approach presented as in our system, even therapy at a distance could be made possible. At least occasionally, therapist and client could be present at different geographical locations to meet in a shared virtual environment. More research is needed here beforehand, in particular on ethical issues, though.

Given the possibilities, limitations, advantages, and lessons learned, we try to deliver a therapy system, which addresses the following questions:

Control: How can one maximize the controllability and stimuli provision of a VRET system?

Affordability: How can one bring a VRET system into the therapist's office? Which type of setup is suitable to deliver an immersive therapy solution while maintaining feasibility and affordability?

Mixed Reality: How can one control the desired / needed degree of virtuality (reality … virtual reality) regarding both the technical setup and the content delivery?

Collaboration: How can one actively incorporate the therapist and the client into the therapeutic environment, even when not using Augmented Reality?

From a research point of view, this aspect is clearly the main novelty in our approach. Therapist and client "inhabit" the same room at the same time. With this, the client's sense of presence in the virtual environment can be maintained throughout the entire session. Eventually, no breaks occur in switching between the real and virtual environment.

We are presenting our conceptual approach towards such a collaborative Mixed Reality Exposure Therapy (cMRET) system as well as our actual first implementation.

2. cMRET system concept

Considering the related work in Virtual and Augmented Reality exposure therapy and our derived questions we have developed a concept for a cMRET system with the following main requirements:

To allow for applications in different treatment scenarios and to support a tailored, graduated therapy the system should provide multi-media capabilities within a configurable virtual environment (texts, pictures, movies, 3D models).

To be applied in non-specialized therapists' offices the system should make efficient use of space (space saving), be financially affordable and competitive compared to methods and systems used to date, consider the computer proficiency of practitioners, and should be easy to use.

To support different types of collaborative therapy sessions, the following location scenarios should be supported: co-located in the same room, co-located in different rooms, remote locations (e.g. for rural health care).

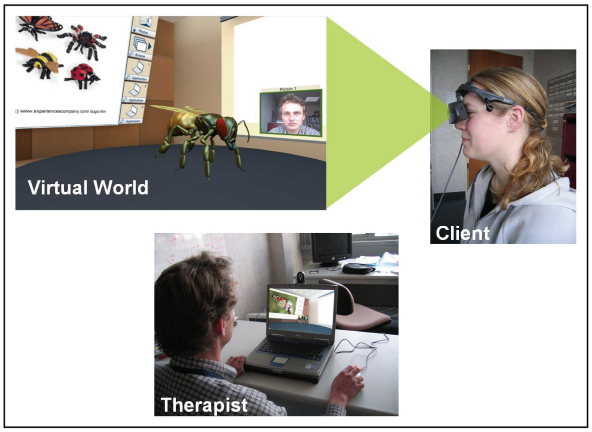

Figure 1. Principle of cMRET system

We propose a system principle as illustrated in figure 1: The therapist is using a standard PC or laptop computer, probably present in the office anyway, which can be used for everyday tasks as well as to control the cMRET system. This PC is connected to a standard Intranet or Internet network. In addition to the standard peripherals the PC needs to be equipped with a web camera and audio devices, like a microphone-headphone-set.

The client, as in many other VRET setups, is wearing a (light-weight) head-mounted display (HMD) connected to a dedicated PC. This client PC is responsible for delivering the virtual world to the client and is connected to the network. The client side also uses microphone and loudspeakers (or head-set) to make use of the acoustic properties of the virtual environment and to communicate with the therapist.

Both client and therapist virtually meet in the same shared virtual space, regardless of the physical locations (co-located in the same or different rooms, remote).

The cMRET software offers different functionalities for therapist and client, resulting in the use of different hardware devices. While both have to have the possibility to navigate within the virtual environment, the therapist should be able to control the entire content of the virtual environment, including the environment itself, The client has limited access to interaction since the main form of interaction for him/her is almost unrestricted navigation within the virtual world, in particular the option to approach or avoid virtual content as a main part of the therapy recording. Therefore the client needs an interaction device for the movement of his/her own "body" through the environment (here either a 6DOF controller, a Joystick or a standard computer mouse) and a tracked head-mounted display. The therapist additionally needs a means to control the environment, e.g. a keyboard, but he does not need to wear a tracked HMD. In contrast to other VRET systems, we opt for a desk-operated setting, where the client is sitting at a table, mainly to ease the interaction control and to save space in the office.

All interaction with the environment and between client and therapist takes place within the virtual world. The (controllable) appearance of the therapist in this environment should be convincing so the client accepts the presence of the therapist in this artificial world. Considering the issues with avatars used in other VRET systems [20] we decided for a representation found in some 3D teleconferencing systems [17, 2, 13], where participants are shown as streamed video textures mapped to planes interactively moving in space. These studies already have shown the convincing character of this kind of representation.

The multi-media content will be shown within the virtual environment as an integral part, instead of switching between different applications. For instance, 3D models are shown on a virtual table in the room as well as pictures that are displayed on a virtual projection screen within that room. With this, there is no break in the metaphoric use of a virtual environment.

To allow for a maximum range of Mixed Reality content, we decided (1) for the use of an optical-see-through HMD (controllable between opaque and transparent view, ranging from VR to AR) and (2) to include streamed video into the virtual environment. This streamed content can either be a video recording of a fear-evoking stimulus (e.g. a spider crawling over a hand) or a live video stream from a camera serving as a "window" to the outside world (Augmented Virtuality).

In the following chapter we describe in brief the implementation of this concept.

3. Implementation

Because of the similarities found in our analysis between the desired cMRET concept and 3D teleconferencing (3DTC) systems, we decided to base our implementation on top of an existing 3DTC software package, namely “cAR/PE!” [17].

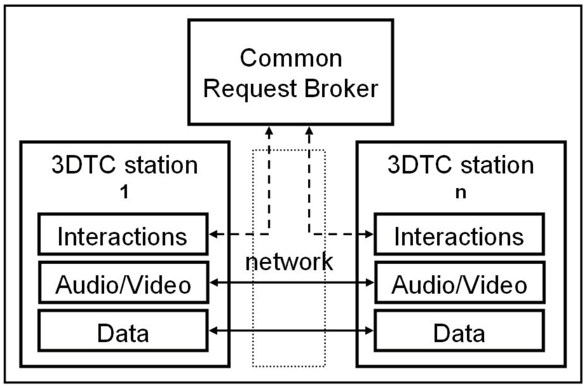

Figure 2. Schematic architecture of 3DTC system

This system already offers a functionality as follows (see figure 2):

A certain number (usually three) of 3DTC participant’s PC’s are connected via a network (Intra-/Internet), each holding a replica of the 3D virtual world model. A common request broker manages the synchronization of the interactions (including initiation and user interactions). The audio and video streams of the participants are delivered point-to-point over the network using standard videoconferencing protocols.

The synchronized virtual world displayed on each computer as a three-dimensional meeting room includes walls, a virtual table, several virtual projection screens, virtual chairs etc. to give the impression of a simulated meeting.

The participants are represented as video plane avatars freely moving in the virtual environment and controlled by the participants. With this, each participant is aware of the other’s position and viewing direction. This effect is even enhanced by the provision of three-dimensional audio rendering.

Within the virtual meeting room different media can be displayed and controlled (simultaneously): pictures, presentation slides, pre-recorded video clips, computer screens of connected PC’s, and 3D models (VRML, Inventor).

This system was extended in different ways to meet the needs of our cMRET approach (see figure 3).

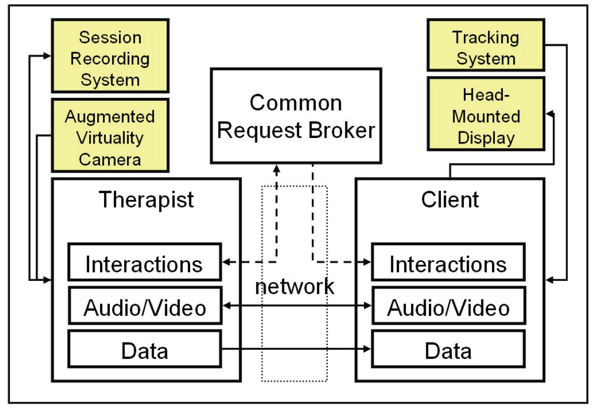

Figure 3. Schematic architecture of cMRET system

First of all, the 3DTC system is extended with two peripheral devices: (1) an optical see-through head-mounted display, here a Sony Glasstron LDI-D100BE and (2) an affordable six degrees of freedom (6DOF) IR-optical tracking system (Naturalpoint OptiTrack). The tracking system camera is placed on the desk mounted to a tripod or existing monitor while the necessary retro-reflective markers are attached to the HMD (see figure 4). This placement allows for a reasonable range and accuracy in tracking of the user’s head position and orientation. Optionally, the system can perform in 2DOF and 3DOF modes, where a computer monitor is used instead of the HMD and the clients head-turns are transformed into 2D rotations within the environment.

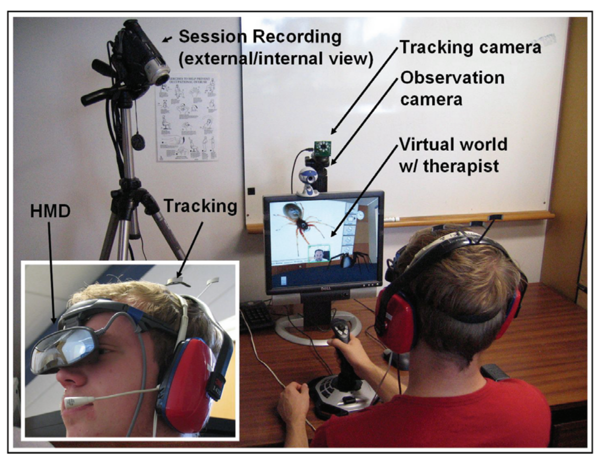

Figure 4. Current experimental therapy setup (client side)

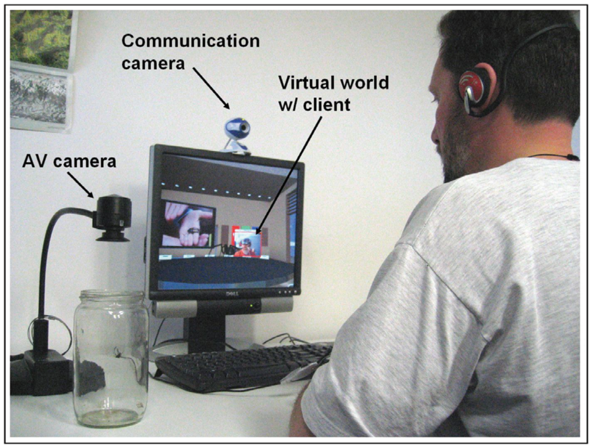

Figure 5. Current experimental therapy setup (therapist side)

The therapist's PC is extended (see figure 5) with an additional (Augmented Virtuality - AV) camera (besides the one for communication purposes) to allow for the display of real world objects (like a real spider). The video stream captured with this camera can be displayed elsewhere in the virtual environment.

Additionally, a session recording system (audio, video) is connected to the therapist's PC to document the therapeutic sessions. This can either be used for the recording of an observational view of the client and/or to record the entire cMRET session from an "inside" viewing angle.

Both, therapist and client can navigate within the virtual environment using either a standard computer mouse interface or a 6DOF controller (SpaceMouse). The client may also use a joystick which is easier to use and in addition easier to locate in the real environment, because it can be grasped even in an "immersive" mode without actually looking at it. This joystick interface provides a 3DOF navigation metaphor. The video plane avatar appearance of the therapist within the room can be switched on and off as needed. The client is always visible within the environment captured by the 3DTC camera connected to the PC, including his/her head and navigation movements.

The content to be displayed within the virtual environment as well as the environment itself was modified and designed to meet the requirements of our first treatment scenario: arachnophobia. In particular, 3D spider models, spider pictures and movies, and some living animals for Augmented Virtuality streaming are provided. In addition, the controls of the environment were modified to the different needs for therapist and client.

4. Findings and future work

We have implemented our system and tested it, without applying it to an actual therapy session yet, because of the stage of development of the current system. We believe, for ethical reasons, that any system has to be developed to a certain quality stage before it can be used in such a context. Therefore we have tested it so far mainly considering technical aspects.

During and after development of our implementation we realized there were a number of flaws and problems, which are our current point of interest for further improvements.

We conducted a usability study involving nine (non-phobic) evaluators. Of particular interest for us was to identify flaws in the current implementation. Selected and modified heuristics from [21] and [22] served as a basis for this evaluation. The identified usability problems were divided into 6 categories, namely usability problems concerning the navigation, the embodiment and gestures, shared artifacts, verbal communication, realism of the simulation, and the hardware. The effectiveness of our system could be proven in this non-therapeutic evaluation. Hence, a number of flaws could be detected by the evaluators, mainly addressing hardware and software implementation issues. While the details of this evaluation are subject to current analysis and review and are going to be published in a subsequent paper, some general findings can be reported here.

Especially when the therapist and the client are co-located in the same room or in a noisy environment, the surrounding, disturbing sound has to be eliminated for the client as much as possible. The client must only hear the therapist via the headphones. In the first setup, highly disturbing echoes occur too. We've developed a solution with closed headphones integrated into acoustic safety gear, to which even the HMD, the microphone, and the retro-reflective markers for the tracking are mounted. This gives us a more robust integrated solution, eventually even sufficient for long-term use in therapists' offices.

The audio and video codecs of the underlying 3DTC system, which were inherently used, have been intentionally chosen for low bandwidth network connections. This is useful for our remote application scenario (rural health care). For our co-located scenarios, connections with a much higher quality will be used to provide both parties with the best possible communication fidelity. Currently we are considering two principal solutions: (1) the use of analog connections for audio and video or (2) high-quality MPEG-4 hardware encoders over a Gigabit network.

To date, we are supporting simple (animated) VRML objects only as 3D models, which are controlled by the therapist using the cursor keys of his keyboard. For a better control of the therapeutic process, more interactively controllable objects would be desirable, e.g. the interactive definition of the "walking path" of a spider or starting, stopping, pace changing of the animation of an animal. In addition the client should be able to interact with the insects, e.g. by trying to kill them.

Currently only one virtual environment is available, but since each client fears different situations, a variety of virtual environments for the treatment of arachnophobia is highly desirable. Naturally, not all possible feared situations can be modeled. We will offer a set of standardized environments which reflects the most common feared situations, such as a garden, a kitchen and so on.

Also, the authoring process is a manual one at this state of the project. While this is sufficient when only used in a single or few installations, this part has to be considered seriously in the future.

With any application of the system in human trials and eventual therapeutic settings, there is a requirement to address ethical aspects of the project and to ensure compliance with relevant ethical standards and protocols. In a review of ethical issues for VR treatment applications [6], it is acknowledged that there is a lack of standardized codes of practice in this area and that local standards need to be developed, based (it is suggested) on appropriately adapted published models such as that proposed by Rizzo et al [18] and the standards promulgated by the International Society for Mental Health Online (ISMHO), cited by Heinlen et al. [8]). As it is envisaged that the project will soon proceed to the subject-based testing stage, applications will need to be made to the university ethics committee, and possibly the regional (Ministry of Health) ethics committee, and approval obtained before the study can proceed. It is our intention that the work envisaged will adhere to "best practice" guidelines such as those suggested by Rizzo et al. and those of the ISMHO, and will also meet the standards established by relevant professional ethics codes (e.g. the American Psychological Association's Ethical Code and the Code of Ethics for Psychologists working in Aotearoa/New Zealand, 2002). Even more ethical issues can be expected when using our approach in a remote scenario. Therefore our starting point in using the system for the actual treatment will be for co-located situations in the therapist's office.

Finally, the entire system has to become very robust and extensively tested (in particular empirically) before we can deploy it for a wider use.

After the completion of this first system to an extent which allows for everyday therapeutic work, we will (1) target more treatment scenarios, like fear of heights, fear of flying, and some specific disorders, (2) test the advantages of Augmented Reality exposure therapy (technology already provided with our system to a certain extent), (3) develop guidelines for the use of cMRET for researchers, developers, and practitioners, and (4) apply and test our system in a remote collaboration setting over an actual distance in a real case scenario.

5. Acknowledgments

We would like to thank Joerg Hauber, Claudia Ott, and Michael T. Wagner for their help in implementing our system as well as Graeme Roxburgh and Brendon Sly for helping us with the manuscript and the three anonymous reviewers for their very valuable comments.
Our nine heuristic usability evaluators gave us very constructive feedback on the flaws and possibilities of our current implementation.
In addition, we would like to thank DaimlerChrysler Research and Technology for supporting our work.

6. References

[1] Alcañiz, M., Botella, C., Baños, R., Perpiña, C., Rey, B., Lozano, J.A., Guillén, V., Barrera, F., & Gil, J.A. (2003). Internet-Based Telehealth System for the Treatment of Agoraphobia. Cyberpsychology & Behavior, 6(4).

[2] AliceStreet, Online product description. http://www.alicestreet.com, last accessed 17/03/06

[3] Anderson, P., Rothbaum, B.O., & Hodges, L.E. (2003). Virtual Reality Exposure in the Treatment of Social Anxiety. Cognitive and Behavioral Practice 10, 240 – 247.

[4] Carlin, A.S., Hoffman, H.G., & Weghorst, S. (1997). Virtual reality and tactile augmentation in the treatment of spider phobia: a case report. Behavior Research and Therapy, 35:153–158.

[5] Choi, Y.H., Jang, D.P., Ku, J.H., Shin, M.B., & Kim, S.I. (2001). Short-Term Treatment of Acrophobia with Virtual Reality Therapy (VRT): A Case Report. Cyberpsychology & Behavior, 4(3)

[6] Dixon, B.G. (2005), Ethical Issues in Clinical Applications of Virtual Reality and Computer-based Technologies. Unpublished report prepared for Lower South Regional Ethics Committee, Otago, New Zealand.

[7] Edmans, J.A., Gladman, J., Walker, M., Sunderland, A., Porter, A., & Fraser, D.S. (2004). Mixed reality environments in stroke rehabilitation: development as rehabilitation tools. Proceedings of the 5th International Conference on Disability, Virtual Reality & Associated Technology.

[8] Heinlen, K.T., Welfel, E.R., Richmond, E.N., & O'Donnell, M.S. (2003). The nature, scope, and ethics of psychologists' E-therapy web sites: what consumers find when surfing the web. Psychotherapy: Theory, Research, Practice, Training, Vol. 40, No. 1/2, 112–124.

[9] Hodges, L.F., Kooper, R., Meyer, T.C., Rothbaum, B.O., Opdyke, D., de Graaff, J.J., Williford, J.S., & North, M.M. (1995). Virtual environments for treating the fear of heights. IEEE Computer, 28(7):27–34.

[10] Hodges, L.F., Rothbaum, B.O., Watson, B., Kessler, G.D., & Opdyke, D. (1996). A virtual airplane for fear of flying therapy. Proceedings of 1996 Virtual Reality Annual International Symposium (VRAIS '96).

[11] [ISMHO 2000] The International Society for Mental Health Online. American Psychological Association (2002) Ethical principles of psychologists and code of conduct, http://www.ismho.org/, last accessed 10/05/06

[12] Juan, M.C., Alcañiz, M., Monserrat, C., Botella, C., Baños, R.M., & Guerrero., B. (2005). Using augmented reality to treat phobias. IEEE Computer Graphics and Applications, 25:31–37.

[13] Nakanishi, H., Yoshida, C., Nishimura, Y., & Ishida, T. (1998). FreeWalk: A Three-Dimensional Meeting-Place for Communities. In Community Computing: Collaboration over Global Information Networks, T. Ishida, Ed.: John Wiley and Sons, 1998, pp. 55-89.

[14] North, M.M., North, S.M., & Coble, J.R. (1996). Virtual Reality Therapy: An innovative paradigm. Colorado Springs, CO: IPI Press.

[15] North, M.M. & North, S.M. (1997). Virtual environments psychotherapy: A case study of fear of flying disorder. Presence: Teleoperators and virtual environments, 6:127-132.

[16] Regenbrecht, H.T., Schubert, T.W., & Friedmann, F. (1998). Measuring the Sense of Presence and its relations to Fear of Heights in Virtual Environments. International Journal of Human-Computer Interaction, 10(3), 233-249.

[17] Regenbrecht, H., Lum, T., Kohler, P., Ott, C., Wagner, M., Wilke, W., & Mueller, E. (2004). Using Augmented Virtuality for Remote Collaboration. Presence: Teleoperators and virtual environments, 13(3), 338-354.

[18] Rizzo, A., Schultheis, M.T., & Rothbaum, B.O. (2003)..Ethical Issues for the Use of Virtual Reality in the Psychological Sciences. In Ethical Issues in Clinical Neuropsychology. Lisse, N.L. (Ed): Swets & Zeitlinger Publishers.243-280.

[19] Rothbaum, B.O., Hodges, L.F., Kooper, R., Opdyke, D., Williford, J.S., & North, M. (1995). Virtual reality graded exposure in the treatment of acrophobia: A case report. Behavior Therapy, 26, 547-554.

[20] Slater, M., Pertaub, D.P., & Steed, A. (1999). Public speaking in virtual reality: Facing an audience of avatars. IEEE Computer Graphics and Applications, 19:6–9.

[21] Nielsen, J. (2006). 'Ten usability heuristics'. retrieved July 30th from http://www.useit.com/papers.

[22] Baker, K., Greenberg, S. and Gutwin, C. (2001). Heuristic evaluation of groupware based on the mechanics of collaboration, in 'Proceedings of the 8th IFIP Working Conference on Engineering for Human-Computer Interaction (EHCI'01)'.