Technological challenges and the Delft virtual reality exposure system

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ABSTRACT

In this paper the architecture and use of the Delft VRET system is described. In this generic VRET system special emphasis is given to usability engineering of the user interface for the therapist. Results of controlled experiments with patients are summarized. The system is in regular use in a few clinics since 2005. New technological and functional challenges of VRET are presented. These challenges will lead to improvements of the system in the future. Agent support for the therapist and tele-VRET are the most promising challenges.

1. INTRODUCTION

Virtual reality exposure therapy (VRET) is an evolving technique that has attracted a lot of interdisciplinary research. VRET is the result of a close collaboration between researchers and practitioners of significantly different disciplines, among others, psychiatry, clinical psychology, psychotherapy, computer science, graphics design, human-computer interaction, and engineering. It has been shown that VRET is effective for patients with acrophobia, arachnophobia (spider phobia) and fear of flying (Emmelkamp et al, 2004). The effectiveness of VRET in other anxiety disorders like claustrophobia, fear of public speaking, fear of driving, posttraumatic stress disorder, and agoraphobia also holds promise for the future (Emmelkamp et al, 2004). At Delft University of Technology, in collaboration with department clinical psychology of University of Amsterdam, a generic system for treatment of phobia has been developed, taking into account a user-centered design process and specific human-computer interaction issues (Gunawan et al, 2004).

Traditional cognitive behavioural therapy has been taken as the main paradigm to be supported by technology in different ways, by providing interactive immersive worlds to "play" the treatment process in virtual reality instead of *in vivo*, as in the behavioural approach or by imagination, as in the cognitive framework. It has proved to be the case that patients are very sensitive to specific multimodal [i.e. more senses involved] stimuli in the virtual world (Krijn et al, 2004a). Medium-level resolution and graphics quality has proven sufficient in many cases to trigger the specific phobia-related reactions that are essential in exposure therapy. The effect of locomotion technique on fear is studied in (Schuemie et al, 2005). In one study (Krijn et al, 2004b), treatment using a standard head-mounted display (HMD) gave the same results for the treatment of acrophobia as a CAVE (computer automatic virtual environment) system providing advanced virtual reality systems. Of course this substitutability may be dependent on the specific type of disorder to be treated. It is proven in many studies that VRET can achieve the same results as traditional cognitive behavioural therapy, but will not outperform it (Emmelkamp 2005). But there are more aspects of cognitive behavioural therapy which are important besides exposure. Technology can also support the therapist in changing in real time to other synthetic worlds to be exposed to the patient, or in recording and replaying sessions in the virtual world for later analysis and planning the following session (Van der Mast et al, 2005).

Current VRET systems are mostly developed and used in laboratories where technical support is available. A few systems are available on the market, but evaluation of practical use on a larger scale has not yet been reported. To provide full support in the clinical roles, it is essential that VRET systems be usable in the clinic by several therapists of a team and without strong and expensive technical support. This usability is important to enhance the performance of the treatments on the one hand, and on the other hand we may expect benefits from other support functions beside the VR exposure technique itself. Interesting new technologies are available to extend a VRET system with new functions in order to measure and analyze details of the treatment process for better understanding of diagnosis and treatment and for improving the efficiency of the therapist's work (Van der Mast et al, 2006).

The goal of this paper is to explore and discuss the technological and functional challenges to implement in VRET systems to be used in the clinic by regular therapists. On a scale that is following requirements given by society and economically interesting. We use the Delft VRET system as an example and model for these challenges.

2. THE ARCHITECTURE OF THE DELFT VRET SYSTEM

The functional architecture of the Delft VRET system (development started in 1999) is based on the main functions as depicted in Figure 1. This architecture is based on task analysis of therapists work by interviews and observations (Schuemie and Van der Mast, 2001; Schuemie, 2003).

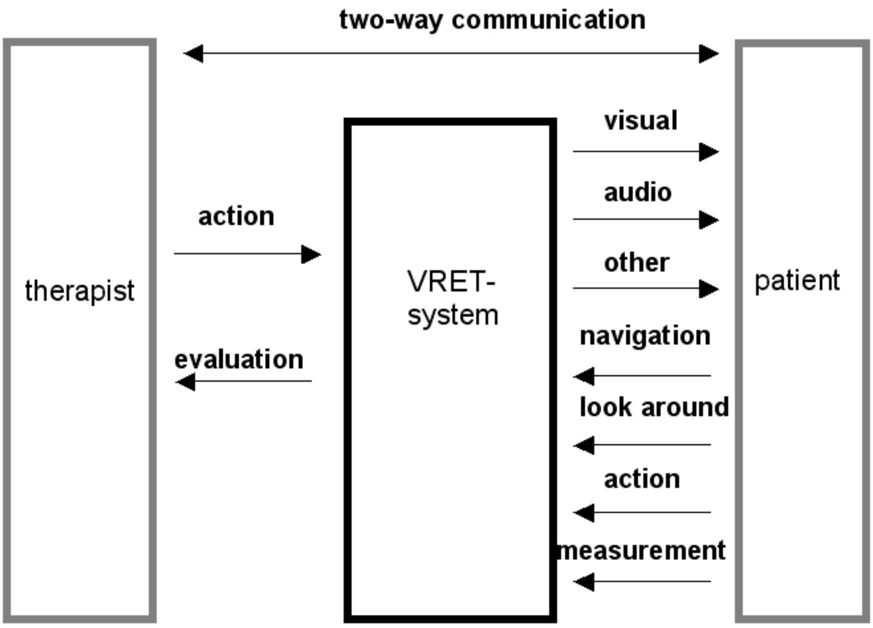


Figure 1. *The functional architecture of the Delft VRET system.The two-way communication of therapist and patient is direct if both are in the same room. An AV intercom connection is needed if both are not in the same room. The Delft VRET system is using two computers to be connected over the internet which supports tele-treatment.*

The two-way communication between therapist and patient is the base of the treatment. The VRET system is the intermediate tool to offer controlled stimuli to the patient. It is important that the therapist can control and evaluate the VRET system through a transparent user interface ("action" and "evaluation" in Figure 1). The user interface between patient and VRET system is in another way essential for the treatment. The patient should receive the visual, audio and other stimuli and she should be able to "navigate", "look around" and "act" in the virtual environment offered. The system should be provided with means to measure mental and physiological data of the patient. The therapist should be able to monitor and to supervise the behavior and experiences of the patient. In Figure 2 the therapist user interface is shown for a virtual world for treating fear of flying. The therapist can control the behavior of the plane (taxiing, taking off, weather conditions, pilot calls, turbulence) and she can follow how the patient is perceiving the virtual world by a live copy of patients view. She has also a second free view in the plane to look around to prepare next actions in the plane.

The technical architecture is based on using two independent computers, one for presenting the interactive worlds to the patient and one offering a control module to the therapist with the user interface (e.g. for fear of flying, see Figure 2). Both computers are connected using the internet protocol in such a way that the therapist is able to control the virtual worlds completely over the internet. This makes it possible to control sessions for tele-treatment. We tested this tele-medicine feature in the lab environment with collegues from the Universita Politecnica de Valencia.

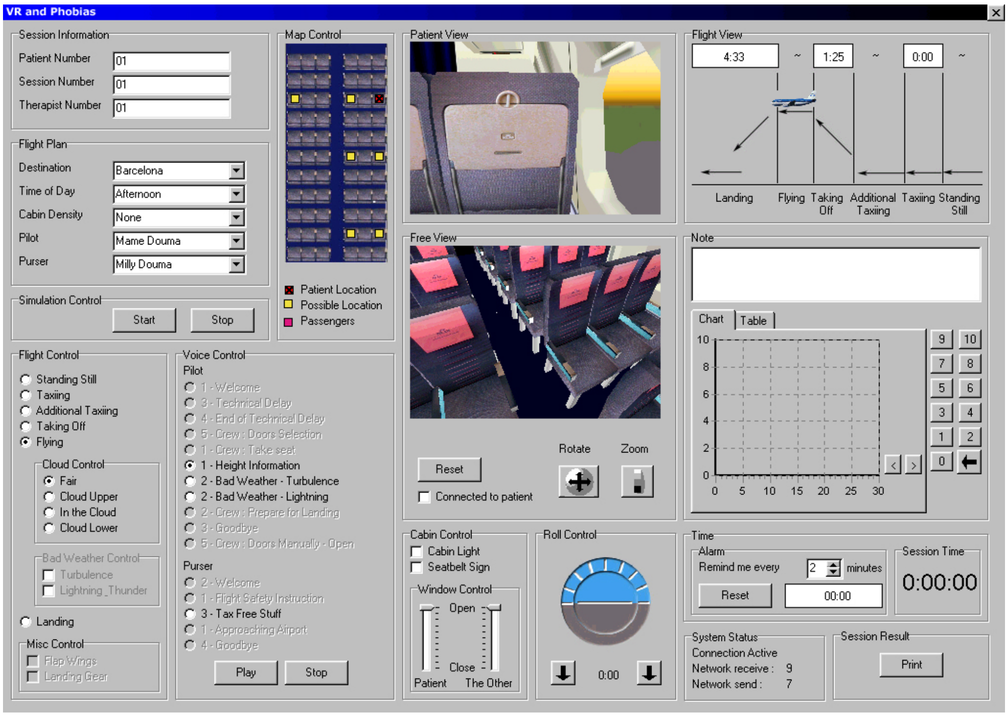


Figure 2. *The therapists user interface to monitor and control the airplane world for treating fear of flying. The upper image in the middle is the patients view. The lower image in the middle is the free view, including some controls for looking around by the therapist.*

3. USABILITY ENGINEERING

The evaluation of the therapist's UI is measured in terms of usability, i.e. effectivity, efficiency and satisfaction (Rosson and Carroll, 2002). We used a mediated evaluation which is a mix between analytical and empirical method, see Figure 3. The analytic evaluation is done early during the design process. The result of this analysis is used to motivate and develop materials for empirical evaluations. Heuristic evaluation as an inspection method was done. The empirical method is done by a user evaluation experiment. Because we have only a very limited number of professional therapists for treating phobias we added other persons to do the same treatment/job. From (Neerincx et al, 2001) we know that this may deliver valid results in usability studies for designing space stations. The therapists tested the system directly with a user/patient in the virtual world. Some specific tasks were given to the therapist to complete. Information was gathered, such as the observation protocol, performance time, errors and subjective evaluation. The subjective evaluation was acquainted by using usability questionnaires and interviews. To improve the therapist user interface of our fear of flying worlds we did usability engineering studies and found new functions to be included e.g. flight plan control, roll control and timer function. This is described in detail in (Gunawan et al, 2004).

Another outcome of our usability engineering approach was a world for treating social phobia. We implemented following the therapists requirements a market place (the Market in the city of Delft which is very well known to almost all inhabitants of the Netherlands) of which several parameters could be controlled online by the therapist during the session. Including weather conditions and number of walking avatars around the patient. How to design weather conditions, avatars, how to find the adjustable number of moving avatars, were all investigated using these usability engineering techniques, see (Van der Mast and Hooplot, 2006).

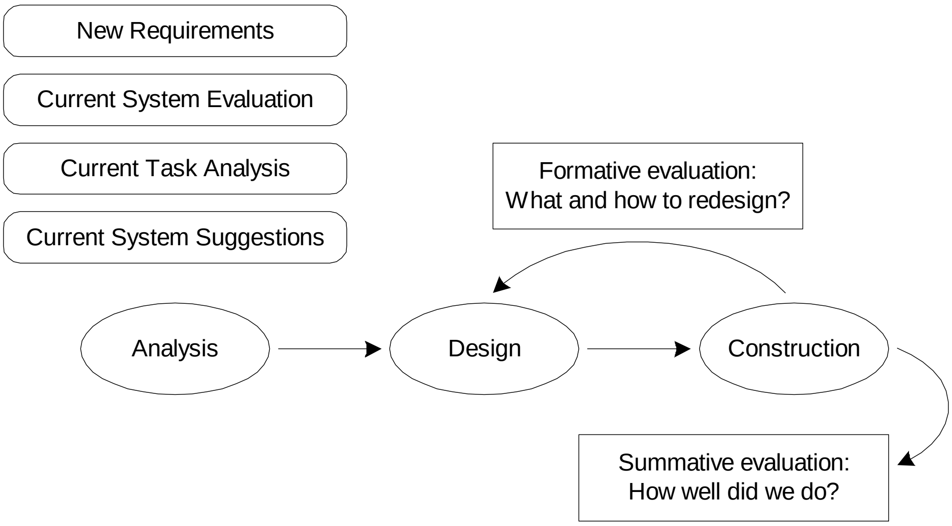
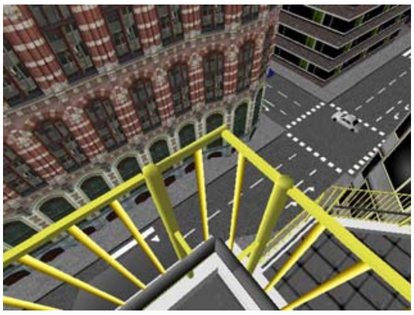


Figure 3. *Usability research methodology (Gunawan et al, 2004).*

4. THE RESULTS WITH THE SYSTEM

The first controlled experiment with the predecessor of the current Delft VRET system was done with *patients* who suffered from acrophobia ((Emmelkamp et al, 2001). This was a within-group design comparing in vivo treatment with VRET. Al patients were treated first with sessions of VRET followed by sessions of in vivo exposure. VRET was found to be as effective as exposure in vivo on all subjective measures. Conclusions were not yet firm because of the potential order effect.

In a second study (Emmelkamp et al, 2002) patients were assigned randomly to either VRET or exposure in vivo. The virtual worlds for acrophobia were built as an exact copy of the real worlds used in the condition in vivo: a shopping mall, a fire escape, and a roof garden (Figure 4a). VRET was found to be as effective as exposure in vivo on all measures. The improvements were maintained at 6-month follow-up.



(a)

(b)

Figure 4. *(a) One of the worlds for treating acrophobia (Schuemie, 2003) and (b) the Delft VRET system in use at the clinic of PsyQ in the Hague.*

A third study (Krijn et al, 2004) focussed on the effectiveness of two different types of virtual environments, varying the degree of presence. A CAVE system was compared with a standard stereoscopic HMD. Patients were randomly assigned accross the two conditions. The virtual environments were implemented exactly the same being the shopping mall, the fire escape, and the roof garden used in the second study mentioned above on acrophobia. The results showed no differences in effectiveness between the two systems on all measures. As expected, presence was significantly higher in the CAVE, but this did *not* result in a more effective treatment.

In other studies and (Schuemie, 2003) this VRET system is used for fundamental research on the influence of patient navigation control modes walk-in-place, trackball, and gaze directed steering (Schuemie

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et al, 2005), and the influence of patient versus therapist navigation control on patients presence. This last study showed no significant difference in presence. Krijn did (Krijn, 2006; Krijn et al, 2006) an extensive study on treatment of fear of flying.

In 2006 new worlds are being built for treatment of agoraphobia (van der Mast and Hooplot, 2006). Controlled experiments are not yet finished.

The Delft VRET system is being used from spring 2005 in the clinics of PsyQ in The Hague by several therapists for treating acrophobia and fear of flying of regular patients, and paid by their insurance companies (Figure 4b). The therapists report that the number of required VRET sessions is lower than with the traditional ways they are used to spend for treatment. This can mean an increase of efficiency. However, this should be confirmed by well designed controlled field experiments. In the summer 2006 the Delft VRET system is being used for regular treatment of fear of flying by VALK foundation in Leiden. VALK is specialized in fear of flying. They will also prepare controlled experiments.

5. NEW TECHNOLOGICAL CHALLENGES

We will discuss the following technical challenges. The order is arbitrary.

5.1 Personalizing the System

A VRET system may be used by different therapists from a clinic. Additionally, each therapist may change over time his or her preferences about using the system for some specific phobias. This gives a rationale for implementation the possibility to personalize the user interface and some of the main functions of the treatment process by the individual therapist and to store the applicable parameters. It is conceivable that this personalization could be extended to prepare for each patient an individual treatment procedure off-line, including some changes in the virtual worlds, specific for each patient to be treated. This kind of personalization is an important research goal sometimes referred to as “adaptive” user interfaces.

5.2 Automated Support for the Therapist

The first function of a VRET system is to offer an interactive virtual environment for the patient to experience the feelings that have to be worked on. But beyond that, the most promising challenge is to develop support functions for the therapist. By analyzing the treatment process and composing task models one can recognize and specify steps and modes in the treatment. In (Schuemie, 2003) examples of task models (treatment procedures, see Figure 5) are described. They are based on observation of sessions. New models have to be developed describing the task in terms of treatment steps and specific aspects and levels of the disorder.

If it is possible to describe a treatment session in terms of steps to be taken under supervision by the therapist it may be possible to develop an electronic agent which provides advice including some rationales to the therapist about the next possible step(s) in the actual context of the treatment. It would also seem interesting to provide a planning mode to the therapist to specify some sequential steps for a session just before it starts. The general goal is to provide extra explicit knowledge to the therapist about the progress of the treatment. The agent can obtain its information from built-in procedures which may be adjusted by the therapist and by measurements of the patients physiological condition, e.g. heart rate. It would be most useful to construct a learning electronic agent that could learn from an experienced therapist. A junior therapist could use this “smart” agent to give better treatment in non-critical sessions, under the responsibility and supervision of an experienced therapist. It would be possible to teach such agents to give good advice by analyzing individual treatment patterns in specific clinical cases. The advice might propose the next procedure step or the next navigation or modification of the virtual world to control the level of fear. Even more measurements can be done by voice-emotion recognition since these can indicate levels of stress, fear, and other emotions. This voice-emotion recognition may replace the standard asking for SUDs (selective units of discomfort).

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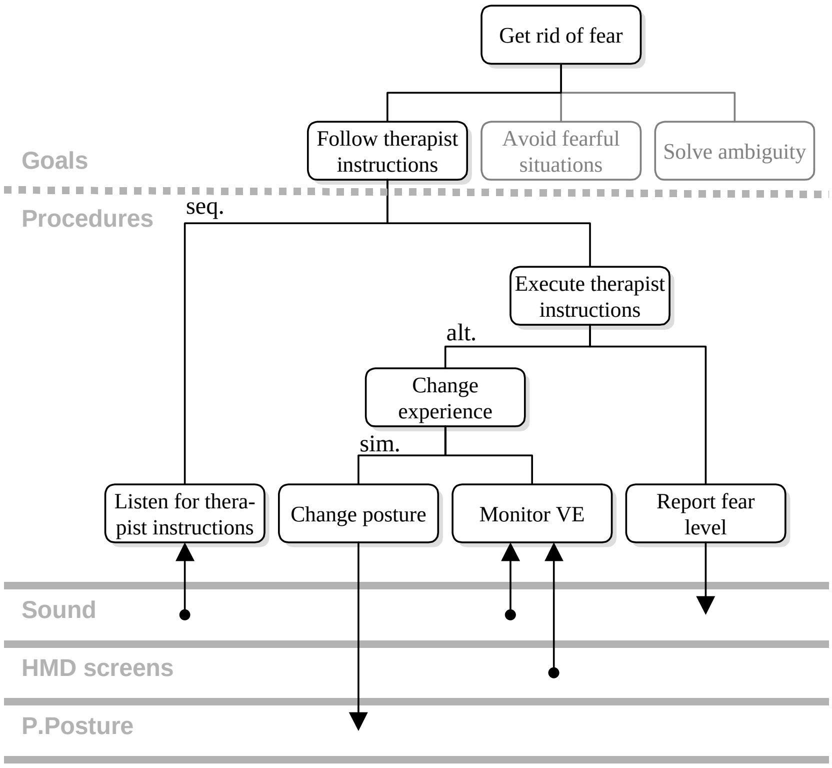

Figure 5. *'Follow therapist instructions' goal decomposition (Schuemie, 2003). Sound, HMD screens and P. Posture are the related communication modes (senses) between patient-machine and patient-therapist. VE is virtual environment.*

As an additional form of support may be considered procedures of computer-supported self-treatment by the patient. The therapist should be able to specify the procedures and constraints of these modules for self-treatment. The therapist could individualize homework scenarios for the patients. Individualization of virtual environments is addressed within a currently ongoing EMMA project (Botella, 2006).

5.3 Computer-based training

A completely different challenge is the construction of a VRET system for computer-based training of junior therapists. This could be done using simulated or real patients or recorded sessions. The learner could be trained how to use the system and how to treat different types of disorders. Simulated patients could include a combination of computer-generated patients and normal people requested to simulate. Computer-generated patients could model non-visible changes happening in real patients (e.g. physiological changes).

5.4 Tele-Care

Because the therapists report to us that the habituation process is going slowly with relatively less interaction between therapist and patient, they express to have time to treat more patients simultaneously, given a good intercom system for personal communication with each patient simultaneously. It is both a technical and an organizational challenge to develop a system for tele-treatment of mental disorders using VRET over the internet. The most serious challenge is to have a ratio *therapist : patient* of more than 1:1. It should be possible to develop a system and a therapists user interface to allow the provision of treatments to more than one patient at the same time, in different rooms in the same clinic or in different clinics. If one senior and one junior therapist could treat more than two patients simultaneously, the ratio will improve. Some experience with tele-treatment of agoraphobia without VR has previously been reported (Lange at al, 2000). In a more general project on tele-care the possibilities of agent support for tele-care at home has been investigated (Riva et al, 2004).

6. CONCLUSIONS

We have seen that several interesting technological challenges are on the horizon. But we must remain aware that we need fundamental research on how new technologies can improve the very personal treatment process supervised by the therapist. This research must be demand-driven by the therapists, and not pushed by technology. We are just in the early stages of some very interesting developments. They will improve our insight in how treatment can be given in the most effective way and how treatment can be deployed on a large scale more efficiently than with the current means. VRET may play an important role in these developments.

In our view, an emerging scenario could characterize the future clinical setting: old (and functional) practices could be integrated and enhanced through new (and promising) media such as VR. The most promising challenges are agent support for the therapist and tele-VRET. The Delft VRET system will be used to work on these challenges.

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7. REFERENCES

C Botella, H Villa, A Garcia-Palacios, R M Banos, C Perpina, M Alcaniz (2004), Clinically Significant Virtual Environments for the treatment of Panic Disorder and Agoraphobia. *Cyberpsychology & Behaviour*, **7**, 5, pp. 527-535.

C Botella (2006), Clinical issues in the application of virtual reality to treatment of PTSD, *Proc. NATO workshop Novel approaches to the diagnosis and treatment of posttraumatic stress disorder.* IOS Press, Amsterdam, pp. 183-195.

P M G Emmelkamp, M Bruynzeel, L Drost, C A P G van der Mast (2001),Virtual Reality Treatment in Acrophobia: A Comparison with Exposure in Vivo, *Cyberpsychology and Behavior*, **4**, 3, pp.335-341

P M G Emmelkamp, M Krijn, A M Hulsbosch, S de Vries, M J Schuemie and C A P G van der Mast (2002), Virtual Reality Treatment versus exposure in vivo: A Comparative Evaluation in Acrophobia, *Behaviour Research & Therapy*, **40**, 5, pp.509-516.

P M G Emmelkamp, M Krijn, R P Olafsson, R Biemond (2004), Virtual reality exposure therapy of anxiety disorders: A review, *Clinical Psychology Review*, **24**, pp. 259-281.

P M G Emmelkamp (2005), Technological innovations in clinical assessment and psychotherapy, *Psychotherapy & Psychosomatics*, **74**, pp. 336-343. (2005)

L T Gunawan, C A P G van der Mast, M Krijn, P M G Emmelkamp, M A Neerincx (2004), Usability of therapist's user interface in virtual reality exposure therapy for fear of flying, *Proc. of Euromedia 2004 Conference*, Hasselt Belgium, pp. 125-132.

M Krijn (2006), *Virtual Reality and Specific Phobias --Welcome to the real world*, PhD thesis, University of Amsterdam. (available from http://mmi.tudelft.nl/~vrphobia)

M Krijn, P M G Emmelkamp, R P Olafsson, M Bouwman, L van Gerwen, M J Schuemie and C A P G van der Mast, (2006), Fear of flying: A comparative evaluation of Virtual Reality Exposure Therapy, Cognitive Behavioural Methods and Bibliotherapy, (submitted).

M Krijn, P M G Emmelkamp, R P Olafsson, R Biemond (2004a), Virtual reality exposure therapy of anxiety disorders: A review, *Clinical Psychology Review* **24** pp. 259-281.

M Krijn, P M G Emmelkamp, R Biemond, C de Wilde de Ligny, M J Schuemie and C A P G van der Mast (2004b), Treatment of acrophobia in Virtual Reality; the role of immersion and presence, *Behaviour Research and Therapy*, **42**, 2:229-239.

A Lange, B A L Schrieken, J Q R van de Ven, B Bredeweg and P M G Emmelkamp (2000), INTHERAPY: The effects of a short protocolled treatment of post-traumatic stress and pathological grief through the internet. *Behavioral* & *Cognitive Psychotherapy*, **28**, 2, 103-120.

C van der Mast, S Popovic, D Lam, G Castelnuovo, P Kral, and Z Mihajlovic (2006), Technological challenges in the use of Virtual Reality Exposure Therapy, *Proc. of the NATO Advanced Research Workshop on Novel approaches to the diagnosis and treatment of posttraumatic stress disorder*, Amsterdam IOS Press, pp. 286-295.

C van der Mast and F Hooplot (2006), Design and evaluation of a VRET system for agoraphobia, *Proc. of Euromedia 2006 Conference,* Athens Greece, pp. 77-84.

M A Neerincx, M Ruijsendaal and M Wolff (2001), Usability Engineering Guide for Integrated Operation Support in Space Station Payloads, *International Journal of Cognitive Ergonomics,* **5,** 3, 187-198.

G. Riva, F. Morganti and M. Villamira (2004), Immersive virtual Telepresence: virtual reality meets eHealth, *Cybertherapy* (G. Riva et al. Eds) , IOS Press Studies in health technology and informatics, **99**, pp. 255-270.

M B Rosson and J M Carroll (2001), *Usability Engineering - scenario-based development of human-computer interaction*, Morgan Kaufmann Series in Interactive Technologies, Academic Press, San Fransisco.

M J Schuemie, P van der Straaten, M Krijn, C A P G van der Mast (2001), Research on Presence in VR: a Survey, *Cyberpsychology and Behavior*, **4**, 2, April 2001, pp.183-202.

M J Schuemie, and C A P G van der Mast (2001), VR Testbed Configuration for Phobia Treatment Research, *Proc. of Euromedia 2001 Conference*, Valencia, Spain, pp. 200-204.

M J Schuemie, C A P G van der Mast, M Krijn and P M G Emmelkamp (2002), Exploratory Design and Evaluation of a User Interface for Virtual Reality Exposure Therapy , in: J.D. Westwood, H.M. Hoffman, R.A. Robb, D. Stredney (Eds.), *Medicine Meets Virtual Reality 02/10*, IOS Press, Amsterdam, pp.468-474

M J Schuemie (2003), *Human-Computer Interaction and Presence in Virtual Reality Exposure Therapy,* Ph.D thesis, Delft University of Technology. (available from http://mmi.tudelft.nl/~vrphobia)

M J Schuemie, B Abel, C A P G van der Mast, M Krijn and P M G Emmelkamp (2005), The effect of locomotion technique on presence, fear and usability in a virtual environment, *Proc. of Euromedia 2005 Conference,* Toulouse France, pp. 129-135.