Studies in Computational Intelligence 337

Sheryl Brahnam
Lakhmi C. Jain (Eds.)

Advanced Computational Intelligence Paradigms in Healthcare 6

Virtual Reality in Psychotherapy, Rehabilitation, and Assessment

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Studies in Computational Intelligence, Volume 337

Editor-in-Chief
Prof. Janusz Kacprzyk
Systems Research Institute
Polish Academy of Sciences
ul. Newelska 6
01-447 Warsaw
Poland
E-mail: kacprzyk@ibspan.waw.pl

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Virtual Reality in Psychotherapy, Rehabilitation, and Assessment

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Dr. Sheryl Brahnam
Associate Professor
Missouri State University
Computer Information Systems
901 South National Avenue, Springfield, MO 65804, USA
E-mail: sbrahnam@missouristate.edu

Prof. Lakhmi C. Jain
Professor of Knowledge-based Engineering
University of South Australia
Mawson Lakes Campus, South Australia, Australia
E-mail: Lakhmi.jain@unisa.edu.au

ISBN 978-3-642-17823-8 e-ISBN 978-3-642-17824-5

DOI 10.1007/978-3-642-17824-5

Studies in Computational Intelligence ISSN 1860-949X

Typeset & Cover Design: Scientific Publishing Services Pvt. Ltd., Chennai, India.

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

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Preface

Human-computer interaction is no longer centered around 2D computer screens and traditional input/output devices. In the second decade of the 21st century, we find ourselves increasingly communicating and interacting with each other in virtual settings—manipulating virtual objects and even relating to colleagues in the guise of avatars. As reported recently in the documentary *Digital Nation* (2010), directed by Rachel Dretzin, many of IBM's offices have closed only to reopen in such virtual worlds as Second Life.

As virtual reality (VR) quietly transforms the way we work together and conduct our personal lives, it is also transforming how we are being treated when unwell. VR is impacting medical practice in at least three ways. First, it is revolutionising how data is being visualized. Information about physical systems and organs are now being modelled for medical training purposes, for developing surgical strategies, and for performing a variety of virtual procedures. VR models of various disease trajectories are also being used to assess treatment potentials and likely outcomes. Second, VR is merging people and facilities located across the globe into seamlessly interconnected virtual centers, bringing the best medical care to patients located in remote regions and facilitating collaborations between teams of world class experts. Third—and this is the focus of this book—VR is being used in mental and physical therapy as a means of helping patients either to learn new behaviors or to relearn skills after suffering, for example, from stroke or severe trauma, be it physical or emotional.

This volume hopes to introduce VR, as it is being applied in psychotherapy, rehabilitation, and the analysis of behavior for neurological assessment, to a broad audience of researchers and partitioners in related areas. This volume contains the latest reviews of the literature and descriptions of some of the most cutting edge VR systems, including detailed account of how they were designed, implemented, and evaluated. This book will be of value to anyone already in the field and to those who are interested in the development of VR systems for therapeutic purposes.

We wish to express our gratitude to the authors for their excellent contributions in this volume and to the reviewers. It is our privilege to introduce this exciting field to a broader audience.

Sheryl Brahnam
USA

Lakhmi C. Jain
Australia

Books on Advanced Computational Intelligence Paradigms in Healthcare

[1] H.-N. Teodorescu, A. Kandel and L.C. Jain (Editors) Fuzzy and Neuro-fuzzy Systems in Medicine, CRC Press, USA, 1999.

[2] H.-N. Teodorescu, A. Kandel and L.C. Jain (Editors) Soft Computing in Human Related Sciences, CRC Press, USA, 1999.

[3] A. Jain, A. Jain, S. Jain and L.C. Jain (Editors) Artificial Intelligence Techniques in Breast Cancer Diagnosis and Prognosis, World Scientific, 2000.

[4] H.-N. Teodorescu and L.C. Jain (Editors) Intelligent Systems and Technologies in Rehabilitation Engineering, CRC Press, USA, 2001.

[5] B. Silverman, A. Jain, A. Ichalkaranje, L.C. Jain (Editors) Intelligent Paradigms in Healthcare Enterprises, Springer-Verlag, 2005.

[6] D. Husmeier, R. Dybowski and S. Roberts (Editors) Probabilistic Modelling in Bioinformatics and Medical Informatics, in Advanced Information and Knowledge Processing Series edited by L.C. Jain and X. Wu Springer-Verlag, 2005.

[7] N. Ichalkaranje, A. Ichalkaranje and L.C. Jain (Editors) Intelligent Paradigms for Assistive and Preventive Healthcare, Springer-Verlag, 2006.

[8] H. Yoshida, A. Jain, A. Ichalkaranje, L.C. Jain and N. Ichalkaranje (Editors) Advanced Computational Intelligence Paradigms in Healthcare 1, Springer-Verlag, 2007.

[9] S. Vaidya, L.C. Jain and H. Yoshida (Editors) Advanced Computational Intelligence Paradigms in Healthcare 2, Springer-Verlag, 2008.

[10] M. Sardo, S. Vaidya and L.C. Jain (Editors) Advanced Computational Intelligence Paradigms in Healthcare 3, Springer-Verlag, 2008.

[11] I. Bichindaritz, S. Vaidya, A. Jain and L.C. Jain (Editors) Advanced Computational Intelligence Paradigms in Healthcare 4: Advanced Methodologies, Springer-Verlag, 2010.

[12] S. Brahnam and L.C. Jain (Editors) Advanced Computational Intelligence Paradigms in Healthcare 5: Intelligent Decision Support Systems, Springer-Verlag, 2010.

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Editors

Sheryl Brahnam is the Director/Founder of Missouri State University's infant COPE (Classification of Pain Expressions) project. Her interests focus on face recognition, face synthesis, medical decision support systems, protein descriptors, embodied conversational agents, computer abuse, and artificial intelligence. She has published a number of articles related to medicine in such journals as *Artificial Intelligence in Medicine*, *Expert Systems with Applications*, *Journal of Theoretical Biology*, *Amino Acids, Neural Computing and Applications*, and *Decision Support Systems*.

Lakhmi C. Jain is a Director/Founder of the Knowledge-based Intelligent Engineering Systems (KES) Centre, University of South Australia. He is a fellow of the Engineers Australia. He has initiated a postgraduate stream by research in the KES area. His interests focus on the applications of novel techniques such as knowledge-based systems, virtual systems, multi-agent intelligent systems, artificial neural networks, genetic algorithms, and the application of these techniques.

Contents

Part 2: Virtual Reality and Rehabilitation

Part 3: Virtual Reality and Assessment

Chapter 1
Virtual Reality in Psychotherapy, Rehabilitation, and Neurological Assessment

Sheryl Brahnam[1] and Lakhmi C. Jain[2]

[1] Associate Professor
Missouri State University
Computer Information Systems
901 South National Avenue, Springfield, MO 65804, USA
sbrahnam@missouristate.edu
[2] Professor of Knowledge-based Engineering
University of South Australia
Mawson Lakes Campus, South Australia, Australia
Lakhmi.jain@unisa.edu.au

Abstract. This chapter presents a brief overview of advances in the application of virtual reality and related technologies in psychotherapy and healthcare. A summary of the chapters on virtual reality and psychotherapy, virtual reality and rehabilitation, and virtual reality in neurological assessment is presented.

1 Introduction

In the last two decades, not only have technological advancements radically changed the way people communicate and do business but new technologies have also transformed medical practice, bringing yesteryear's science fiction vision of medicine closer to today's standard practice. One such futuristic technology, virtual reality (VR), is now making substantial inroads into medicine, especially in the areas of physical and mental rehabilitation and psychotherapy.

The term *virtual reality* was coined in 1986 by Jaron Lamier to describe a collection of technologies that simulate a computer-generated 3D virtual environment (VE) that users feel they can actually inhabit rather than simply view on a 2D display. Virtual environments immerse users by providing visual, auditory, tactile, and even olfactory sensory stimulation using such devices as head mounted displays and instrumented clothing. As users move and manipulate virtual objects, the VE changes to reflect expected alterations in the environment. Thus, users experience virtual worlds similarly to the way they experience the real world.

McCloy and Stone [1] define VR as any "collection of technologies that allow people to interact efficiently with 3D computerised databases in real time using their natural senses and skills" p. 912. The focus in this definition is on data visualization. Their avoidance in mentioning any specific technologies opens the definition to related areas of human-computer interaction (HCI), such as augmented reality (AR) and mixed reality environments. AR combines the real and virtual in a variety of ways,

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 1–9.
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oftentimes with the virtual superimposed on the real, as when football broadcasts draw a yellow first-down line across the playing field. Mixed reality refers to any mixture of the virtual with the real. One way to conceptualize the diverse possibilities offered by mixed reality systems is to utilize Milgram's Reality-Virtuality Continuum [2], which spans possible combinations of the real and virtual along the two extremes of the purely real and the purely virtual (VE).

There are many areas in medicine where VR and mixed reality technologies have made a substantial impact. In surgery, for instance, many VR applications have been developed for surgical training, operative planning and strategy, and telesurgery [1, 3-6], for some recent example applications see [7-10]. In diagnostics, current applications include virtual colonoscopy [11] and virtual bronchoscopy [12], and VR has proven particularly beneficial and popular in medical training [13-18].

An opportunity offered by VR is the possibility of finely controlling user interactions and carefully applying therapeutic stimuli. Controlled virtual environments [19] are particularly useful in rehabilitation, psychotherapy and neurological assessment [19-21]. Riva [21] explicitly contrasts McCloy's and Stone's definition of VR above to one offered by Schultheis and Rizzo [22]: VR is an "advanced form of human-computer interface that allows the user to interact with and become immersed in a computer-generated environment in a naturalistic fashion." This definition better suits the behavioral sciences as it is focused on the environment and how incremental changes in the environment can result in changes in behavior. Much evidence, as reported in the chapters of this book, supports the conclusion that what is learned by patients in their controlled interactions in VEs generalizes well when applied in the real world [23].

The chapters presented in this volume serve as an excellent introduction to the state-of-the-art in VR as it is currently being applied in rehabilitation, psychotherapy and assessment. Many of the chapters offer comprehensive reviews of the literature; others provide excellent examples and detailed accounts describing the design and evaluation process of VR in cutting edge therapeutic systems. The chapters also discuss limitations, problems, and ethical concerns using VR in mental and physical therapy.

2 Synopsis of the Chapters in This Book

The chapters in this book are divided into the following three parts:

Part 1: Virtual Reality and Psychotherapy
Part 2: Virtual Reality and Rehabilitation
Part 3: Virtual Reality and Assessment

The first five chapters in Part 1 provide comprehensive literature reviews of the very latest work in VR and psychotherapy. Each chapter covers slightly different aspects of this growing field, and several chapters include discussions of the technologies being employed. This section ends with a paper reviewing the literature on presence that is centered on concerns specific to psychotherapy and a look at using virtual worlds, such as Second Life, to change opinions about psychotherapy and to offer educational resources and some psychological support to veterans.

In Part 2, we focus on new developments in VR and rehabilitation. The chapters in this section cover the benefits of VR in combination with video games, in stroke therapy, in amblyopia (lazy eye) therapy, and in play therapy for children with cerebral palsy. The latest technologies, frameworks, and other notes on implementing VR systems in rehabilitation therapy are also provided in these papers.

In Part 3, we look at VR as a means of assessing diseases that impact behavior by examining in detail the benefits of using VR in neurological assessment.

Below we provide a synopsis of each of the remaining twelve chapters in this book.

Part 1: Virtual Reality and Psychotherapy

In chapter 2, *Virtual Reality Supporting Psychological Health*, Maj. Melba C. Stetz, Richard I. Reis, and Raymond A. Folen provide a good introduction to VR as a method for increasing the psychological health of people in general. The focus of the chapter is on stress and anxiety, a problem that has a major impact on the wellbeing of people in modern society. This chapter begins by exploring stress and anxiety and their relationship to other medical and psychological disorders. The chapter then explores the use of VR in treating a host of anxiety disorders that range in severity from ordinary stress to Post Traumatic Stress Disorder (PTSD). These conditions are examined within both civilian and military contexts. Following the general introduction to stress is a brief review of traditional methods for managing stress. These include self-management techniques, such as deep diaphragmatic breathing, and the more intensive methods offered by psychopharmacology and psychotherapy, especially Cognitive Processing Therapy (CPT), Eye Movement Desensitization and Reprocessing (EMDR), Prolonged Exposure Therapy (PE), and Emotion-Focused Therapy (EFT). The authors then introduce VR technology as a viable alternative or complement to these therapies, providing a brief history of VR, especially as it is used in the military in managing stress and treating anxiety disorders. The authors note the many benefits VR offers over traditional therapies.

In chapter 3, *Current Trends and Future Directions for Virtual Reality Enhanced Psychotherapy*, Marilyn P. Safir and Helene S. Wallach provide a review of the various psychological disorders that have incorporated VR in their treatment. The authors begin the chapter by summarizing the best treatment regimens for a wide range of psychological disorders based on Cognitive Behavior Therapy (CBT). They discuss current difficulties that arise with various components of CBT as it is practiced today, for example, lack of therapist control and loss of confidentiality in the exposure component. The authors then focus attention on Virtual Reality CBT (VRCBT), a new and effective technology which overcomes difficulties that are typical of both *in vivo* and *in vitro* exposure. VRCBT has been used in therapy for various psychological disorders (phobia-specific, as well as social phobias, PTSD, eating disorders, pain management, sexual dysfunction, and others). This review includes cutting edge work in PTSD. This up-to-date review of VRCBT also reports studies exploring new developing techniques, including a look at training therapists in virtual worlds using virtual agents and avatars. Results are very promising. Where possible, the authors suggest modifications in treatment regimes augmented with VR, which they believe will improve treatment results.

In chapter 4, *Virtual Reality Exposure Therapy for Anxiety Disorders: The State of the Art*, Katharina Meyerbröker and Paul M. G. Emmelkamp discuss the treatment of anxiety disorders using virtual reality exposure therapy (VRET). VRET is a natural extension of exposure-based therapies, which are carried out either in the imagination or *in vivo*. In exposure therapy, anxiety is thought to subside through a process of habituation, and considerable evidence exists that supports the notion that anxiety decreases when a person manages to stay within anxiety provoking environments and situations. Currently, exposure therapy is the gold standard in anxiety therapy, but within the last decade VRET therapy has become a viable alternative. This chapter presents an excellent review of research into the outcome of VRET for various anxiety disorders: phobias, panic attacks, and PTSD. Within the literature review section, the authors discuss a number of factors, for example, presence, that play an important role in the effectiveness of VRET. Also included in this chapter is an examination of the process used by VRET, i.e., the underlying psychophysiological and cognitive mechanisms of change in VRET. Throughout the discussion the authors note some of the advantages and drawbacks using VRET and suggest areas in VRET that are in need of further investigation.

In chapter 5, *Virtual Reality as a Tool for Cognitive Behavioral Therapy: A Review*, Simona Scozzari and Luciano Gamberini provide a comprehensive review of over 140 articles on VR as it is used in CBT. This detailed review goes beyond reporting studies using VR in Exposure Therapy (VRET) to include a look at how VR is being employed to help patients suffering from other psychological disorders, such as substance abuse and eating disorders. Also included in this chapter is a detailed look at VR in CBT approaches to pain management. The chapter concludes with a description of some of the VR equipment being adopted in this domain and with a few remarks on the ethical implications of using VR in the psychological treatment of patients.

In chapter 6, *Virtual Reality and the Training of Military Personnel to Cope with Acute Stressors*, Stéphane Bouchard, Tanya Guitard, François Bernier and Geneviève Robillard provide an overview of studies that focus on the use of VR in training military personnel to handle stressful situations, a subject known as Stress Inoculation Therapy (SIT), in order to increase operational effectiveness and reduce the likelihood of developing PTSD, the only mental disorder that is significantly associated with exposure to combat. Soldiers in operational situations are confronted by a number of stressors, including the stress of being a target, killing enemy combatants, living continuously in unpredictable and threatening environments, and witnessing the horrifying sights of battle. The authors describe and discuss the effectiveness of a number of structured programs currently available that intend to teach soldiers how to manage stress and prevent psychological injury. A major shortcoming of current programs is that they fail to provide opportunities for practicing what is taught about stress reduction. There is also reluctance in military personnel for implementing these practices as the need for stress management is oftentimes seen as a sign of weakness. Since VR has a proven track record of eliciting fear reactions in people when exposed to stressful virtual stimuli, VR is providing the military with a socially acceptable method of practicing stress management. This chapter provides a brief but critical review of the literature on people's reactions to virtual stressors and the use of VR in the treatment of PTSD before focusing on the use of VR in stress management training. Included in this section is work using VR to train pre-school children and children suffering from

Down syndrome to evacuate classrooms in the advent of an earthquake. This chapter also discusses the notion of presence, its relationship to the feeling of anxiety, and methods for augmenting anxiety in VR stress training.

In chapter 7, *How Can Presence in Psychotherapy Employing VR Be Increased?*, Helene S. Wallach, Marilyn P. Safir, Roy Samana, Idan Almog, and Reut Horef discuss the importance of presence in exposure therapy. After all, for exposure to be effective, a virtual reality fear stimulus must succeed in eliciting an anxiety reaction. The chapter begins by discussing the notion of presence in detail. Roughly speaking, presence is the experience of actually being "in" the situation or environment being simulated by VR. The specific goal of this chapter is to provide a detailed review of the many variables that influence the spatial dimension (as opposed to the social dimension) of presence in VR applications in psychotherapy.

In chapter 8, *The Healing Potential of Online Virtual Worlds*, Jacquelyn Ford Morie looks at the potential offered by social networks such as Second Life (SL) to provide veterans with a socially acceptable and enjoyable means of continuing to work on stress management and other psychological problems that have arisen due to military service. The authors discuss the many benefits offered by virtual veteran healing centers; for instance, virtual healing centers could do much to reduce the stigma and cultural barriers associated with mental health disorders and therapy, as well as provide additional motivation for completing programs. Virtual worlds, such as SL, are also easily accessible from remote regions. Included in this chapter is a detailed description of various environments in a virtual healing center, colloquially known as *Coming Home*, for veterans that is being funded by the US Army's Research Office. These environments include a labyrinth with a storied activity called "The Warriors Journey," a central "Great Hall" resembling a real-world lodge, and a number of wings for playing a large variety of games and listening to music. The SL healing center's primary purpose is to provide information about stress disorders and their associated symptoms and to encourage veterans to participate in various therapies, specifically Complementary and Alternative Medicine (CAM) therapies, which can be implemented in SL. This chapter ends with a description of supporting research for virtual world effectiveness and the use of a variety of intelligent agents. A brief history of social networking, SL, and other related SL healing facilities, and a discussion of important issues and concerns are also addressed in this chapter.

Part 2: Virtual Reality and Rehabilitation

In chapter 9, *Virtual Reality and Serious Games in Healthcare*, Minhua Ma and Huiru Zheng discuss rehabilitation applications that merge VR with video game technologies. The advantage of adding video games in VR rehabilitation is that they increase the patient's willingness to continue therapy and to concentration on the task at hand. We begin part 2 with this chapter because it includes a good overview of VR devices that are currently being employed in healthcare rehabilitation applications: haptic force feedback devices, tracing devices, initial sensors, and motion tracking sensors. The discussion of VR games for healthcare also includes relevant background material on dynamic simulation, which can be controlled in rehabilitation VR so that patients can be exposed gradually to tasks that require skills approaching real-world complexity. The chapter discusses research showing that playing games is effective in improving neuromotor coordination while simultaneously engaging patients, rendering what would otherwise be an arduous process of rehabilitation more enjoyable. To explain engagement, the authors use Csikszentmihalyi's concept of *flow* and report on research in game design that could be applied to VR that attempts to enhance the experience of flow. Ma and Zheng also report their work on modeling patients. The chapter ends with a description of experiments and results in using VR (plus video games) intended for stroke rehabilitation.

In chapter 10, *Development and Evaluation of a Mixed Reality System for Stroke Rehabilitation*, Dave Hilton, Sue Cobb, Tony Pridmore, John Gladman and Judi Edmans describe the user-centered design of a Tactile User Interface (TUI) combined with a Virtual Reality Environment (VE), collectively known as a Mixed Reality (MR) environment, intended for stroke rehabilitation. Sequential tasks, such as preparing a hot cup of coffee, can become very difficult and dangerous to perform for people who have suffered from stroke. A number of computer supportive systems have been developed that offer the potential of monitoring task performance and of providing feedback in a safe virtual environment, but these systems discourage naturalistic movement of the body and fail to provide patients with realistic force feedback. To overcome these problems, Hilton, et al., have designed a MR system for assisting stoke victims in relearning to prepare hot drinks. Included in this chapter are sections describing stroke and stroke rehabilitation, home-based rehabilitation systems, and User Center Design (USD), or product development, that considers the specific needs of the intended users. The chapter outlines in considerable detail the steps that were taken by the researchers to develop their system and includes a number of feasibility and evaluation case studies as well as a number of recommendations for developers of MR systems that are for stroke rehabilitation.

In chapter 11, *Design and Development of a Virtual-Reality Based System for Improving Vision in Children with Amblyopia*, Paula Waddingham, Richard Eastgate, and Sue Cobb discuss their work using adapted VR in the treatment of children suffering from amblyopia, or 'lazy eye.' Current therapies center on forcing the patient to use the amblyopic eye by either wearing an eye patch for prolonged periods of time, a treatment that is resisted by most children, or by repeated application of eye drops to blur the vision in the good eye. The authors developed a VR system, called the Interactive Binocular Treatment (I-Bit) system, that allowed patients to use both eyes in a therapeutic setting that is entertaining. I-Bit provides preferential stimulation to the amblyopic eye. This system is a novel therapeutic solution for amblyopia. Included in this chapter is ample background material on amblyopia and its treatment, a description of relevant VR display technologies, and a detailed discussion of the development of I-Bit prototypes, usability studies, benefits and problems encountered in the design process. The chapter also presents the results of clinical evaluation trials that took place in two separate research centers.

In chapter 12, *Doing Play in a Virtual Environment*, Denise Reid provides a theoretical perspective on how VR influences the *person-environment process* with children with disabilities. The person-environment process is a theoretical construct in occupational literature that describes the fit between people with disabilities, their occupational activities, and their environment. Reid extends this construct in examining the main occupation of children—play. She examines environmental centralization (the manipulation of the environment to accommodate increasing limitations of the body), entexturement (the intensification of body awareness through an experience of textures and the regulation of activity through aural and visual stimuli to produce a satisfying experience) and personalization (environment possession) as a framework for explaining positive person-environment interaction in VR systems, specifically for children with cerebral palsy (CP) doing play. Case studies that reflect on environmental centralization, entexturement, and personalization are provided and discussed. This is followed by a detailed discussion of virtual play's impact on the playfulness, motivation, and self-perceptions of children with CP. Also included in this chapter is background material on play theory, its benefits and purpose.

Part 3: Virtual Reality and Assessment

In chapter 13, *Neuropsychological Assessment using Virtual Environments: Enhanced Assessment Technology for Improved Ecological Validity*, Thomas D. Parsons discusses the reasons for and the resulting limitations behind the slow acceptance of technological advancements in neuropsychological assessment. This is followed by a detailed discussion of how VR environments (VEs) can provide methods for creating ecologically oriented neuropsychological assessments. Included in this chapter is detailed background material on current neuropsychological assessment instruments, especially computer-based instruments. Parsons defines and critiques notions of validity and then presents a case for using VEs to create ecologically valid instruments. He then provides a framework for developing VEs that satisfy the demands of internal, external, and ecological validity.

3 Conclusion

This book is a continuation of the previous five volumes in our series on *Advanced Computational Intelligence Paradigms in Healthcare*. The recent advances in virtual reality have highlighted the importance of this technology in healthcare. The primary aim of this series is to report the emerging paradigms of computational intelligence and applications in healthcare.

References

1. McCloy, R., et al.: Science, medicine, and the future: Virtual reality in surgery. British Medical Journal 323, 912–915 (2001)
2. Milgram, P., et al.: Augmented Reality: A class of displays on the reality-virtuality continuum. In: Proceedings of Telemanipulator and Telepresence Technologies, pp. 2351–2334 (1994)
3. Spicer, M.A., et al.: Virtual reality surgery: Neurosurgery and the contemporary landscape. Neurosurgery 52(3), 489–498 (2003)
4. Erel, E., et al.: Microsurgery simulators in virtual reality: Review. Microsurgery 23(2), 147–152 (2003)
5. Cho, J.E., et al.: New technologies for reproductive medicine: laparoscopy, endoscopy, robotic surgery and gynecology: A review of the literature. Minerva Ginecologica 62(2), 137–167 (2010)

6. Kong, M., et al.: A robot-assisted orthopedic telesurgery system. In: Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 97–101 (2005)
7. Fornaro, J., et al.: An interactive surgical planning tool for acetabular fractures: Initial results. Journal of Orthopaedic Surgery and Research 5, 50 (2010)
8. Sugimoto, M., et al.: Image overlay navigation by markerless surface registration in gastrointestinal, hepatobiliary and pancreatic surgery. Journal of Hepato-Biliary-Pancreatic Sciences 17(5), 629–636 (2010)
9. Liao, H., et al.: 3-D augmented reality for MRI-guided surgery using integral videography autostereoscopic image overlay. IEEE Transactions on Bio-Medical Engineering 57(6), 1476–1486 (2010)
10. Shekhar, R., et al.: Live augmented reality: a new visualization method for laparoscopic surgery using continuous volumetric computed tomography. Surgical Endoscopy 24(8), 1976–1985 (2010)
11. Mohammed, A., et al.: Virtual cystoscopy. Expert Review of Molecular Diagnostics 8(4), 449–454 (2008)
12. Jones, C.M., et al.: Is virtual bronchoscopy an efficient diagnostic tool for the thoracic surgeon? The Society of Thoracic Surgeons 79, 365–374 (2005)
13. Snyder, C.W., et al.: Retention of colonoscopy skills after virtual reality simulator training by independent and proctored methods. The American Surgeon 76(7), 743–746 (2010)
14. Rhienmora, P., et al.: A virtual reality simulator for teaching and evaluating dental procedures. Methods of Information in Medicine 49(4), 396–405 (2010)
15. Andreatta, P.B., et al.: Virtual reality triage training provides a viable solution for disaster-preparedness. Academic Emergency Medicine: Official Journal of the Society for Academic Emergency Medicine 17(8), 870–876 (2010)
16. Issenberg, S.B., et al.: Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. Medical Teacher 27(1), 10–28 (2005)
17. Gallagher, A.G., et al.: Approval of virtual reality training for carotid stenting: what this means for procedural-based medicine. Journal of the American Medical Association 292(24), 3024–3026 (2004)
18. LeBlanc, F., et al.: A comparison of human cadaver and augmented reality simulator models for straight laparoscopic colorectal skills acquisition training. Journal of the American College of Surgeons 211(2), 250–255 (2010)
19. Moline, J.: Virtual reality for health care: A survey. In: Riva, G. (ed.) Virtual Reality in Neuro-psycho-physiology: Cognitive, Clinical and Methodological Issues in Asessment and Rehabilitation, pp. 3–34. IOS Press, Amsterdam (1997)
20. Riva, G.: Virtual reality as assessment tool in psychology. In: Riva, G. (ed.) Virtual Reality in Neuro-Psycho-Physiology: Cognitive, Clinical and Methodological Issues in Assessment and Rehabilitation, pp. 71–80. IOS Press, Amsterdam (1997)
21. Riva, G.: Virtual reality in psychotherapy: Review. CyberPsychology & Behavior 8(3), 220–230 (2005)
22. Schultheis, M.T., et al.: The application of virutal reality technology in rehabilitation. Rehabilitation Psychology 46, 296–311 (2001)
23. Riva, G. (ed.): Virtual Reality in Neuro-psycho-hysiology: Cognitive, Clinical and Methodological Issues in Assessment and Rehabilitation. Technology and Informatics. IOS Press, Amsterdam (1997)

List of Acronyms

AR	Augmented Reality
CAM	Complementary and Alternative Medicine
CBT	Cognitive Behavior Therapy
CP	Cerebral Palsy
CPI	Cognitive Processing Therapy
EFT	Emotion-Focused Therapy
EMDR	Eye Movement Desensitization and Reprocessing
HCI	Human Computer Interface
I-Bit	Interactive Binocular Treatment
PE	Prolonged Exposure Therapy
PTSD	Post Traumatic Stress Disorder
SIT	Stress Inoculation Therapy
SL	Second Life
TUI	Tactile User Interface
USD	User Center Design
VE	Virtual Environment
VR	Virtual Reality
VRCBT	Virtual Reality Cognitive Behavioral Therapy
VRET	VR in Exposure Therapy

Part 1: Virtual Reality and Psychotherapy

Chapter 2
Virtual Reality Supporting Psychological Health*

MAJ Melba C. Stetz, Richard I. Ries,
and Raymond A. Folen

Research Psychology, Department of Psychology,
Tripler Army Medical Center,
1 Jarrett White Road
Hawaii, 96859
melba.stetz@us.army.mil

Abstract. For a country to continue its' viable existence, it must be healthy. That is, it must not only maintain physical health but also psychological health. In fact, psychological health has a direct impact on the physiological health of people. The open literature suggests evidence-based strategies for helping individuals that suffer from psychological distress. Since technology is increasingly taking over the way humans relate with the world, virtual reality (VR) might be a great addition to psychotherapy sessions. In this chapter, the authors specifically discuss the effects of stress on one's health and provide a short background of VR contributions to human health.

1 Health Care in the USA

In the year 2000, the United States of America (USA) spent more on health care than any other country in the world. Seven years later, the USA spent over 2 trillion dollars on health care, tripling its 1990 reported figure.[1] However, as depicted on Figure 1, the perception by the USA population is one of enjoying "Very good" health in general.[2] The purpose of this chapter is to remind readers of some psychological health care concerns, particularly stress, and to propose the use of Virtual Reality (VR) as a complementing approach for their aid via psychotherapy.

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* The views expressed in this manuscript are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government.

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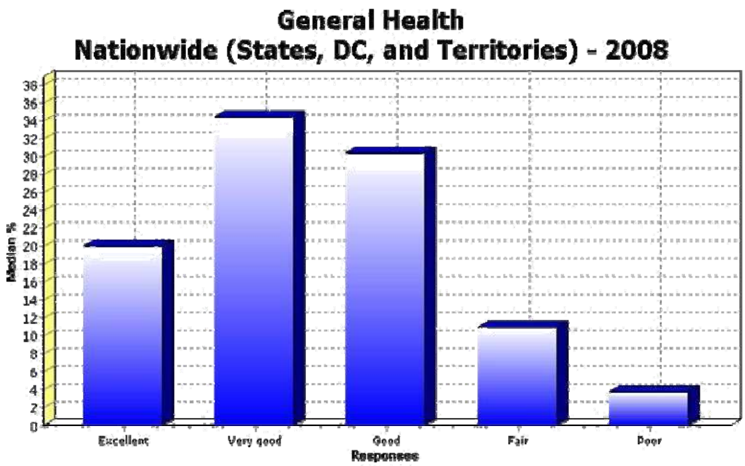

Fig. 1. General Health Nationwide (States, DC, and Territories) – 2008.

2 Health and Stress

Heart disease, cancer, and diabetes have been listed as the leading causes of death and disability in the USA.[3] In connection with this, psychological problems in health also take a toll on the USA community. Specifically, "stress" seems to be a central reported problem associated with poor health.

In 2007, The American Psychological Association conducted a survey study on USA's stress (n = 1,848).[4] Results suggest that one-third of surveyed individuals endure extreme stress. Many participants reported experiencing psychological symptoms related to stress, including irritability or anger (50 %); feeling nervous (45 %); having a lack of energy (45 %); and feeling ready to cry (35 %). Almost half of respondents (48 %) reported lying awake at night due to stress. In this study, participants' main symptoms of physical stress were reported as: fatigue (51 %); headache (44 %); upset stomach (34 %); muscle tension (30 %); change in appetite (23 %), teeth grinding (17 %); change in sex drive (15 %); and feeling dizzy (13 %).

This information begs the question; "what is "stress"? The American Stress Institute notes that it is hard to operationally define the term since it is a subjective sensation associated with varied signs and symptoms that differ for each person.[5] The word stress originates from the Latin word "stringi," which means "to be drawn tight."[6] Stress is typically associated with negative and debilitating psychological and physiological tension.

Stress-related symptoms may manifest variably in humans. It can influence mood, motivation-level, life outlook, and even physiological health. Chronic activation of stress response systems, such as the sympathetic adrenomedullary system, may also lead to physiological and psychological difficulties, including decreased vitality of the immune system.[7]

Advances in neuroimaging, oculometrics and electroencephalographic measures have identified changes in attention and alertness under sleep deprivation associated with stress.[8,9] For instance, severe sleep deprivation impairs cognitive performance and results in profound metabolic deficits in brain areas associated with perception and attention.[10, 11]

Stress can also be associated with positive reactions and can have different roles as either an independent variable ("stressor") or a dependent variable ("strain").[12] Dr Hans Selye, known as the "Father of Stress," argues that stress is necessary in life and does not always involve negative consequences.[13] He defines "eustress" (e.g. motivation to go jogging) as a positive type of stress and "distress" as a negative aspect of stress. Similarly, Yerkes and Dodson offered the inverted-U theory, which proposes that moderate stress can improve performance while too much stress decreases performance.[14] One might think how butterflies in the stomach can improve a theatrical performance by ushering up greater artistic passion as an example.

Moving forward in this chapter, the authors will treat the term stress as *"A physical, chemical, and [or] emotional factor that causes measurable bodily or mental tension and which may be a factor in disease causation".[15]*

3 Stress and Mental Health

3.1 Stress and Anxiety Mental Health Disorders

The field of psychology is especially interested in stress disorders rooted in conscious experience. In the psychology nomenclature, a powerful response to a traumatic stressor may develop into a psychological disorder called "Acute Stress Disorder (ASD)." As implied by the name, the response is acute, or temporary, and related to stress. Specifically, ASD is an Anxiety Disorder that may develop in individuals who have been exposed to a traumatic event in which there was the threat of death or severe injury to the individual and/or others. The person's emotional response to this danger typically involves intense fear, vulnerability, and/ or terror to a degree considered outside the realm of normal experience. Trauma survivors who develop ASD experience at least three dissociative symptoms, such as a reduced awareness of their surroundings, numbed emotions, a sense of unreality or derealization, depersonalization (or deep isolation even amongst caring others), or dissociative amnesia (the inability to recall important aspects of a trauma). The survivor also relives the trauma through such experiences as dreams, persistent and recurrent thoughts and images, and flashbacks. There is a sense that one cannot control the content or vividness of such thoughts. ASD sufferers may also experience distress when confronted with stimuli that trigger memories of their traumatic experience. Some consider ASD a "normal" response to an abnormal experience (or set of abnormal experiences).

When ASD symptoms last longer than four weeks it is time to consider "Post-Traumatic Stress Disorder" (PTSD) as a diagnosis. PTSD was codified as a mental disorder in 1980 and resembles ASD in its characteristic features (hyperactivity, avoidance, and re-experiencing).[16] It's symptoms manifest within 6 months after exposure to a traumatic stressor and last at least three months, but is often of significantly longer duration.[17] In fact, according to the DSM-IV-TR, approximately 80 percent of individuals diagnosed with ASD after exposure to an automobile accident or violent crime will go on to meet criteria for a diagnosis of PTSD one month later.

Some individuals with PTSD may attempt to actively suppress thoughts and feelings related to their trauma(s). That is, places, people, and activities that resemble the event in some manner may be repeatedly avoided. Drug and alcohol abuse are frequently used as maladaptive coping attempts.[18] Individuals can also exhibit responses that are not on the surface of consciousness or that are not intentional. For example, many PTSD sufferers have difficulty remembering important details of a trauma; they experience amnesia related to the event. Avoidance of trauma-related stimuli is usually coupled with a generalized sense of numbing across many areas of potential responsiveness. Individuals may become starkly uninterested in activities that were previously important and enjoyable to them. They may feel deeply estranged, or isolated from others to whom they had previously felt close.[19]

In PTSD, a restricted range of affect or a sense of foreshortened future can also sometimes be identified. Increased arousal may be apparent in the traumatized individuals' inability to fall or stay asleep or to achieve a deeply relaxed state. Individuals with PTSD may be prone to angry outbursts or irritability, as is commonly depicted in the media. These individuals often find that they have difficulty concentrating. Since their sense of safety has been compromised, individuals with PTSD often demonstrate hypervigilance and an exaggerated startle response.[20] Other symptoms associated with PTSD include: feelings of deep-seated betrayal by a figure or figures of authority or power (i.e. the government, or G-d), guilt about surviving a traumatic event when others have not; feelings of guilt about what one did, or did not do, in order to survive; social withdrawal; self-destructiveness, impulsive behavior; various somatic symptoms; impairments in dealing with interpersonal relationships; feelings of hopelessness and despair; feeling incapable or impotent; feelings of being damaged; persistent distressing existential questions, thoughts of meaninglessness and marked changes in personality.[21]

The severity of PTSD symptomology is influenced by the gravity or extent of the actual exposure to a stressful event.[22] For instance, the sudden unexpected death of a loved one carries a risk of 14.3% for triggering PTSD while combat, mass violence, and bombing can evoke incidences as high as 20-40%.

Aside from the defining sequelae characteristic of PTSD, there is a high degree of comorbidity with related or overlapping disorders including depression [17] substance abuse (likely connected to broad avoidance symptoms) [18] and other anxiety disorders. These other symptoms have been considered attributable to the general and specific forms of distress that PTSD brings forth into the awareness and internal experience of the sufferer. They result in ongoing psychic pain and may even lead to suicidality.[17]

3.2 Combat Stress and Combat Stress Prevalence Rates

The military has been at the forefront on research regarding stress and its subsequent psychological and physical effects. Several studies indicate that battlefield stressors can impair performance functioning, including a soldier's concentration, attention, vigilance, language memory, and recall.[24] Battlefield stressors can also impair other high order cognitive processes, such as judgment, planning, situational awareness, and sound decision making. Combat-related mental health problems range from sub-clinical mental distress that can affect cognition to psychiatric illnesses (e.g. panic disorder, depression, obsessive-compulsive disorder, bipolar disorder, and schizophrenia). Furthermore, trauma victims may develop posttraumatic stress disorder several years after exposure.[25] Despite military mental health care's efforts to screen for these conditions and avoid deploying soldiers with these disorders, many soldiers will acquire these conditions after a single deployment.

According to the National Institute of Mental Health, PTSD affects an estimated 5.2 million Americans per year. This impacts the quality of life, not just of those who fit the diagnosis, but also to others around them in the families, work places and communities.[26] The military, as a social sub-culture, is often considered a stress-inducing organization. It should not be surprising that many warfighters (i.e. Soldiers, Airmen, Sailors, Marines) return from fighting the current War on Terror with psychological problems (e.g., PTSD) along with associated physiological symptoms (e.g., high blood pressure). Combined with Depression and Anxiety disorders in general, PTSD impacts 3% - 15% of marines and soldiers.[27] In fact, Hoge and his team have suggested that 1 out of 10 Operation Iraqi Freedom (OIF) veterans in the USA typically suffer from some type of stress disorder. Similarly, another study on veterans (e.g., OIF; n = 103,788) suggested that about 1/3 of those that received care from 2001 to 2005 were either diagnosed with general mental health or psycho-social problems.[28] Undoubtedly, chronic psychological and physiological symptoms of distress can negatively impact warfighters' operational performance and vulnerability in the warzone as well as her/his physicality.[29]

Greatly associated to the stigma that warfighters have been shown to associate with seeking help, participants in a study by Stetz (author) reported preferring to chat with peers, chaplains, and military leaders in lieu of consulting a mental health professional.[45] Furthermore, in that same study (n = 283) deployed warfighters reported a preference for using their five senses (suggesting the preference with being immersed in activity) when managing their stress. Specifically, their main preferences were: listening to music (65%), watching movies (62%), and playing computer games (39%). Similarly, other researchers have reported that warfighters would rather utilize technologies for mental health care (e.g., video teleconferencing, internet-based treatments, and virtual reality) than talk to a counselor in person.[46]

3.3 Stress and Neurophysiology

The biological basis of PTSD remains under scientific investigation, but most consider the expression of the syndrome to relate to overactivity of the noradrenergic nervous system. The common reports of hyperarousal and exaggerated startle would seem to corroborate this. Hippocampal involvement (volume reduction) has been further suggested, likely due to the frequency of reported memory deficits in patients with PTSD. In a manner comparably suggested with respect to depression, PTSD-related hippocampal damage (also volume loss) has been attributed to abnormal stress levels over time.[18] In addition to replicating the finding of reduced hippocampal volumes in individuals with PTSD, research has consistently found increased cerebrospinal fluid intracranial volume ratios as well as decreased white matter intracranial volume ratios, indicative of white matter atrophy.[30] Changes (in this case, shrinkage) in hippocampal or anterior cingulated areas (i.e., structures involved in memory, emotional processing, and attention) may account for PTSD emotional impacts and cognitive effects.[31,32,33]

In PTSD, the recollection of traumatic events has been associated with increased brain activity in the amygdala, anterior temporopolar cortex, insular cortex, and orbitofrontal cortex, and relatively decreased brain activity in the subcallosal gyrus, anterior cingulated gyrus, and medial frontal gyrus. Functional magnetic imaging research using cognitive activation paradigms have further demonstrated the significance of the medical prefrontal regions and amygdala in PTSD brain processes.[24]

4 Psychotherapy for Stress Problems

A typical magazine rack will offer several approaches to self-management of stress. Deep diaphragmatic breathing, taking a walk, or talking with a supportive friend might be suggested for immediate stress management. Longer term stress reduction techniques might include diet and exercise changes or better adherence to a sound sleep schedule. While these management techniques are quite effective for everyday stressors, they would not be considered sufficient for dealing with the aftermath of a severe trauma.

4.1 Chemical Approaches

While psychotherapy is generally the treatment of choice for PTSD, some situations may call for the use of psychopharmacology. For example, when flashbacks, derealization, transient psychoses, or avoidance and numbing become too intense or overwhelming, short-term psychotropic medication may be applied in treatment. Longer-term medications may be warranted if major depression, panic attacks, or persistent psychotic symptoms are present and interfere with daily functioning or are too intense and overwhelming. Indeed, the original psychopharmacological approach to PTSD treatment seemed to target the comorbid symptoms of the disorder (i.e. depression).[37]

At present, medications are often prescribed in conjunction with Cognitive Behavioral Therapy (CBT), as the combined effects of these two treatment approaches appear to address anxiety symptoms effectively. Since PTSD is so often found to involve self-medication efforts with addictive substances, benzodiazepine usage is generally discouraged.[18] Anxiety disorders in general (including ASD and PTSD) may be associated with a decreased number of benzodiazepine receptors in the brain located on GABA (A) receptors.[18] Another hypothesis posits the presence of a neuromodulator that blocks these benzodiazepine receptor sites from doing what they normally do. One can see the increased risk of addiction if such viewpoints are accurate.

Several studies suggest that serotonin may play a role in anxiety disorders, by way of specific, or selective, serotonin reuptake inhibitors (SSRIs). SSRI’s have shown promise in PTSD treatment as well as the newer antidepressants (i.e. nefazodone). Fluvoxamine, a serotonin agonist, has been shown to be helpful in treating anxiety disorders and has become a first line choice for psychopharmacological treatment. Effexor (venlafaxine), which is a serotonin and norepinephrine reuptake inhibitor (SNRI) has shown notable efficacy for treating anxiety and may replace SSRIs as the most popular treatment choice for this family of disorders. The effectiveness of GABAergic, noradrenergic, and serotonergic drugs in treating anxiety suggests the role of respective neurotransmitters in the biological bases of anxiety experiences. People with anxiety show chronically elevated levels of the stress hormone, cortisol, and a corresponding desensitization of cortisol receptors in the brain. This system is modulated by the hypothalamus through the anterior pituitary gland.[7,37]

Beta-adrenergic blocking drugs such as propranolol may be used in treating acute anxiety associated with specific stressful events (e.g., public speaking, stage fright). Beta-adrenergic blocking drugs affect peripheral manifestations of anxiety, including palpitations, tachycardia, tremors, and sweating. Propranolol may produce side effects such as bradycardia, fatigue, malaise, and decreased sex drive. General medical conditions need to be ruled out before making a formal psychiatric diagnosis. A common physiological problem that may masquerade as an anxiety disorder is hyperthyroidism, which produces symptoms that can appear similar to anxiety. While Monoamine oxidase inhibitors (MAOIs) and tricyclic antidepressants have demonstrated efficacy for PTSD treatment comparable to other medicines, they are no longer considered first or even second line treatments.[18]

4.2 Behavioral Approaches

"Psychological Debriefing" is a common treatment for trauma survivors. During Psychological Debriefing, individuals exposed to traumatic events are brought together to receive psychoeducation about possible responses to the trauma and to share their experiences of the trauma (e.g., being in a hostage situation, or dealing with a natural disaster). The debriefing takes place within two to three days of the traumatic event. It involves attempts to normalize how people typically respond to trauma and encourages individuals to express feelings. Attention is given to teaching trauma survivors coping skills and ultimately to providing them with referrals to other professional counselors should continued attention seem necessary. Research seems to indicate that psychological debriefing is not effective in preventing the development of PTSD.[38] In fact, it has been suggested that single-session psychological debriefings may even aggravate onset of PTSD symptoms. That is, as debriefing approaches are updated and brought to better levels of sophistication in the future, they may be shown to mature into more effective preventive measures. At present, however, it has not been scientifically demonstrated to be broadly effective as a trauma intervention.

As mentioned earlier, Cognitive-Behavioral Therapy (CBT) seems to be the trend, or treatment of choice for both ASD and PTSD in psychological arenas. CBT is a psychotherapeutic approach characterized by application of thought-based and action-based approaches to improve well-being. It emphasizes the interactive relationships between thoughts, feelings and behaviors in shaping the human experience. Lately, the current top evidenced-based cognitive-behavioral treatments for PTSD seem to be Cognitive Processing Therapy (CPT), Eye Movement Desensitization and Reprocessing (EMDR) Therapy and Prolonged Exposure Therapy (PE).[40]

CPT is a commonly offered treatment for patients with PTSD, particularly in the military. The central idea of this form of psychotherapy is that beliefs and conceptions of the world have been altered as a result of a trauma, leading to a generalized loss of the sense of safety that likely characterized the patient's worldview prior to the trauma. Such generalized and negative beliefs are referred to as "stuck-points" and are reevaluated in a psychotherapy and homework context against more realistic expectations.

In EMDR, an individual's mind is flooded with memories of their trauma while they are instructed to move their eyes or head in a specific, side-to-side, manner following their therapist's prompts.[43] Alternatively tones or taps might be used as the trauma information is processed. Patients appear to become desensitized to the more emotionally distressing aspects of their trauma during EMDR treatment, and some theorists have postulated that there may be a psychoneurological factor related to the eye movement itself that assists with psychological healing. Although proponents of EMDR believe that this method helps the client to reprocess traumatic events more rapidly, some research indicates that it is no more effective than other forms of CBT. That is, the added element of eye movement does not seem to effectively influence the treatment's efficacy. In fact, many researchers have concluded that EMDR is simply a dressed-up form of exposure therapy. Such assertions should be taken with a grain of salt, as polity interferes with even the best efforts toward identifying and conveying what works in treatment.

Finally, PE involves engaging a patient in exercises of "in vivo" and "imaginal" exposure while also teaching deep relaxation and self-monitoring skills. Specifically, in vivo exposure asks the patient to face situations that they would customarily avoid. Psychotherapists assist patients in designing a list that is comprised of a series of avoided situations to be later confronted. The patient then goes in to a distress inducing circumstance with the plan to endure until anxiousness abates. Unfortunately, in vivo experiments always bear risks of uncontrollable eventualities that may set back patient progress. Self monitoring using Subjective Units of Distress (SUDS) and deep breathing relaxation techniques are greatly used in PE to balance against potentially deleterious levels of angst. In imaginal exposure, the patient is asked to bring her or his thoughts to memories of a trauma in as experience-near a manner as possible. Often language is encouraged to be in the present tense, and from a first person vantage point, so as to facilitate the immersion and immediacy of the experience. Eventually the goal of imaginal exposure is habituation, or getting used to, the memory content. Imaginal exposure seems, in research studies, to be more effective than relaxation training alone or eye-movement desensitization and reprocessing techniques used to reduce avoidance behavior, reduce the re-experiencing of the trauma, and maintain symptom remission after treatment has ended.

Now, while both imaginal and in vivo exposure treatments are effective, both also have potential shortcomings.[44] For example, imaginal exposure can be limited by the individual's ability to create and manipulate mental images. Providers are only able to connect to what the patient is experiencing by way of what patients tell them. It is conceivable that a particular patient might have a vivid imaginal experience, but be unable to adequately communicate the depth and charge of this experience due to vocabulary limitations, conceptualization limitations or even low motivation. On the other hand, while in vivo exposure does not rely on imagination or verbal fluency, it involves risks that cannot be controlled by a provider and which may introduce harmful elements that could derail or impede psychotherapeutic gains (i.e. a fight breaking out in a crowded mall while a patient is hoping to overcome fears in such a context).

Emotion-focused therapy (EFT) is also showing notable promise.[39] EFT mixes methods of the Gestalt and Person-centered approaches to psychotherapy while incorporating some cognitive therapy elements. It essentially involves using specific experiential psychotherapeutic techniques to help patients identify and resolve internal conflicts.[41]

The approach aims to facilitate accurate emotional expression, to clarify the truest roots of feelings and, eventually, to allow a natural transformation of emotion toward healthy and more liberated ways of relating to the world.[42] Both cognitive processing and emotional processing are involved in emotion coaching in the aftermath of a trauma. A traditional CBT interpretation of EFT approaches might suggest that the success of the treatment relates to exposure, through psychotherapeutic exploration, to trauma memory content. CBT treatments for trauma, on the other hand, might be interpreted by EFT psychotherapists as venues for emotional processing that usher forth healing opportunities while exposure is applied. Primary mechanisms of change, aside, in general terms, it seems that the key components of successful psychotherapy for traumatic stress involve exposure, habituation, changing of faulty beliefs, and emotional transformation.

4.3 Biofeedback

Generally speaking, all stressors elicit a similar physiological response or "strain" within the body.[13] These include increased blood pressure, mydriasis (dilated pupils), tachycardia (elevated heart rate), and increased sweat production. In addition, because psycho-physiological disorders often afflict organs innervated by the autonomic nervous system, researchers and clinicians have been intrigued by biofeedback aimed at giving people control over autonomic functions.[18] Harvard studies have demonstrated that human volunteers can use biofeedback to achieve significant short-term changes in blood pressure and heart rate. Some people can even be trained to increase their heart rate while decreasing their blood pressure. Current research using biofeedback to treat hypertension has proved somewhat encouraging, but results have not been certain enough to establish biofeedback as a standard treatment for the disease.

The body's own natural biofeedback is comprised of the impulses received by the brain from our muscle tissue and visceral organs. These impulses allow the human nervous system to process what our bodies are doing and the state it is in. The central nervous system uses this information to regulate the body's internal systems and ultimately, to maintain physiologically desirable levels. These same signals can be registered by external measuring devices and used in therapy to teach people how to control and maintain target levels of autonomic nervous system activity, resulting in health benefits and in some cases, reduced stress impact. This type of treatment has been used to successfully treat and control hypertension, migraine headaches, and anxiety attacks.

"Biofeedback" as a treatment is often used in conjunction with autogenic training, whereby individuals are directed to use their thoughts and concentration to alter their body state (i.e. imagining a cooling sensation to soothe acid reflux symptoms). Studies, however, done on hypertension are still inconclusive as to whether combining autogenic training and biofeedback is more effective than either treatment on its own. Biofeedback can also be useful in managing somatoform disorders, if stress is a key factor for the client when feeling pain. Biofeedback is a noteworthy therapeutic technique because it allows people to acquire control over their behaviors that are commonly regarded as not being under voluntary control (for example, brain waves, heart rate, skin temperature, blood pressure, and other bodily functions).[35] Biofeedback interacts with the parasympathetic nervous system, which is responsible for rest, relaxation, recuperation and sexual arousal.

This type of feedback entails operant conditioning of the normally involuntary functions of the autonomic nervous system. The patient is taught to regulate certain physiological functions, and is given visual and/or auditory feedback about the status of these functions, with the goal of affecting physical symptoms. One important aspect of biofeedback is that the person is able to know immediately, through auditory or visual signals, if the somatic activity of interest is increasing or decreasing certain biometric markers that relate to levels of relaxation. The biometric data trumps psychological denial mechanisms, or can attune someone directly to what the body is telling one about it's state. Biofeedback is still controversial in some ways, as is virtual reality, since some believe that using it for stress and anxiety is an expensive treatment for difficulties that could be addressed with relaxation training, meditation, or self-hypnosis alone. In fact, several investigators believe that relaxation training actually does more than biofeedback to reduce blood pressure.

The most common methods of recording biofeedback impulses use galvanic skin response (GSR), peripheral skin temperature (PST), electromyography (EMG), electrocardiography (EKG), and electroencephalography (EEG).[36]

Neurofeedback is another way of capturing biometric markers. Brainwave activity via electrodes placed on the scalp is measured by sensors and indicates information about consciousness level. The goal with this approach is to record and provide feedback to individuals regarding what it feels like to attune one's Central Nervous System functioning toward certain desirable consciousness-states, and to maintain them for health benefits.

4.4 Virtual Reality in Psychotherapy

Many youngsters (e.g., "Generation Internet"), including those in the military, seem to gravitate towards varied types of technology as a form of leisure and lifestyle.[47] In fact, the US Army recently released the new Field Manual 7.0 "Training for Full Spectrum Operations" [48] which corroborates technology and gaming as a needed military tool. Therefore, warfighters may be more inclined to engage in a psychotherapeutic dynamic if it involves technology or video games. Virtual Reality (VR), as its name implies, is a reproduced or simulated actuality. It can be defined as a set of computer technologies that, when combined, provide an interface to a computer-generated world. The benefit of this type of reproduced reality is that it can be experienced, simultaneously, by both the therapist and the client. There is no need to imagine or directly expose the patient again to his or her traumatic stressor. Furthermore, stressors can be presented in a progressive and measured manner.

Virtual reality technology has arrived, taking birthright from combined investments from the military, NASA and the entertainment industry.[49] Scholars have traced its history as far back as the early 1800's when simulated environments were used to create a sense of savage environs and motion, through the use of moveable circular partitions. One hundred years later simulator rides hit the public scene, incorporating lighting changes, sound effects, and even artificially produced scents to invigorate the senses and scaffold the sense of realness of the experiences. In 1975 NASA contracted out construction of a system much like the Head Mounted Displays used in modern times, featuring stereoscopic and wide angled views, presumably for purposes of generating experience-near and immersive perceptions. In the eighties, many advances were made in technology but the devices remained relatively obscure from the general public. Still, it's being featured in the media (television, movies) seemed to spark a public interest. In the Mid-nineties Virtual environments became increasingly available, interactive and realistic, with liquid crystal displays, three-dimensional audio and even gloves that could be used for "navigation". A public market did not seem on the horizon, however, so the technology increasingly became directed toward government use. Fast forwarding to the present day, computer technology has clearly maintained a central role in virtual reality and application has become a boon to mental health and behavioral science.[49]

Gladly, shortcomings from the above-mentioned psychotherapeutic approaches (e.g., the risks of distressing patients with in vivo and imaginal approaches) may be addressed by placing individuals in virtual reality (VR) worlds that merge elements from both of these approaches. VR, as simply as its' name implies, is a reproduced or fake "reality." That is, this experience feels real, yet it is not, and "events" are controllable — minimizing risk. Also, part of the beauty of this approach is that it can be experienced, in unison, by both the therapist and the client. The typical technology used in VR therapies and research involve having an individual play a computer video game while wearing a head mounted display (see Figure X) while a therapist observes or prompts him/her to practice positive coping strategies (e.g., controlled breathing). There is no need to request a person to imagine their trigger, or risk further traumatization by setting them out into uncontrolled environments, rather habituation can be gently presented with a safe, virtual, experience. Also, since this modality makes use of modern technology, stressors can be presented gradually and consistently. Virtual zones can be so convincing that many research participants come to experience the suspended belief that that they are (phenomenologically) "actually present in a three-dimensional world".[49]

Psychology literature frequently references the stress response as being divisible by three reactions; fight, flight or freeze. In a VR session, the typical way to capture information about which of the "flight, fight, or freeze" stress-response options becomes activated in response to a stressor, is via the use of a battery of tests consisting of surveys and physiological apparatuses (AKA: biofeedback equipment). For example, pulse is an indirect means to assess heart rate. A decrease in pulse, and therefore heart rate, is indicative of reduction of sympathetic arousal. Sympathetic arousal can be measured by taking the peripheral skin temperature too. Similarly, since perspiration contains salt, sweat production can be measured via the ease with which an electric current runs across electrodes placed at two points on the body. A change in stress is often paired with a decrease in muscular tension, which can be measured by electromyography (EMG) technology. The muscles on the forehead, or frontalis, are the most typically used for measurement. Resting respiratory rate may be captured with elastic bands placed around the chest or abdomen.

Wiederhold, Bullinger and Wiederhold have reported success when using VR to mitigate the negative impact of combat stress.[50] Similarly, Stetz, Long, Wiederhold, and Turner examined the usefulness of VR technology with a deployed sample of combat medics (n = 60).[51] Most of them (n = 48, 80%) reported having previous experience with video gaming systems (e.g., computerized games). This study examined the emotional levels of participants who were in one of three groups: saving a virtual patient ("VR" group); practicing relaxation techniques only ("Coping" or "CT" group); or participating in a group that practiced relaxation techniques while attempting to save the patient ("CT + VR" group). The VR-only group showed higher levels of hostility than the other groups, suggesting effective immersion, hence inoculation potential, in the VR world (see Figure 3). Stetz, Bouchard, Wiederhold, and Folen reported that many individuals who practiced relaxation via VR scenarios (n = 29 out of 30) would continue practicing after the conclusion of the study.[52]

The Department of Psychology at the Tripler Army Medical Center in Hawaii continues helping distressed warfighters and their families while also testing the efficacy of VR clinical research protocols. Preliminary data in one of these studies[53] suggests that participants wearing HMDs to watch videos of angry bosses yelling at them, showed higher levels of presence/ immersion and emotional reactivity to anger than those watching the videos just on a flat screen (n = 30). Anecdotal data from another of these clinical research protocols suggests pain distraction by urology patients playing videogames during cystoscopy procedures [23]. Finally, relaxation exercises paired with VR or other technology-based interventions, when compared with standard therapist interventions, are showing superior usefulness for reducing the intensity of chronic pain endorsed by patients [24].

Fig. 2. Data collection in a temporary laboratory setting.

Fig. 3. Virtual Reality Relaxation Training

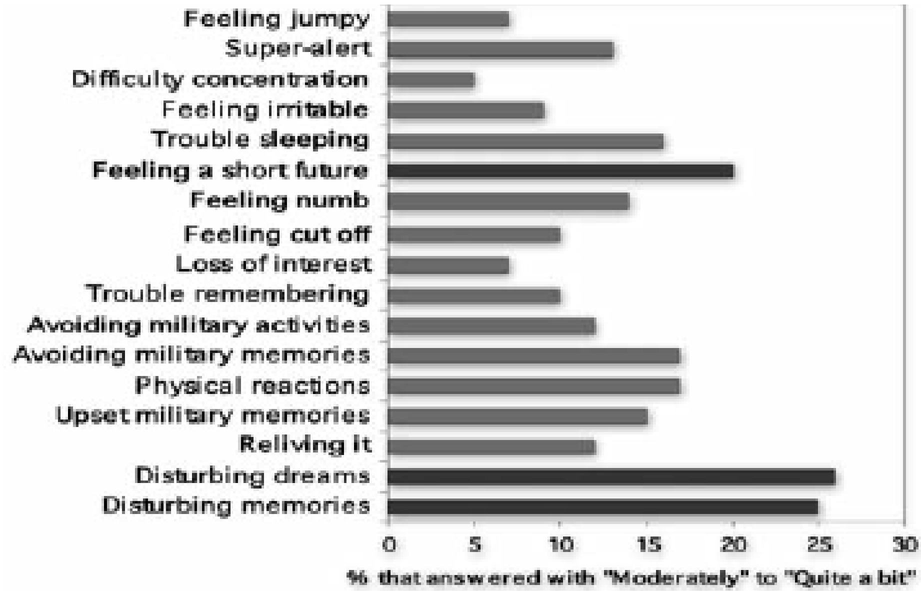

Fig. 4. PCL-M results during a screening session.

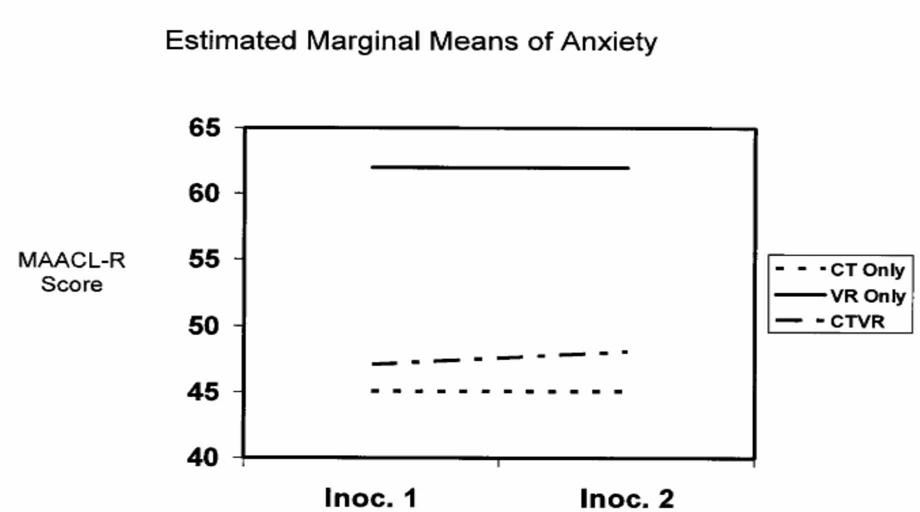

Fig. 5. Inferential Analysis of Respiratory Rate.

5 Discussion

Across the past 10 years virtual reality (VR) has begun to make meaningful inroads into the behavioral health field. Its flexibility offers a variety of uses, one of which has been for the treatment and training of individuals who have been exposed to trauma.[23] While effective treatments have been supported by a research base, anyone moderately sophisticated in understanding empirical findings understands that what works for the average may not work for the outlier in a clinical setting. Patients that did not appear to be benefitting from imaginal exposure treatment were found to make significant gains when imaginal exposure was replaced with VR exposure.[23] VR has been featured broadly in studies on PTSD treatment and seems to range from a success rate between 66% and 90%. Specifically, VR was found to be notably effective in the treatment of collision-related PTSD[16].

Aside from treating PTSD, VR has also been explored as a potential catalyst for Stress Inoculation Training, or to prepare individuals for facing stressful situations with less damage to their psyche. It may be seen as a form of desensitization that is effective shortly after sessions as well as a potential salve against future long-term stress reactions. While research in this area is cutting-edge, experts are claiming that it has shown quite promising outcomes to date.[23]

References

1. Centers for Medicare and Medicaid Services, Office of the Actuary, National Health Statistics Group: 2007 National Health Care Expenditures Data (March 2009)
2. http://apps.nccd.cdc.gov/brfss/display.asp?yr=2008&cat=HS&qkey=1100&state=US
3. http://www.cdc.gov/nccdphp/
4. http://www.apa.org/releases/stressproblem.html
5. The American Stress Institute. Stress, Definition of Stress, Stressor, What is Stress?, Eustress? http://www.stress.org
6. Stetz, M.C., Thomas, M.L., Russo, M.B., et al.: Stress, mental health, and cognition: A brief review of relationships and countermeasures. Aviation, Space and Environmental Medicine 78(5), B252–B260 (2007)
7. Kemeny, M.E.: The Psychobiology of Stress. Current Directions in Psychological Science 12(4), 124–129 (2003)
8. Banderet, L.E., Russo, M.B.: Cognitive Performance and communications in a network-centric battle laboratory. Aviat. Space Environ. Med. 76(Suppl. 7), C21-3 (2005)
9. Fukuda, K., Stern, J.A., Brown, T.B., Russo, M.B.: Cognition, blinks, eye-movements and papillary movements during performance of a running memory task. Aviat. Space Environ. Med. 76(7), C75–C85 (2005)
10. Thomas, M.L., Sing, H.C., Belenky, G., et al.: Neural basis of alertness and cognitive performance impairments during sleepiness. I. Effects of 24 hours of sleep deprivation on waking human regional brain activity. J. Sleep Res. 9, 335–352 (2000)
11. Villarreal, G., Hamilton, D.A., Petropoulos, H., et al.: Reduced hippocampal volume and total white matter volume in posttraumatic stress disorder. Biol. Psychiatry 52, 119–125 (2002)
12. Selye, H.: Confusion and controversy in the stress field. Journal of Human Stress 1(2), 37–44 (1975)
13. Selye, H.: The stress of life. McGraw-Hill, New York (1956)

14. Yerkes, R.M., Dodson, J.D.: The relation of strength of stimulus to rapidity of habit-information. J. Comp. Neurol. Psychol. 18, 269–274 (1908)
15. Merriam-Webster (2009), `http://www.merriam-webster.com/dictionary/stress`
16. Wiederhold, B.K., Walshe, D.G., O'Sullivan, K., Lewis, E.J., Kim, S.I.: Exploring the Use of Computer Games and Virtual Reality in Exposure Therapy for Fear of Driving Following a Motor Vehicle Accident. In: CyberTherapy Conference, San Diego, California, January 19-21 (2003)
17. American Psychiatric Association: Diagnostic and statistical manual of mental disorders DSM-IV-TR, 4th edn. American Psychiatric Association, Washington (2000)
18. Stahl, S.M.: Essential Psychopharmacology: neuroscientific basis and practical applications, 2nd edn. Cambridge University Press, New York (2006)
19. First, M.B., Spitzer, R.L., Gibbon, M., Williams, J.B.W.: Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I). American Psychiatric Association, Arlington (1997)
20. Kubany, E.S., McKenzie, W.F., Owens, J.A., Leisen, M.B., Kaplan, A.S., Pavich, E.: PTSD among women survivors of domestic violence in Hawaii. Hawaii Medical Journal 55, 164–165 (1996)
21. Foa, E.B., Tolin, D.F.: Comparison of the PTSD Symptom Scale–Interview Version and the Clinician-Administered PTSD Scale. Journal of Traumatic Stress 13, 181–191 (2000)
22. Danckwerts, A., Leathem, J.: Questioning the link between PTSD and cognitive dysfunction. Neuropsychol. Rev. 13, 221–235 (2003)
23. Shin, L.M., Shin, P.S., Heckers, S., Krangel, T.S., et al.: Hippocampal function in posttraumatic stress disorder. Hippocampus 14, 292–300 (2004)
24. Klonoff, H., McDougall, G., Clark, C., et al.: The neuropsychological psychiatric, and physical effects of prolonged and severe stress: 30 years later. J. Nerv. Men Disord. 163, 246–252 (1976)
25. Wiederhold, B.K., Wiederhold, M.D.: Virtual reality for posttraumatic stress disorder and stress inoculation training. Journal of CyberTherapy & Rehabilitation 1 (2008)
26. James, L.C.: Fixing Hell; and army psychologist confronts abu ghraib COL (RET), p. 224. Grand Central Publishing, New York (2008)
27. Hoge, C.W., Auchterloni, J.L., Milliken, C.S.: Mental health problems, use of mental health services, and attrition from military service after returning from deployment to Iraq or Afghanistan. Journal of the American Medical Association 295, 1023–1032 (2006)
28. Stetz, M.C., McDonald, J.J., Lukey, B.J., Gifford, R.K.: Psychiatric diagnoses as a cause of medical evacuation. Aviation, Space, and Environmental Medicine 76(Suppl. 7), C15–C20 (2005)
29. Villarreal, G., Hamilton, D.A., Petropoulos, H., et al.: Reduced hippocampal volume and total white matter volume in posttraumatic stress disorder. Biol. Psychiatry 52, 119–125 (2002)
30. Bremner, J.D., Randall, P., Scott, T.M., et al.: MRI-based measurement of hippocampal volume in patients with combat-related posttraumatic stress disorder. Am. J. Psychiatry 152, 973–981 (1995)
31. Gurvitis, T.G., Shenton, M.R., Hokama, H., et al.: Magnetic resonance imaging study of hippocampal volume in chronic combat-related posttraumatic stress disorder. Biol. Psychiatry 40, 192–199 (1996)
32. Rauch, S.L., Shin, L.M., Segal, E., et al.: Selectively reduced regional cortical volumes
33. Nestoriuc, Y., Martin, A., Rief, W.: Biofeedback treatment for headache disorders; a comprehensive efficacy review. Applied Psychiphysiology and Biofeedback 33, 125–140 (2008)
34. Russo, M.B., Stetz, M.C., Thomas, M.L.: Monitoring and predicting cognitive state and performance via physiological correlates of neuronal signals. Aviation, Space, and Environment Medicine 76, C59–C63 (2005)

35. Klein, S.B., Thorne, B.M.: Biological Psychology. Worth Publishers, New York (2007)
36. Foa, E.B., Keane, T.M., Friedman, M.J., Cohen, J.A. (eds.): Effective treatments for PTSD: Practice guidelines from the International Society for Traumatic Stress Studies, 2nd edn. (2009)
37. Greenberg, L.S.: Emotion-focused therapy: Coaching clients to work through their feelings. American Psychological Association, Washington (2002)
38. Kennedy, K.: No quick fix. Army Time, December 7, pp. 12–14 (2009)
39. Johnson, S.M.: Emotionally focused couple therapy with trauma survivors: Strengthening attachment bonds. Guildford Press, New York (2002)
40. Taillefer, A., Drouin, M.: Integration of behavioural and humanist techniques for the PTSD treatment. Revue Quebecoise de Psychologie 27(1), 171–184 (2006)
41. Michael, M.L., Metzger, L.J., Lasko, N.B., Berry, N.J., Orr, S.P., Pitmen, R.K.: Five-year follow-up study of eye movement desensitization and reprocessing therapy for combat-related posttraumatic stress disorder. Comprehensive Psychiatry 41(1), 24–27 (2000), doi:10.1016/S0010-440X(00)90127-5.
42. North, M.M., North, S.M., Coble, J.R.: Virtual Reality Therapy: An Effective Treatment for Psychological Disorders. In: Riva, G. (ed.) Virtual Reality in Neuro-Psycho-Physiology, Milan, Italy. IOS Press, Amsterdam (1997)
43. Stetz, M.C., Thomas, M.L., Russo, M.B., Stetz, T.A., Wildzunas, R.M., McDonald, J.J., Wiederhold, B.K., Romano, J.A.: Stress, Mental Health, and Cognition: A brief review of Relationships and Countermeasures. Aviation, Space, and Environmental Medicine 78(Suppl. 5), B252–B260 (2007)
44. Wilson, J.A., Onorati, K., Mishkind, M., Reger, M.A., Gahm, G.A.: Soldier attitudes about technology-based approaches to mental health care. Cyberpsychology & Behavior 11, 767–769 (2008)
45. Neuborne, E., Kerwin, K.: Cover Story Feburary 15 (1999), `http://www.businessweek.com/1999/99_07/b3616001.htm`
46. Headquarters Department of the Army. Field Manual 7.0 "Training for Full Spectrum Operations" (2009)
47. Wiederhold, B.K., Wiederhold, M.D.: Virtual Reality Therapy for Anxiety Disorders: Advances in Evaluation and Treatment, p. 225. American Psychological Association, Washington (2005)
48. Wiederhold, B.K., Bullinger, A.H., Wiederhold, M.D.: Advanced technologies in military medicine. In: Novel Approaches to the Diagnosis and Treatment of Posttraumatic Stress Disorder, pp. 148–160. IOS Press, Amsterdam (2006)
49. Stetz, M.C., Long, C.P., Wiederhold, B.K., Turner, D.D.: Scenarios and Relaxation Training to Harden Medics Against Stress. Journal of CyberTherapy & Rehabilitation 1(3), 239–246 (2008)
50. Stetz, M.C., Bouchard, S., Wiederhold, B.K., Folen, R.A.: The Receptiveness of Stress Management Techniques by Military Personnel. In: Presentation at the 14th Annual b International CyberTherapy and CyberPsychology Conference, Verbania-Intra, Italy (June 2009)
51. Folen, R.A., Miyahira, S.D., Stetz, M.C.: Immersive panoramic video display compared to flat screen display: Psychological and physiological reactions to anger stimuli. In: Presentated at the 14th Annual International CyberTherapy and CyberPsychology Conference, Verbania-Intra, Italy (June 2009)

Chapter 3

Current Trends and Future Directions for Virtual Reality Enhanced Psychotherapy

Marilyn P. Safir and Helene S. Wallach

Abstract. To date, the best treatment regimens for a wide range of psychological disorders have been found to be Cognitive Behavior Therapy (CBT). However, difficulties arise with various components of CBT, for example, lack of therapist control and loss of confidentiality in the exposure component. Virtual Reality CBT (VRCBT) is a new and effective technology that overcomes these difficulties. VRCBT has been used in therapy for various psychological disorders (phobias, eating disorders, sexual dysfunction, etc.) with promising results. In addition, new approaches in VR assisted Psychotherapy and Psychotherapy training are also being developed. This chapter presents an up to date review of these studies.

1 Current Trends and Future Directions for Virtual Reality Enhanced Psychotherapy

When Wiederhold and Wiederhold (1998) published their article on the potential of Virtual Reality (VR) as a tool in psychotherapy, the existing research consisted primarily of a few case studies on the treatment of simple phobias. In a review of the current state of the art and predictions of future developments in the integration of VR into psychotherapy, two of the early VR pioneers, Skip Rizzo and Ken Graap (Glantz, Rizzo and Graap, 2003) presented an excellent forecast about potential developments in this field that are still relevant. Since the major application of VR enhanced Psychotherapy has been for treatment of anxiety disorders, and Cognitive Behavior Therapy (CBT) has been demonstrated to be the treatment of choice for these disorders, we focus on the integration of VR into CBT. In 2005, Riva published the review: "Virtual Reality and Psychotherapy" in *CyberPsychology and Behavior* in which he cited the increasing numbers of studies in this area and stated that VR is becoming an important tool in psychotherapy. The past 10 years have witnessed an amazing interest and growth in this field as a result of major advances in and development of new technologies. This field also stands out in the formation of international and interdisciplinary collaboration within research teams. In addition, decreasing costs of apparatus parallel the growth of research, laboratories and clinicians working in this field.

To date, *VRCBT* has been employed for treatment of phobias (social phobia, acrophobia, flight phobia, fear of driving, claustrophobia, agoraphobia, arachnophobia), as well as for many other disorders (e.g. Anderson, Rothbaum, & Hodges, 2003; Botella, Osma, Garcia-Palacios, Quero, &Banos, 2004; Harris, Kemmerling, & North,

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 31–45.
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2002; Klinger et al., 2005; Optale et al., 1997; Rothbaum, et al., 1995; Wallach & Bar-Zvi, 2006; Wallach, Safir& Bar-Zvi, 2009, 2010; Wiederhold&Wiederhold, 2005. also reviews by Krijn, Emmelkamp, Olafsson, &Biemond, 2004; Parsons & Rizzo, 2008; Riva, 2005).

2 VRCBT for Specific Phobias

2.1 Fear of Flying

Six randomly controlled studies combining VR and CBT found VR to be an effective tool for flight phobia (Bornas, Tortella-Feliu, &Llabrés, 2006; Maltby, Kirsch, Mayers, & Allen, 2002; Muhlberger, Herrmann, Wiedemann, Ellgring, & Pauli, 2001; Muhlberger, Wiedemann, & Pauli, 2003; Rothbaum, Anderson, Zimand, Hodges, Lang, & Wilson, 2006; Rothbaum, Hodges, Anderson, Price, & Smith, 2002; Wiederhold, Gevirtz, &Spira, 2001). However, in another study the post-treatment effect (which was very small) disappeared on follow-up (Maltby et al., 2002). In an additional study, only two thirds of the patients actually flew by follow-up (Muhlberger, et al., 2001). Furthermore, Muhlberger et al. (2003) found no differences between the treatment and wait list groups in actual flying rates. Only two studies reported significant differences both post-treatment and in follow-up (Bornas, et al., 2006; Rothbaum et al., 2002, 2006). One study reported no differences on subjective ratings. However, in this study, there were large differences on the number of patients flying post-treatment with more VR patients flying than the control treatment patients (Wiederhold, Gervitz, &Spira, 2001). These results were maintained in a three year follow-up (Wiederhold&Wiederhold, 2003).

2.2 Claustrophobia

Botella, Baños, Villa, Perpiña, & Garcia-Palacios (2000) treated four claustrophobic patients with eight sessions of VR therapy. They reported significant improvement on fear and depression ratings and on a behavioral avoidance test at both post-treatment and a three month follow up. Malbos, Mestre, Note, &Gellato, (2008) treated six claustrophobic patients with VR and reported improvement on questionnaires and on a behavioral test. Results generalized to real life environments and were maintained in a six month follow-up.

2.3 Acrophobia

Emmelkamp, Bruynzeel, Drost, & van der Mast, (2001) used an exploratory within group design, for ten patients suffering from acrophobia (fear of heights). Patients received two sessions of VR followed by two of in vivo exposures and completed questionnaires pre-test, post-test and following the two VR sessions. VR was found to be as effective as exposure in vivo. However, the 10 patients were not randomly chosen but selected from a group of 15 volunteers. Emmelkamp, Krijn, et al (2002) then compared VR with in-vivo exposure for subjects suffering from acrophobia. They found no significant differences on subjective measures (questionnaires) or on a behavioral (avoidance) test between the two treatments on post-test or at a six month follow up. Unfortunately, they did not employ a no-treatment control group. Rothbaum, Hodges, Kooper, Opdyke, Williford, & North, (1995) compared seven VR Exposure (VRE) sessions with a no-treatment control group and found significant differences on self-reported fear and avoidance. Their participants were students who were selected from a large student population, who had not requested therapy. VRE was only compared with a non treatment wait- list control, and no follow-up data was obtained. In addition, there was a large attrition rate from pre-therapy to post therapy testing. Participants also dropped out during the VRE therapy, resulting in small groups (10 in VR and 7 in Wait List). Krijn, et al. (2004) randomly assigned patients to one of three groups: three 1.5 hour sessions of VR therapy with a head mounted display, three 1.5 hour sessions of VR therapy with a cave system, and Wait List Control group. They found that both VR therapy groups improved significantly more than the Wait List Control group on all self report anxiety and discomfort measures, as well as on a behavioral avoidance test. No differences were found between the two VR treatment groups. Treatment gains were maintained at a six month follow up. However, there was a large attrition rate: of the 37 patients assigned to one of the two therapy groups, only 25 completed the treatment and three did not complete the follow up.

2.4 Panic Disorder Combined with Agoraphobia

Two studies examined the use of VR for agoraphobia with panic. Vincelli, et al. (2003) randomly allocated 12 patients to one of three treatment groups. One group received VR with cognitive therapy components, administered in eight sessions and three booster sessions: one, three and six months post-therapy. A second group was treated with conventional CBT in 12 sessions and the third was a wait-list control group. Significant reductions in anxiety, depression and number of panic attacks for both treatment groups were reported. However, the sample was small, and no follow-up data was obtained. Choi, et al. (2005) conducted a larger study composed of 40 patients with two treatment groups (20 in each). The first group received four sessions of VR combined with CBT and the second, a traditional 12-session panic control program. Both treatment groups improved significantly on subjective (questionnaire) ratings of anxiety and depression, on ability to reduce or discontinue medication, and on clinician's rating of end-state functioning. There was only one significant difference between the two groups. The panic control group demonstrated greater reduction on the Panic Belief Questionnaire pre- post scores. No differences were found on the other self report questionnaires, in discontinuation of medication, or end-state functioning. At the six month follow-up, the panic control program outperformed the VR treatment in medication discontinuation. No difference was demonstrated on end-state functioning. Unfortunately, no self-report questionnaires were administered at follow-up. While Choi et al. demonstrated effectiveness of VR for Agoraphobia with panic, it appears that four VR sessions were not sufficient to produce effects similar to those of the more traditional 12 session treatment. No Wait List control was employed in this study. Botella, et al. (2004) treated 37 patients with Panic Disorder with and without Agoraphobia. They compared VRE with in-vitro Exposure and with a Wait List control following treatment and at a 12 month follow up. Their results demonstrated the efficacy of VRE both post treatment and at follow-up.

2.5 Arachnophobia

Garcia-Palacios, Hoffman, Carlin, Furness, &Botella, (2002) used tactile augmentation in VR exposure for 23 spider phobics. They found that subjects improved statistically and clinically more significantly than the control group on both objective and subjective measures of fear, and were able to approach a live spider post-therapy. None of the patients dropped out of treatment. Cote & Bouchard (2005) treated 28 spider phobics with VR exposure in seven sessions. They used physiological (cardiac), behavioral avoidance, and subjective (questionnaires) measures of anxiety, and found that the treatment was effective in reducing fear on all measures. However, no control group was used. Although 61% of their clients reached step 9 (of 10 steps) in the behavioral (avoidance) test at post-therapy, only 46% of the participants were able to complete all stages of the behavioral (avoidance) task. In a second study, Bouchard, Cote, St-Jacques, Robillard, &Renaud (2006) examined the utility of employing existing video games to treat spider phobia. Eleven phobics were treated with VR in a modified video game composed of five sessions lasting 90 minutes. They found significant reductions on self report measures as well as on the behavioral (avoidance) task. However, their sample was very small, they had no control group, and while there was a significant improvement on the behavioral task, the average obtained score was about 6 (out of 10) indicating that the participants had not overcome their difficulties in approaching the spider. However, by employing a one session VR Augmented Reality (the participant views the real world enhanced by virtual elements), Botella, Bretón-López, Quero, Baños&García-Palacios (2006) successfully treated six individuals. All participants improved significantly in all outcome measures after treatment. Furthermore, the treatment gains were maintained at 3, 6 and 12-month follow-up periods.

2.6 Social Phobia

2.6.1 Generalized Social Phobia

To date, only one study has been conducted using VR to treat 36 patients suffering from *generalized social phobia* (Klinger, et al., 2005; Klinger, et al., 2004; Roy, et al., 2003). Four situations were employed: performance, intimacy, scrutiny and assertiveness. VR treatment was compared to cognitive behavior group therapy (CBGT). VR therapy was conducted in 12 individual sessions lasting 45 minutes each, while CGBT was conducted in 12 group sessions lasting two hours each. Allocation to group was not random, nor did they employ a wait-list control group. No differences were found between the two treatment groups. Both groups improved significantly on fear reduction, assertiveness and global functioning measures from pre to post test. There was no follow up.

2.6.2 Non-generalized Social Phobia

A thorough literature search for studies to include in this chapter, revealed no studies employing VR for non-generalized social phobia, other than for the treatment of public speaking anxiety.

VRCBT has been used in therapy for public speaking anxiety in a few studies. North, North, and Coble (1998) compared VRCBT with a no-treatment group and found significant reduction in fear measures in the treatment group. However, this study included only 16 participants and no comparison was made between the treatment and control groups. Harris, Kemmerling, and North (2002) found that four sessions of VRCBT were effective for reducing social fear in university students. However, they also used a small sample (only 14 completed the study) and group assignment was not totally random. Although there were significant reductions in the VRCBT group's reports on anxiety on some measures, only one comparison between the treatment and Wait List group proved to be significant. Anderson, Zimand, Hodges, and Rothbaum (2005) used VRCBT for ten clients (open clinical trial) and found it to be effective. However, their sample was small and they did not use a control group. Wallach, Safir and Bar-Zvi (2009) performed a randomized control trial treating 88 participants suffering from public speaking anxiety, who were randomly assigned to one of three treatment groups: VRCBT (28), CBT (30) and Wait List Control (WLC) (30). VRCBT and CBT were significantly more effective than WLC in anxiety reduction on four of the five anxiety measures used, and on subject's self rating of anxiety during a behavioral task. No significant differences were found in observer ratings of the behavioral task. However, twice as many subjects dropped out of CBT than from VRCBT, suggesting that VRCBT may be more appealing as a therapeutic technique.

2.7 Post Traumatic Stress Disorders (PTSD)

While research on VR enhanced psychotherapy had primarily focused on treatment of more limited anxiety disorders, awareness of the vast numbers of combat veterans (Vietnam, Afghanistan and Iraq) suffering from Post Traumatic Stress Disorders (PTSD) has propelled increases in research employing VRCBT for this debilitating and often chronic disorder. A VR system, Virtual Vietnam, was first employed by Rothbaum, and colleagues (1999) to treat combat PTSD in a case study of a 50-year-old, Caucasian male veteran meeting DSM-IV criteria for PTSD. They found post-treatment improvement with significant reductions all measures of PTSD and maintenance of these gains at a 6-month follow-up with a 34% decrease in clinician-rated symptoms of PTSD and a 45% decrease on a measure of self-reported symptoms of PTSD. This case study was followed by an open clinical trial of VRET for Vietnam veterans (Rothbaum, et. al., 2001). In this study, 16 male PTSD patients were exposed to a series of virtual environments, in which the therapist controlled various visual and auditory effects (e.g. rockets, explosions, day/night, yelling). After an average of 13 exposure therapy sessions over 5-7 weeks, there was a significant reduction in PTSD and related symptoms.

Similar positive results have also recently been reported for VR in the treatments of civilians, firefighters and police suffering from PTSD as a result of the attack on the World Trade Center. Difede, & Hoffman, (2002) first reported a case study employing VR to provide re-exposure to the trauma with a patient who had failed to improve with traditional exposure therapy. These researchers have now reported positive treatment outcomes from a wait-list controlled VR study with patients who were not successful in previous imaginal therapy (Difede et. al., 2007). The VR group demonstrated statistically and clinically significant decreases in clinician rated symptoms of PTSD relative to pre-treatment and relative to the waitlist control group. Treatment gains were maintained at six-month follow-up.

Preliminary studies with VR for soldiers suffering from combat PTSD from Iraq are also promising (Ready, Pollack, Rothbaum, & Alarcon, 2006; Gerardi, et. al., 2007; Reger, et. al., 2007; Rizzo, et. al., 2007, Ready, Gerardi, Backscheider, &Rothbaum, 2010; Wood, Wiederhold, &Spira, 2010). These studies continue to demonstrate that VR is a valuable technology in the treatment of PTSD. It is a promising component of a comprehensive treatment approach for persons with combat-related PTSD and as well as civilians who have suffered from attacks in non-combat situations. It has the potential to more effectively activate patients' fear structures (Courtney, Dawson, Schell, & Parsons, 2009) then Prolonged Exposure and to facilitate emotional engagement by augmenting the re-living of the traumatic event with a sensory-rich environment that includes visual, auditory, and tactile experiences. This results in a more significantly heightened physiological arousal than can be achieved through Prolonged Exposure (PE) alone. This heightened arousal, along with the multi-sensory nature of the VR experience, should significantly improve clinical outcomes, especially for patients who have difficulty engaging memories of traumatic events. Additionally, VRCBT may also attract patients who would otherwise avoid treatment. Soldiers may be more likely to seek treatment with VRET because it employs technologies that they find appealing, thus resulting in a reduction of perceived stigma and an increased inclination to discuss aspects of treatment with friends or family. Findings reported by Wilson, Onorati, Mishkind, Reger, and Gahm (2008), who surveyed 325 soldiers in a deployment screening clinic in order to assess their knowledge of current technologies and attitudes towards behavioral healthcare, give support for this view. Wilson, et al (2008) also reported that 83% of respondents were neutral-to-very willing to use some form of technology as part of their behavioral healthcare, 58% reported some willingness to use a VR treatment program, 71% were equally or more willing to use some form of technological treatment than only talking to a therapist in a traditional setting. Furthermore, 20% of the soldiers who stated they were not willing to seek traditional psychotherapy rated their willingness to use a VR-based treatment as neutral to very willing. It appears that the lower dropout rate in VRCBT, reported above, gives additional support to these findings.

VR assisted treatment for individuals suffering from PTSD from non combat related traumas has also shown promise. Botella, García-Palacios, Guillen, Baños, Quero, &Alcaniz (2009) report on the successful results in treating clients suffering from diverse trauma with a unique and flexible VR program entitled Emma's World. Recently, Wiederhold, &Wiederhold (2010) presented a case study of successful treatment of PTSD resulting from a traffic accident and Freedman, Hoffman, Garcia-Placios, Weiss, Avitzous and Josman (2010) reported employing Virtual Reality Prolonged Exposure (VRPE) in the successful treatment for PTSD of a survivor of a terrorist attack in Jerusalem. The terrorist used a massive bulldozer to attack two buses and several automobiles, in which a number of individuals were killed or severely wounded. This patient was riding in one of the two buses that were overturned, and especially terrifying for the patient was the decapitation of one of the other passengers, and remaining trapped in the bus for a period of time while gasoline leaked into the bus. This patient received 19 90 minute sessions over a 12 week period. This client showed great reduction in PTSD Symptoms following treatment. This is the first published report of a VRPE adapted treatment program with the survivor of a specific terrorist attack and gives additional support for the efficacy of this treatment for severe PTSD in civilians who come under terrorist attack.

3 New Developments in VR Applications

3.1 Pain Management

Pain management is an area in which VR applications show great potential when employed as a means of distracting the patent from focusing on intensive pain. For example, a vivid and compelling program entitled Snow World was developed by Hoffman and colleagues as a distraction from the intense pain that accompanies changing bandaging of severe burn victims (Hoffman, Blough, & Patterson, 2007). Much of the current research is based on case studies and small samples, but suggests the great potential in this field. (Hoffman, Patterson, Carrougher, and Sharar, 2001; Gershon, Zimand, Lemos, Rothbaum, & Hodges, 2003; Hoffman, et al., 2004; Hoffman, et al., 2009; ONeal, Patterson, Soltani, Teeley, & Jensen, 2008). A somewhat larger study was designed with 20 juvenile patients, for whom an intravenous placement of an attachment for MRI was painful but necessary for their successful medical treatment. VR distraction was compared with the use of a topical anesthetic with no distraction (standard of care). The children, parents and nurses all rated the VR distraction positively for lowering reports of pain. More noteworthy, the VR distraction seemed to prevent the fourfold increase in anxiety that accompanied the usual standard of care (Gold, Kim, Kant, Joseph, & Rizzo, 2006). In a preliminary report summarizing three on-going studies with a total of 88 patients, ranging from 6 to 65 years, when VR was added to standard analgesic therapy, VR distraction provided a clinically meaningful degree of pain relief for burn patients. Hoffman, Blough, & Patterson (2007) concluded that employing immersive VR to distract patients from pain is not only a safe and effective analgesic technique that reduces pain without pharmacological support, but it facilitates the patients' active participation in their rehabilitation.

3.2 Eating Disorders

Eating disorders have a different etiology than anxiety disorders, and appear to result, in large part, from distorted body image (Cash, &Pruzinsky, 1990; Thompson, 1996). A large majority of women appear to be dissatisfied with their body image (Safir, Flaisher- Kellner&Rosenmann, 2005). An early study was designed to investigate the use of VR to treat body image disturbance (Perpina, et al., 1999). In this study, 13 patients with eating disorders were assigned to two groups: a standard treatment and a VR treatment condition to change distorted body image (BI). The authors' reported that patients treated in the VR condition showed significantly greater improvement in specific BI measures. Including the patient's image in VRCBT enables the client to view a more realistic image than she might imagine (Myers, Swan- Kremeier, Wonderlich, Lancaster & Mitchell, 2004).

Riva and his group have been quite active in the development of treatment for eating disorders and obesity. Originally their approach was entitled Virtual Environment for Body Image Modification (VEBIM), and was designed to treat body image disturbances and body dissatisfaction associated with eating disorders. CBT (the cognitive element) was employed to revise the patients' feelings of dissatisfaction; VR, in this instance, was employed as both a visual and behavioral therapy that aimed at increasing the patient's awareness of her body within the VRE (Riva &Melis, 1997/8). The current designation of this therapy approach is entitled Integrated Experiential Therapy and is also based on CBT. The treatment goal is to enable the client to identify and change the elements that maintain the disorder. Therapy consists of 10 VR sessions. A novel addition is the focus on changing the negative emotions about the patients' bodies, thus motivating them to lose weight. Riva proposes that the VRE enables the patient to feel empowered by providing a non-threatening setting in which to work on improving their body image (Riva, Bacchetta, Cesa, Conti, & Molinari, 2003; Riva, Bacchetta, Baruffi, &Mollinari, 2001). Incorporating a photograph of the patient and actual changes that occur in body shape, enables the patient to recognize and accept these changes in a non-threatening environment and increase feelings of self efficacy (Riva, 2005).

3.3 Sexual Dysfunction

Presenting a detailed discussion on sexual dysfunction and its treatments are beyond the scope of this chapter. However, elements of CBT are basic to the major therapies for these disorders. The focus of these treatments was to reduce anxiety about sexual functioning, and specifically, to reduce performance anxiety, negative ideations, with the gradual reestablishment of appropriate and positive cognitions and behaviors leading to positive sexual interactions (Heiman, LoPiccolo, &Palladini, 1987; LoPiccolo, Heiman, &LoPiccolo, 1976; Masters & Johnson 1966, 1970). Currently most published research in this area has been reported by Guiseppe Optale and his colleagues. Their focus has been on Male Sexual Dysfunction - both premature ejaculation and impotence (Optale, Marin, Pastore, Nasta&Pianon, 2004; Optale, et al., 1998; Optale, et al., 1997; Optale, et al., 1995) Since his program uses VR environments to aid in a psychodynamic approach to recover unconscious motivations that result in the dysfunction, we cite this research but are not presenting it in detail.

However, we foresee the development of programs with augmented elements that enable the patient/client to enter the VRE, experience sexual interactions with non threatening avatars, and gradually develop behaviors/interactions that may be transferred and generalized to real life situations. So, for example, Thomas von Wiegand and Wendelin-Sachtler of Corpora Systems, Somerville, MA have developed a penis like prototype that can be used with in a VRE for women with problems involving intromission, intercourse and orgasm.

3.4 Training New Therapists

This is a new and emerging application of VR. Ryan Howes interviewed Albert (Skip) Rizzo and published on line by *Psychology Today* (February 9, 2010) (*http://www.psychologytoday.com/blog/in-therapy/201002/cool-intervention-2-virtual-reality*). Skip Rizzo, whom we have noted is a leader in the development of VR applications, for a variety of treatments and for training programs for therapists. Of great interest to us, was Rizzo's presentation of a program that is being developed "with virtual patients (with voice recognition) *(avatars designed with verbal recognition- our notation*) that allow novice clinicians to practice both diagnostic and therapeutic interviewing skills with a range of challenging virtual clinical populations (e.g., resistant clients, sexual assault, PTSD exposure therapy, etc.)."

We have had the opportunity of viewing this type of program. We cannot over emphasize its potential and extreme importance in the training of future clinicians. After studying various psychotherapeutic techniques in an academic setting, one way of becoming experienced is to role play. In addition, novice clinicians may view experienced clinicians at work. They may view training films. In some instances, they work as co-therapists before they begin to work directly with patients. If they are fortunate, their supervisor can view them in real time or film or tape them in their therapy sessions. They then meet with their supervisors to receive supervision. Anyone who has supervised clinicians in training, is aware of the anxiety the novices' experience when they begin treating clients. Unlike medical training, where the supervisor is present and can take over when the intern is uncertain about how to proceed, or unable to continue, the psychotherapy trainee "must sink or swim." The supervisor must then help the trainee overcome missteps that occur in their early treatment experiences. The avatars that are currently being developed for clinical training experiences are very realistic and have been programmed to interact with the novice therapist. Through interactions with patient avatars, the trainee can be gradually exposed to various and more and more complex problems. As with VR programs in therapy, the supervisor can exert control, enabling the therapist trainee to avoid inappropriate responses. The trainee clinicians can be exposed to extreme cases in a controlled environment. Thus this type of training will enable the novice clinician to learn new and appropriate treatment techniques and to improve his/her skills, reaching a high professional level before s/he actually works with "real" patients. Clinical training employing patient avatars can be incorporated into academic training programs as well as into clinical settings. A number of recent publications provide support for the value of enabling the new, inexperienced therapist the opportunity to interact with a virtual patient (Kenny, Parsons, & Rizzo, 2010; Parsons, et al., 2010). Completing such training can create new therapists who begin work with patients at much higher therapeutic skill levels than current training programs offer.

References

Anderson, P., Rothbaum, G.O., Hodges, L.F.: Virtual Reality exposure in the treatment of social anxiety. Cognitive and Behavioral Practice 10, 240–247 (2003)

Anderson, P.L., Zimand, E., Hodges, L.F., Rothbaum, B.O.: Cognitive Behavioral Therapy for public-speaking anxiety using Virtual Reality for exposure. Depression and Anxiety 22, 156–158 (2005)

Bornas, X., Tortella-Feliu, M., Llabrés, J.: Do all treatments work for flight phobia? Computer-assisted exposure versus a brief multicomponent nonexposure treatment. Psychotherapy Research 16, 41–50 (2006)

Botella, C., Baños, R.M., Villa, H., Perpina, C., García-Palacios, A.: Virtual reality in the treatment of claustrophobic fear: A controlled, multiple-baseline design. Behavior Therapy 31, 583–595 (2000)

Botella, C., Garcıa-Palacios, A., Guillen, V., Banos, R.M., Quero, S., Alcaniz, A.: An Adaptive Display for the Treatment of Diverse Trauma PTSD Victims. Cyberpsychology, Behavior, and Social Networking 13, 67–71 (2009)

Botella, C., Osma, J., Garcia-Palacios, A., Quero, S., Banos, R.M.: Treatment of flying phobia using virtual reality: Data from a 1-year follow-up using a multiple baseline design. Clinical Psychology and Psychotherapy 11, 311–323 (2004)

Botella, C., Villa, H., Garcia-Palacios, A., Banos, R.M., Perpina, C., Alcaniz, M.: Clinically significant virtual environments for the treatment of panic disorder and agoraphobia. CyberPsychology and Behavior 7, 527–535 (2004)

Botella, C., García-Palacios, A., Guillen, V., Baños, R.M., Quero, S., Alcaniz, A.: An Adaptive Display for the Treatment of Diverse Trauma PTSD victims. CyberPsychology, Behavior and Social Networking 13, 67–71 (2009)

Botella, C., Bretón-López1, J., Quero1, J., Baños, R.M., García-Palacios, A.: Treating Cockroach Phobia with Augmented Reality. Behavior Therapy (in press, 2010)

Bouchard, S., Cote, S., St-Jacques, J., Robillard, G., Renaud, P.: Effectiveness of virtual reality exposure in the treatment of arachnophobia using 3d games. Technology and Health Care 14, 19–27 (2006)

Cash, T.F., Pruzinsky, T. (eds.): Body Images - Development, Deviance and Change. Guilford Press, New York (1990)

Choi, Y.-H., Vincelli, F., Riva, G., Wiederhold, B.K., Lee, J.-H., Park, K.-H.: Effects of group experiential cognitive-therapy for the treatment of panic disorder with agoraphobia. Cyber Psychology & Behavior 8, 387–393 (2005)

Cote, S., Bouchard, S.: Documenting the efficacy of Virtual Reality exposure with psychophysiological and information processing measures. Applied Psychophysiology and Biofeedback 30, 217–232 (2005)

Courtney, C., Dawson, M., Schell, A., Parsons, T.D.: Affective Virtual Reality Exposure: Psychophysiological Support for Increased Elicitation of Negative Emotions in High and Low Fear Subjects. LNCS (LNAI), vol. 5638, pp. 459–468. Springer, Heidelberg (2009)

Difede, J., Cukor, J., Jayasinghe, N., Patt, I., Jedel, S., Spielman, L., Giosan, C., Hoffman, H.: Virtual Reality exposure therapy for the treatment of posttraumatic stress disorder following September 11, 2001. Journal of Clinical Psychiatry (in press, 2007)

Difede, J., Hoffman, H.: Virtual reality exposure therapy for World Trade Center Post Traumatic Stress Disorder. Cyberpsychology and Behavior 5, 529–535 (2002)

Emmelkamp, P.M.G., Bruynzeel, M., Drost, L., van der Mast, C.A.P.G.: Virtual reality treatment in acrophobia: A comparison with exposure in vivo. Cyberpsychology and Behavior 4, 335–339 (2001)

Emmelkamp, P.M.G., Krijn, M., Hulsbosch, A.M., de Vries, S., Schuemie, M.J., van der Mast, C.A.P.G.: Virtual reality treatment versus exposure in vivo: A comparative evaluation in acrophobia. Behaviour Research and Therapy 40, 509–516 (2002)

Freedman, S.A., Hoffman, H.G., García-Palacios, A., Weiss, P.T., Avitzour, S., Josman, N.: Prolonged Exposure and Virtual Reality–Enhanced Imaginal Exposure for PTSD following a Terrorist Bulldozer Attack: A Case Study. CyberPsychology, Behavior & Social Networking 13, 95–101 (2010)

Freeman, A., Pretzer, J., Fleming, B., Simon, K.M.: Clinical Applications of Cognitive Therapy, 2nd edn. Kluwer Academic, New York (2004)

García-Palacios, A., Hoffman, H., Carlin, A., Furness III, T.A., Botella, C.: Virtual reality in the treatment of spider phobia: A controlled study. Behaviour Research and Therapy 40, 983–993 (2002)

Gerardi, M., Rothbaum, B.O., Ressler, K., Heekin, M., Rizzo, A.A.: Virtual Reality Exposure Therapy Using a Virtual Iraq: Case Report. Journal of Traumatic Stress (in press, 2007)

Gershon, J., Zimand, E., Lemos, R., Rothbaum, B.O., Hodges, L.: Use of Virtual Reality as a Distracter for Painful Procedures in a Patient with Pediatric Cancer: A Case Study. Cyberpsychology and Behavior 6, 657–661 (2003)

Glantz, K., Rizzo, A(S.), Graap, K.: Virtual Reality for Psychotherapy: Current Realities and Future Possibilities. Psychotherapy: Theory, Research, Practice, Training 40, 55–67 (2003)

Gold, J.I., Kim, S.H., Kant, A.J., Joseph, M.H., Rizzo, A(S.): Effectiveness of Virtual Reality for Pediatric Pain Distraction during IV placement. Cyberpsychology and Behavior 9, 207–212 (2006)

Goldberg, J., Zwiebel, A., Safir, M.P., Merbaum, M.: Mediation factors in the modification of smoking behavior. Journal of Behavior Therapy and Experimental Psychiatry 14(4), 325–330 (1984)

Harris, S.R., Kemmerling, R.L., North, M.M.: Brief virtual reality therapy for public speaking anxiety. Cyber Psychology and Behavior 5, 543–550 (2002)

Heimberg, R.G., Becker, R.E.: Cognitive-Behavioral Group Therapy for Social Phobia: Basic Mechanisms and Clinical Strategies. The Guilford Press, New York (2002)

Heimberg, R.G., Liebowitz, M.R., Hope, D.A., Schneier, F.R., Holt, C.S., Welkowitz, L.A., Juster, H.R.: Cognitive behavioral group therapy versus phenelzine therapy for social phobia. Archives of General Psychiatry 55, 1133–1141 (1998)

Hope, D.A., Heimberg, R.G.: Social phobia and social anxiety. In: Barlow, D.H. (ed.) Clinical Handbook of Psychological Disorders, 2nd edn., pp. 99–136. The Guilford Press, New York (1993)

Holt, C.S., Heimberg, R.G., Hope, D.A.: Success from the outset: Predictors of cognitive-behavioral therapy outcome among social phobics. In: Poster presented at the annual meeting of the Association for Advancement of Behavioral Therapy, San Francisco, CA (1990)

Hoffman, H.G.: Virtual reality: A new tool for interdisciplinary psychology research. Cyber Psychology & Behavior 1, 195–200 (1998)

Hoffman, H.G., Blough, D.K., Patterson, D.R.: Factors Influencing the Efficacy of Virtual Reality Distraction Analgesia During Postburn Physical Therapy: Preliminary Results from 3 Ongoing Studies. Archives of Physical & Medical Rehabilitation 12(suppl. 2), S43–S49 (2007)

Hoffman, H.G., Patterson, D.R., Carrougher, G.J., Sharar, S.R.: Effectiveness of Virtual Reality–Based Pain Control with Multiple Treatments. The Clinical Journal of Pain 17, 229–235 (2001)

Hoffman, H.G., Patterson, D.R., Magula, J., Carrougher, J.G., Zeltzer, K., Dagadakis, S., Sharar, S.R.: Water-friendly virtual reality pain control during wound care. Journal of Clinical Psychology 60, 189–195 (2004)

Hoffman, H.G., Patterson, D.R., Soltani, M., Teeley, A., Miller, W., Sharar, S.S.: Virtual Reality Pain Control during Physical Therapy: Range of Motion Exercises for a Patient with Multiple Blunt Force Trauma Injuries. Cyber Psychology and Behavior 12, 47–49 (2009)

Hutchinson, M.G.: Imagining ourselves whole: A feminist approach to treating body image disorders. In: Fallon, P., Katzman, M.A., Wooley, S.C. (eds.) Feminist Perspectives on Eating Disorders, pp. 152–170. Guilford Press, New York (1994)

Kahan, M., Tanzer, J., Darvin, D., Borer, F.: Virtual reality-assisted cognitive–behavioral treatment for fear of flying: Acute treatment and follow-up. CyberPsychology and Behavior 3, 387–392 (2000)

Kenny, P., Parsons, T.D., Rizzo, A.A.: Comparative Analysis between Experts and Novices Interacting with a Virtual Patient with PTSD. Studies in Health Technology and Informatics (in press, 2010)

Klinger, E., Bouchard, S., Legeron, P., Roy, S., Lauer, F., Chemin, I., Nugues, P.: Virtual Reality Therapy versus Cognitive Bewhavior Therapy for social phobia: A preliminary controlled study. CyberPsychology & Behavior 8, 76–88 (2005)

Klinger, E., Legeron, P., Roy, S., Chemin, I., Lauer, F., Nugues, P.: Virtual Reality exposure in the treatment of social phobia. In: Riva, G., Botella, C., Legeron, P., Optale, G. (eds.) Cybertherapy: International Virtual Reality as Assessment and Rehabilitation Tools for Clinical Psychology and Neuroscience. IOS Press, Amsterdam (2004)

Krijn, M., Emmelkamp, P.M.G., Biemond, R., de Wilde de Ligny, C., Schuemie, M.J., van der Mast, C.A.P.G.: Treatment of acrophobia in virtual reality: The role of immersion and presence. Behaviour Research and Therapy 42, 229–239 (2004)

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

LoPiccolo, J., Heiman, J., LoPiccolo, L.: Becoming Orgasmic, 219 pages. Prentice Hall, Englewood Cliffs (1976)

Heiman, J., LoPiccolo, J., Palladini, D.: Becoming Orgasmic: A Sexual and Personal Growth Program for Women, 288 pages. Prentice Hall, Englewood Cliffs (1987)

Malbos, E., Mestre, D.R., Note, D., Gellato, C.: Virtual reality and claustrophobia: Multiple components therapy involving game editor virtual environments exposure. Cyber Psychology & Behavior 11, 695–697 (2008)

Maltby, N., Kirsch, I., Mayers, M., Allen, G.J.: Virtual reality exposure therapy for the treatment of fear of flying: A controlled investigation. Journal of Consulting and Clinical Psychology 70, 1112–1118 (2002)

Masters, W.H., Johnson, V.E.: Human Sexual Response. Bantam Books, Toronto (1966)

Masters, W.H., Johnson, V.E.: Human Sexual Inadequacy. Bantam Books, Toronto (1970)

Muhlberger, A., Herrmann, M.J., Wiedemann, G., Ellgring, H., Pauli, P.: Repeated exposure of flight phobics to flights in virtual reality. Behaviour Research and Therapy 39, 1033–1050 (2001)

Muhlberger, A., Wiedemann, G., Pauli, P.: Efficacy of a one-session virtual reality exposure treatment for fear of flying. Psychotherapy Research 13, 323–336 (2003)

Myers, T.C., Swan-Kremeier, L., Wonderlich, S., Lancaster, K., Mitchel, J.K.: The Use of alternative Delivery Systems and New Technologies in the treatment of Patients with Eating Disorders, pp. 123–143 (2004)

North, M.M., North, S.M., Coble, J.R.: Virtual reality therapy: An effective treatment for the fear of public speaking. The International Journal of Virtual Reality 3, 1–6 (1998)

ONeal, B.J., Patterson, D.R., Soltani, M., Teeley, A., Jensen, M.: Virtual Reality Hypnosis in the Treatment of Chronic Neuropathic Pain: A Case Report. International Journal of Clinical and Experimental Hypnosis 56, 451–462 (2008)

Optale, G.: VR in the treatment of Male Erectile Disorders (Impotence and Premature Ejaculation) (1998), http://www.cybertherapy.info/pages/optale.htm

Optale, G., Munari, A., Nasta, A., Pianon, C., Baldero Verde, J., Viaggia, G.: Multimedia and virtual reality techniques in the treatment of male erectile disorders. International Journal of Impotence Research 4, 197–203 (1997)

Optale, G., Marin, S., Pastore, M., Nasta, A., Pianon, C.: Male Sexual Dysfunctions and Multimedia Immersion Therapy (Follow-Up). Cyber Psychology & Behavior 6, 289–294 (2004)

Optale, G., Munari, A., Nasta, A., Pianon, C., Baldaro Verde, J., Viggiano, G.: A VR Based Therapy for the Treatment of Impotence and Premature Ejaculation. In: Riva, G., Wiederhold, B.K., Molinari, E. (eds.) Virtual Environments in Clinical Psychology and Neuroscience, pp. 136–139. IOS Press, Amsterdam (1998)

Optale, G., Munari, A., Nasta, A., Pianon, C., Baldaro Verde, J., Viggiano, G.: Multimedia and Virtual Reality Techniques in the Treatment of Male Erectile Disorders. International J. Impotence Research 9, 197–203 (1997), `http://www.stockton-press.co.uk/0955-9930/v9n4/3900316.html`

Optale, G., Munari, A., Rizzo, C., Nasta, A., Pianon, C., Viggiano, G., Baldaro Verde, J.: Use of Virtual Reality in the Treatment of Impotence, Premature Ejaculation, Orgasmic Disorders and Lack of Sexual Desire: a Preliminary Report. International J. Impotence Research 7, 77 (1995)

Otto, M.W.: Cognitive-behavioral therapy for social anxiety disorder: Model, methods and outcome. Journal of Clinical Psychiatry 60(suppl. 9), 14–19 (1999)

Parsons, T.D., Rizzo, A.A.: Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. Journal of Behavior Therapy and Experimental Psychiatry 39, 250–261 (2008)

Parsons, T.D., Kenny, P., Rothbaum, B.O., Difede, J., Reger, G., Rizzo, A.A.: Optimizing Clinical Training for the Treatment of PTSD using Virtual Patients. Studies in Health Technology and Informatics (in press, 2010)

Perpina, C., Botella, C., Banos, R., Marco, H., Alcaniz, M., Quero, S.: Is Exposure to Virtual Reality More Effective than the Classical Body Image Treatment? CyberPsychology & Behavior 2, 149–155 (1999)

Ready, D.J., Pollack, S., Rothbaum, B.O., Alarcon, R.D.: Virtual reality exposure for veterans with posttraumatic stress disorder. Journal of Aggression, Maltreatment & Trauma 12, 199–220 (2006)

Ready, D.J., Gerardi, A.G., Backscheider, N.M., Rothbaum, B.O.: Comparing Virtual Reality Exposure Therapy to Present-Centered Therapy with 11 U.S. Vietnam Veterans with PTSD. CyberPsychology, Behavior and Social Networking 13, 49–54 (2010)

Reger, G.M., Gahm, G.A., Rizzo, A.A., Swanson, R.A., Etherage, J., Reger, M.A.: Virtual reality in operational and garrison psychology: A review of the applications of the VR Iraq at Fort Lewis. In: Cybertherapy 2007, Washington D.C, June 11-14 (2007)

Riva, G.: Virtual reality in Psychotherapy: Review. Cyber Psychology & Behavior 8, 220–230 (2005)

Riva, G.: Virtual reality in the treatment of eating disorders and obesity (2005), `http://www.cybertherapy.info/other/VR_in_Eating_Disorders`

Riva, G., Bacchetta, M., Baruffi, Mollinari, E.: Virtual reality-based multidimensional therapy for the treatment of body image disturbances in obesity: a controlled study. Cyberpsychology & Behavior 4, 511–526 (2001)

Riva, G., Bacchetta, M., Cesa, G., Conti, S., Molinari, E.: Six-MonthFollow-Up of In-Patient Experiential Cognitive Therapy for Binge Eating Disorders. CyberPsychology & Behavior 6(3), 251–258 (2003)

Riva, G., Melis, L.: Virtual Reality for the Treatment of Body Image Disturbances. In: Riva, G. (ed.) Virtual Reality in Neuro-Psycho-Physiology. IOS Press, Amsterdam (1997)

Rizzo, A.A., Graap, K., Mclay, R.N., Perlman, K., Rothbaum, B., Reger, G., Difede, J., Parsons, T., Pair, J.: Initial Case Reports from a VR Exposure Therapy Application for Combat-Related Post Traumatic Stress Disorder. Virtual Rehabilitation (in press, 2007)

Rothbaum, B.O., Anderson, P., Zimand, E., Hodges, L., Lang, D., Wilson, J.: Virtual reality exposure therapy and standard (in vivo) exposure therapy in the treatment of fear of flying. Behavior Therapy 37, 80–90 (2006)

Rothbaum, B.O., Hodges, L., Anderson, P.L., Price, L., Smith, S.: Twelve-month follow-up of virtual reality and standard exposure therapies for the fear of flying. Journal of Consulting and Clinical Psychology 70, 428–432 (2002)

Rothbaum, B.O., Hodges, L., Kooper, R., Opdyke, D., Williford, J.S., North, M.: Effectiveness of computer generated (virtual reality) graded exposure in the treatment of acrophobia. American Journal of Psychiatry 152, 626–628 (1995)

Rothbaum, B.O., Hodges, L.F., Opdyke, D., Williford, J.S., North, M.: Virtual reality graded exposure in the treatment of acrophobia: A case report. Behavior Therapy 26, 547–555 (1995)

Rothbaum, B., Hodges, L., Ready, D., Graap, K., Alarcon, R.: Virtual reality exposure therapy for Vietnam veterans with posttraumatic stress disorder. Journal of Clinical Psychiatry 62, 617–622 (2001)

Roy, S., Klinger, E., Legeron, P., Lauer, F., Chemin, I., Nugues, P.: Definition of a VR-based protocol to treat social phobia. Cyber Psychology & Behavior 6, 411–420 (2003)

Ruscio, A.M., Brown, T.A., Chiu, W.T., Sareen, J., Stein, M.B., Kessler, R.C.: Social fears and social phobia in the USA: Results from the National Comorbidity Survey Replication. Psychological Medicine 38, 15–28 (2008)

Safir, M.P., Flaisher-Kellner, S., Rosenmann, A.: When gender differences surpass cultural differences in personal satisfaction with body shape in Israeli college students. Sex Roles 52, 369–378 (2005)

Thompson, K.: Body Image, Eating Disorders and Obesity: An Integrative Guide for Assessment and Treatment. American Psychological Association, Washington (1996)

Vincelli, F., Anolli, L., Bouchard, S., Wiederhold, B.K., Zurloni, V., Riva, G.: Experiential cognitive therapy in the treatment of panic disorders with agoraphobia: A controlled study. Cyberpsychology and Behavior 6, 321–328 (2003)

Wallach, H.S., Bar-Zvi, M.: Virtual reality assisted treatment of flight phobia. The Israel Journal of Psychiatry 44, 29–32 (2006)

Wallach, H.S., Safir, M., Bar-Zvi, M.: Virtual Reality Cognitive Behavior Therapy for Public Speaking Anxiety: A Randomized Clinical Trial. Behavior Modification 33, 314–333 (2009)

Wallach, H.S., Safir, M.P., Bar-Zvi, M.: Exposure versus Cognitive Restructuring therapy in the treatment of Public Speaking Anxiety – a pilot study (2010) (accepted for publication in Israel Journal of Psychiatry)

Wiederhold, B.K., Wiederhold, M.D.: A Review of Virtual Reality as a Psychotherapeutic Tool. Cyber Psychology & Behavior 1, 45–52 (1998)

Wiederhold, B.K., Gevirtz, R.N., Spira, J.L.: Virtual Reality therapy vs. imagery desensitization therapy in the treatment of flying phobia. In: Riva, G., Galimberti, C. (eds.) Towards CyberPsychology: Mind, Cognitions and Society in the Internet Age. IOS Press, Amsterdam (2001)

Wiederhold, B.K., Wiederhold, M.D.: Three-year follow-up for Virtual Reality exposure for fear of flying. CyberPsychology & Behavior 6, 441–445 (2003)

Wiederhold, B.K., Wiederhold, M.D.: Virtual Reality Therapy for Anxiety Disorders: Advances in Evaluation and Treatment. American Psychological Association, Washington (2005)

Wiederhold, B.K., Wiederhold, M.D.: Virtual Reality Treatment of Posttraumatic Stress Due to Motor Vehicle Accident. CyberPsychology, Behavior & Social Networking 3, 21–27 (2010)

Wilson, J.A.B., Onorati, K., Mishkind, M., Reger, M.A., Gahm, G.A.: Soldier attitudes about technology-based approaches to mental health care. CyberPsychology & Behavior 11, 767–769 (2008)

Wood, D.P., Wiederhold, B.K., Spira, J.: Lessons Learned from 350 Virtual- Reality Sessions with Warriors Diagnosed with Combat-Related Posttraumatic Stress Disorder. Cyberpsychology, Behavior, and Social Networking 13, 3–11 (2010)

Chapter 4

Virtual Reality Exposure Therapy for Anxiety Disorders: The State of the Art

Katharina Meyerbröker and Paul M.G. Emmelkamp

Department of Clinical Psychology, University of Amsterdam
Roetersstraat 15, 1018 WB Amsterdam, The Netherlands

Abstract. In the past 10 years virtual reality exposure therapy (VRET) has become a viable alternative for exposure in vivo, the gold standard for the treatment of anxiety disorders. VRET is often regarded as a natural extension of the systematic exposure component of (cognitive) behavior therapy. The objective of this chapter is to discuss the treatment of anxiety disorders with VRET and review research into the outcome of VRET and the presumed (underlying) mechanisms of VRET. We discuss variables, which could play an important role during therapy such as the capability of people to experience the virtual world as real (presence), cognitions, psychophysiology, and the therapeutic alliance. Treatment procedures will be illustrated with case vignettes for different anxiety disorders.

1 Introduction

Since the seventies of the last century exposure-based therapies [1] have been developed to treat anxiety disorders and these treatments are worldwide considered the gold standard for these disorders. One core element in most treatments for phobic patients is exposure to anxiety arousing cues. Exposure therapy consists of exposing patients to situations they fear. Exposure can be carried out in two ways: (1) *in imagination*, in which patients must imagine themselves to be in a fearful situation or (2) *in vivo*, in which patients are actually exposed to the situation, the latter being much more effective in agoraphobia [1]. The treatment is based on the notion that anxiety subsides through a process of habituation after a person has been exposed to a fearful situation for a prolonged period of time, without trying to escape. According to the emotional processing theory two basic conditions have to be fulfilled for successful therapy [2], [3]. The fear structure of the patient has to be activated and information, which is incompatible with the existing anxiety structure has to be presented and emotionally processed. Considerable evidence exists, on subjective as well as on physiological measures, that anxiety decreases by staying in the situation, a process that is called extinction of fear or habituation [4], [5]. In the last decade virtual reality exposure therapy (VRET) has become a viable alternative for exposure in vivo in treating anxiety disorders, more specifically in treating specific phobias. VRET is regarded as a natural extension of the systematic exposure component of

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 47–62.
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behavioral therapy [6]. The most successful programs are carried out *in vivo*, during a long uninterrupted period of time (prolonged), and in which escape and avoidance of the situation are prevented [5], [7]. If anxious patients escape the situation that they fear, anxiety usually will subside. This escape behavior, however, will reinforce the anxiety and hence lead to further avoidance and escape behavior in the future. Therefore, in exposure programs it is often necessary to deal with this escape behavior by response prevention, which means that the patients are no longer allowed to perform escape behavior. Exposure in vivo is well documented in numerous randomized controlled clinical trials (see reviews [5], [7], [8]). Thus, exposure has become the gold standard treatment of phobic patients. In the case of panic disorder and agoraphobia, exposure in vivo not only leads to a reduction of anxiety and avoidance, but also to a reduction of panic attacks and cognitive changes, i.e. a reduction of anxiety inducing thoughts or negative self-statements [9], [10].

2 The Effectiveness of Virtual Reality Exposure Therapy

Especially in specific phobias virtual reality exposure therapy has been found to be at least as effective as the state of the art treatment exposure in vivo [6], [11], [12]. Although a number of studies have investigated the outcome of VRET, not all studies meet high methodological criteria and are externally valid [13], [14]. It should be noted that most of the randomized controlled trials (RCTs) within this research field have been limited to subjects with acrophobia and fear of flying. Research concerning the effectiveness of VRET in other anxiety disorders is still in its infancy. After a brief description of the various anxiety disorders we will summarize the effects that have been achieved with treatments using virtual reality exposure for each specific disorder. Results will be illustrated with case studies.

2.1 Specific Phobias

One of the most widespread anxiety disorders is the specific or simple phobia. The term specific phobia refers to a broad scale of phobias associated with different stimuli. Specific phobias are restricted to specific situations or objects. According to the diagnostic criteria of DSM-IV-TR of the American Psychiatric Association [15], a specific phobia should be diagnosed in the case of a persistent excessive or irrational fear of a circumscribed stimulus (object or situation), which is avoided, or endured with intense anxiety. The fear or the avoidance behavior has to interfere significantly with the person's normal life. The DSM-IV distinguishes four types of specific phobias: animal type (e.g. spiders, dogs, cats, snakes, and birds), natural environment type (e.g. storms, heights or water), blood-injection-injury type (e.g. dental phobia), and situational type (e.g. tunnels, bridges, elevators, flying, driving, or enclosed places). When individuals with a specific phobia are confronted with the phobic object or situation, this immediately induces extreme distress and panic. When the phobic stimulus is away, the anxiety decreases. Research into the effects of virtual reality exposure therapy has primarily been conducted on the natural type (fear of heights or acrophobia) and situational type (fear of flying).

2.2 Specific Phobias: Acrophobia (Fear of Heights)

The first clinical trial on VRET with acrophobia involved a within group design [16]. Ten patients were first treated with 2 sessions of VRET followed by 2 sessions of exposure in vivo. This design was chosen while the investigators found it unethically at that time to withhold the gold standard treatment exposure in vivo from patients. Virtual reality exposure therapy, however, was found to be at least as effective as exposure in vivo on anxiety and avoidance, which made it ethically acceptable to directly compare these treatments in a between group design. In a following study by the same research group 3 sessions of VRET and 3 sessions of exposure in vivo were compared in a randomized controlled trial (RCT) [17]. To enhance the comparability of the exposure conditions virtual environments and real life situations were identical. Measures also included a behavioral avoidance test (BAT) at post assessment. Results indicated that both treatments were equally effective and that practicing in a virtual environment did generalize to the real world as assessed with a BAT. Results were maintained at six months follow up.

In another study [18] patients with acrophobia were randomly assigned to either VRET administered by a head mounted display (HMD), or a computer animated virtual environment (CAVE), or a no-treatment control group. Subjects in the active treatment conditions received three sessions of one hour each. Although in the CAVE condition patients experienced more presence than in the HMD condition, this did not influence the effectiveness of therapy. Cognitive restructuring is an effective component in therapy in treating anxiety disorders as well [5], [7], thus it would be of interest if adding cognitive restructuring to VRET would lead to a better outcome than just treatment by VRET as stand alone therapy. In a following study the role of cognitive self-statements was investigated [19]. Results of this study revealed that cognitive restructuring did not enhance the effectiveness of VRET.

Casus

Susan, is a 39 year old woman, who comes into treatment because her fear of heights is interfering more and more with her daily life. Susan lives together with her partner, who is supporting her when she is having difficulties with heights. Susan works as consultant, which demands regularly that she enters high buildings. Susan indicates that she has always been afraid of heights: she remembers being a kid and having troubles to pass gym lessons because she was afraid of climbing. Also during leisure time she never dared to jump of into a swimming pool, or climb into trees. When Susan is in a height situation nowadays she is afraid that she will fall. Her legs start to shake and she becomes dizzy and she has the idea that she is attracted by the depth. Susan does not trust the construction of stairs or buildings and does also not trust in her own body to stay in heights because of her shaking legs and dizziness. The fear of heights is becoming more and more dominant in her daily life because she has to make a lot of effort to avoid difficult situations (e.g. work meetings in a high building). Additionally, in her private life the avoidance is restricting Susan and her partner more and more in their spare time.

After explaining the rationale of the therapy, to break the avoidance behavior, Susan starts with the exposure to situations in virtual reality. Together with the therapist she makes up an anxiety hierarchy for height situations.

Susan starts to ascend with an outside fire escape, six stories high. The stairs are build with a grid floor where it's possible to look through. Looking through the floor is very difficult for Susan because then she is confronted with the height. While going up the stairs Susan starts to have shaking legs and by looking into the depth over the handrail she also becomes dizzy. On the fourth floor Susan is able to stand through her anxiety and persists the attraction to sit down. After a short break (to prevent motion-sickness), Susan starts again ascending the fire escape and although experiencing some symptoms of anxiety again on the fourth floor, she is able to wait until the symptoms decrease again and Susan goes successfully upstairs until the sixth floor. On the top of the fire escape it takes her a bit to get accustomed to the view. But after a while Susan even dares to loan over the handrail, looking straight into the depth. At the end of the session Susan can't believe that she succeeded in breaking her avoidance behavior and doing things she has not done in years. In the lasting three therapy sessions Susan practices to go into heights step by step on the virtual fire escape, going to a virtual roof garden and going upstairs in a virtual construction place. After the last treatment session Susan is very happy with the results. A few weeks later we receive a photography of her and her partner in a ferris wheel waving and smiling!

In sum, VRET has been found to be an effective treatment for patients with fear of heights. It has been found to be as effective as the gold standard exposure in vivo and results generalize to real life. Further, adding cognitive restructuring did not enhance treatment effectiveness. Presentation of the virtual worlds through a HMD or CAVE enhanced feelings of presence, but did not affect the effectiveness of treatment.

2.3 Specific Phobias: Fear of Flying

A number of studies has evaluated the efficacy of VRET in subjects with fear of flying. A number of studies [20], [21], [22], [23] found 5 to 8 sessions of VRET more effective than controls, but results are difficult to interpret because in these studies VRET was combined with anxiety management training and the specific effects of the different components were not investigated. Mühlberger et al. [24] found 4 sessions of VRET more effective than relaxation. In a series of studies by the same group was found that even one prolonged session of VRET was effective [25], [26]. Further, motion simulation did not enhance the effectiveness of VRET [25]. In the study of Mühlberger et al. [26] results indicate that the attention or presence of a therapist during a test flight did not enhance the capability of clients to fly. Results where stable at 12 months follow up. Three quarter of the whole group was able to take the graduation flight after only one treatment session.

VRET has also been compared with other treatments than relaxation. Wiederhold and Wiederhold [27] found 8 sessions of VRET more effective than 8 sessions of imaginal exposure. Krijn et al. [28] compared four sessions of VRET with four sessions of cognitive behavioral therapy (CBT) or with bibliotherapy over a five week period. Subjects in the bibliotherapy condition did not receive any treatment during the next five weeks. After five sessions no differences between VRET and CBT were found, but both treatments were more effective than bibliotherapy.

Casus

Tom, is a 33 year old man, who comes into treatment because his fear of flying interferes with his professional life. Tom is married and father of two young children. For his job he has to fly on regular basis, in busy times twice or more a week. Tom has never been afraid of flying until a few years ago. On one flight home he suddenly experienced intense fear of crashing and even experienced physical symptoms as heart-racing and sweetening. Since then his anxiety about flying became only worse. When Tom has to fly, he cannot sleep the night before, he is constantly busy with catastrophic thoughts about the flight and he ruminates what might happen to his family in case he dies in a plane crash. The last months he only succeeds in flying by taking great amounts of tranquilizers and a number of glasses of alcohol. His fears are getting worse and he has hangovers from the tranquilizers and alcohol, which impairs the quality of his work. Tom is convinced that the airplane he sits in will crash. To him it is very difficult to not have control in a situation and not to be able to leave the situation when he can't bear it anymore. Given that the quality of his work is severely impaired, Tom is highly motivated to work on his problems.

After introducing Tom to the virtual environments and explaining the importance of breaking the avoidance behavior, Tom starts with the exposure to a virtual airport. Tom enters the airport and first has to get in line to check in. After that he passes the security check and then enters the duty-free area. On the background Tom can hear last calls for passengers and incoming and outgoing flights. The tension increases when Tom is getting closer to the gate and he can hear the outgoing flights better. Although he almost experiences panic, he is able to walk all the way to the gate.

After a short break (to prevent motion-sickness), Tom sits in real airplane chairs provided with subwoofers for tactile support. He sees a virtual airplane and other people sitting around him. Tom makes a first virtual flight from Amsterdam to Italy. During take-off and also during landing Tom experiences intense fear. After the flight he is exhausted but happy that he did the flight without taking any medication. The following three therapy sessions Tom practices every session two virtual flights. As sessions succeed the virtual flights become more and more difficult and besides heavy turbulence also thunderstorms take place. In the beginning his anxiety becomes almost overwhelming but the more he practices the more relaxed he becomes. In the last therapy session he still experiences some tension during turbulent flights, but his general anxiety level has decreased enormously. After treatment termination Tom is confident about his next real flight without alcohol and medication. After that flight Tom lets us know that he still was a bit tense – but that he, for the first time in years was able to go to the restrooms and even "dared" to look out of the window.

In sum, VRET is an effective treatment for fear of flying. It is more effective than bibliotherapy, imaginal exposure or relaxation. Clear advantages in costs are obvious, since treatment can be done in virtual airplanes, rather than having to take a real flight.

2.4 Social Phobia

Social phobia is characterized by a marked and persistent fear of social or performance situations in which the person may be scrutinized by others and fears coming across in way that would be embarrassing or humiliating [15]. People with a social phobia have a strong fear of one or more social situations, such as talking in public, entering a room with other people, ordering food in a restaurant etc. The effect of this phobia on patients includes depression, substance abuse (e.g. alcoholism, drug abuse), restricted socialisation, and poor employment and education performance. It is a chronic disorder, which usually begins in early adolescence and results in considerable impairment on role functioning and reduction of quality of life that increases over an individual's lifespan. A lifetime prevalence ranging from 3% to 13% has been reported by epidemiological and community studies [29]. In the western world, social phobia leads to intensive use of (mental) health services.

As discussed above, exposure in vivo is the gold standard for treatment of phobias. With exposure in vivo, patients are exposed to gradually more anxiety arousing situations for prolonged periods of time per session until anxiety dissipates and habituation occurs. One of the problems with exposure in vivo with social phobics is that it is difficult to build a hierarchy of gradually more difficult social situations to be practiced during treatment, given the unpredictability of reactions of other people. Moreover, many social interactions are time-limited, often not long enough for habituation of anxiety to occur. These aspects are a serious drawback for the 'normal' use of exposure in vivo for social phobics and may explain why treatment with exposure in vivo with social phobics is less effective than with individuals with specific phobia such as fear of heights or claustrophobia [30].

Exposure using virtual reality may solve many of the problems currently associated with conducting exposure therapy with social phobics. In virtual reality exposure to virtual social situations can be repeated over and over again until habituation occurs. Moreover, the therapist can control a hierarchy of increasing difficulty within and between the virtual social scenes. Further, In clinical practice treatment often consists of group therapy, which might be too aversive for socially anxious patients. Taken these considerations into account, VRET could be an ideal treatment for patients with social anxiety since exposure can be better controlled and VRET is given individually rather than in a group. Unfortunately, until to date very few studies have investigated this possibility. In one study [31] individually conducted VRET was compared to group treatment consisting of cognitive behavioral therapy. Results are difficult to interpret for a variety of reasons, including non random allocation to treatment conditions, no behavioral measure to investigate generalization to real rather than virtual social situations, and no control group. In addition, a possible confound is the comparison of an individual treatment (VRET) with a groups treatment. Especially in the treatment of social phobia where social contact in the context of participation in a group can be interpreted as exposure in vivo to a feared stimulus, group treatment may confound the effects of CBT per se.

The only RCT on the treatment of social phobia with VRET was reported by Wallach et al. [32] and involved subjects with a specific social phobia: fear of public speaking. Results indicated that cognitive behavior therapy plus VRET was not more effective than standard cognitive behavior therapy for fear of public speaking. Both treatments were superior to the control condition on anxiety measures and on a behavioral avoidance measure (BAT). Twice as many subjects dropped out of the cognitive behavioral condition than out of the cognitive behavioral plus VRET condition, which suggests that VRET made the treatment less aversive and more palatable for patients.

For social phobia most experimental systems focus on the fear of speaking in front of a group of people. In these systems people are asked to talk in front of a number of human avatars as part of a presentation to peers or a job interview. In an interesting study of Pertaub, Slater and Barker [33] it was found that the attitude of a virtual audience (positive, neutral or negative) results in different anxiety-level (high, medium, low) of the subjects. Besides more formal public speaking scenes, environments for other scenes have also been developed such as an informal dinner with friends, entering a public space like a cafeteria or a bar, public transport, and a store, but none of these virtual worlds has been investigated in the context of a treatment outcome study.

In sum, although the first results of VRET in public speaking are promising further controlled studies are needed in other forms of social phobia before this treatment can be recommended for social phobic patients.

2.5 Panic Disorder

Panic disorder is characterized by recurrent panic attacks, which are discrete periods of intense fear and discomfort, often occurring unexpectedly. Panic attacks are accompanied by a number of symptoms, such as shortness of breath, dizziness, palpitations, trembling, sweating, choking, abdominal distress, depersonalization or derealization, fear of dying or fear of going crazy. Panic disorder often leads to extensive avoidance behavior, since these patients fear being in places or situations from which it is difficult to escape, or in which there is no help at hand in case of a panic attack. Agoraphobia is anxiety about being in situations from which escape might be difficult or in which help may not be available in the event of having a panic attack or panic-like symptoms. This anxiety typically leads to a pervasive avoidance of a variety of situations such as being home alone, being in crowded places, entering shops and walking and travelling alone either by car or public transport. Panic disorder usually starts between late adolescence and early 30s. In many cases the first attack is triggered by psychosocial stress (e.g. living on ones own, physical illness, delivery or medical treatment).

In more complex anxiety disorders as panic disorder controlled studies (RCTs) into VRET are scarce. In patients with panic disorder and agoraphobia treatment has to focus on two components: panic and agoraphobic avoidance behavior [7]. Treatment of panic consists of cognitive therapy. Exposure to agoraphobic avoidance behavior consists of exposing individuals to situations they fear – which can be easily done in virtual environments. Three clinical trials (RCTs), which investigated the effects of VRET in subjects with panic disorder, have been published. In the first controlled study a combination of cognitive therapy and VRET was less effective than a standard cognitive behavioral program ("panic control") at 6 month follow-up [34]. A major limitation of this study is that both treatment conditions received an unequal amount of treatment sessions. Interestingly the cognitive therapy plus VRET condition achieved at post-assessment the same results with fewer therapy sessions than the panic control program, although at follow up standard cognitive behavior therapy was found to be more effective. This aspect and the multi-component package of which the specific contribution of each component on its own was not evaluated makes generalization difficult. In a study of Botella et al. [35] CBT directed at the panic plus VRET was found to be as effective as CBT plus exposure in vivo; both treatments were more effective than a no-treatment control condition. The results remained stable at 12 months follow up. Unfortunately, neither in the Botella study [35] nor in the Choi study [34] was investigated whether results generalized to the real world since no BAT was included.

One study found that results of VRET in patients with panic disorder and agoraphobia generalized to the real world [36]; CBT and a combined VRET-CBT program were found to be equally effective at post-test and at 3 months follow up. All subjects received antidepressant medication as well, so results cannot be attributed alone to the effects of VRET.

Casus

Jenny, a 51 year old woman, comes into treatment because her anxiety and panic overrule her whole life. Jenny is mother of three children who are grown up and since the divorce from her husband she lives alone. One day a week she works as a volunteer in a tourist organization. Although she has known panic attacks al her life, Jenny is tired because her panic costs her so much energy. She has ten to fifteen full-blown panic attacks a month in a variety of situations. During a panic-attack she is afraid that she will faint or die of a heart attack. Besides the intense and sudden anxiety she suffers from palpitations and breathlessness, a feeling of choking, transpiration and trembling, she is dizzy and has the idea that things around her are unreal. Due to intensity of her panic attacks, Jenny is avoiding especially unknown places, public transport, bridges and tunnels and social events (party's or meetings).

After four sessions of therapy, wherein is worked with the cognitive model of panic and interoceptive exposure, Jenny starts with exposure to situations in virtual reality. Together with the therapist she makes up an anxiety hierarchy for situations, which are difficult for her in daily life. To start with, Jenny wants to practice in a virtual underground metro-station. Jenny puts on the 3D-glasses and the therapist guides her through the virtual metro-station. After the first stairs and after passing the metro-ports on the escalator to the platform, the anxiety becomes so overwhelming that Jenny experiences a panic attack. Although she is having a hard time, Jenny succeeds in staying in the virtual situation and after a few minutes the fear decreases and Jenny is able to move on to the platform. After a short break (to prevent motion-sickness), Jenny enters the metro-station again. Although she feels tension and anxiety, she is able to descend to the platform without experiencing too much anxiety and without entering into panic again. After the session Jenny is exhausted but also very proud because she succeeded in breaking her avoidance behavior, albeit virtually. In the following treatment sessions Jenny practices in for her unknown virtual places, as a small town, a crowded market square and a wide open square in a foreign city. Almost every session Jenny also practices in the virtual metro-station and even though it always triggers a bit of tension and in the beginning still a bit of panic, at the end of the treatment she is able to walk it all the way through, without experiencing any anxiety. After six sessions of virtual reality exposure Jenny is very happy because she succeeded in breaking her avoidance behavior also in real life.

In sum, the results of pure VRET have hardly been investigated in panic disorder and agoraphobia. Only Botella et al. [35] compared VRET and in vivo exposure directly and found both components equally effective.

2.6 Posttraumatic Stress Disorder

Posttraumatic stress disorder (PTSD) is the development of characteristic symptoms following the exposure to an extreme traumatic event, involving threat to someone's personal integrity or witnessing happening something like that to someone else [15]. People with PTSD suffer from persistently re-experiencing the traumatic event with intrusive thoughts or nightmares. Often they are acting or feeling as if the traumatic event were recurring. People tend to avoid stimuli, which are associated with the trauma and do efforts to avoid also feelings or thoughts or conversations associated with the trauma.

Treatment of PTSD has focused on repeated exposure (in imagination) to the traumatic event and on breaking avoidance behavior in daily life of stimuli associated with the traumatic event. The focus of treatment of PTSD with VRET has been on war veterans who severely are impaired by traumatic experiences made on missions. Typical war scenarios are replicated virtually (e.g. entering with a tank a hostile city), so that veterans can be repeatedly exposed to these scenarios.

To date studies concerning the treatment of PTSD with VRET are scarce. Only one comparative treatment outcome study was published. In a study by Difede et al. [37] patients with PTSD underwent a flexible amount of exposure sessions (VRET), with a maximum of 14 sessions. At post-assessment the VRET group improved significantly on specific PTSD measures, whereas the no-treatment control group did not. Thus, these preliminary results indicate that VRET could be a useful intervention in subjects with PTSD at least in some cases. These results are also supported in a report by Ready, Pollack, Rothbaum and Alarcon [38], in which the data of two open studies are pooled on the treatment of Vietnam veterans diagnosed with PTSD who underwent VRET. Subjects improved significantly on specific PTSD measures, with stable results at follow up three and six months later. Possible problems in this patient group are that traumata are often too idiosyncratic to be treated with standard virtual environments and that it often will be impossible to create virtual environments that are realistic (e.g. child abuse, rape).

2.7 Meta-analyses

Two meta-analyses have been reported concerning the effectiveness of VRET in anxiety disorders [11], [12]. In both studies VRET was found to be equally effective or superior to a variety of control groups. In the meta-analysis of Powers and Emmelkamp [12] 13 studies (n = 397) were included. Studies were excluded that involved case reports, multiple components of treatment conditions, and unequal amount of treatment sessions in the treatments compared. VRET was more effective than control conditions and as least as effective as exposure in vivo. Generally, effect sizes of VRET were large to very large, but most of the studies involved specific phobias. In the other meta-analysis less strict criteria were applied and 21 studies (n = 300) were included in the analysis [13]. Unfortunately also case reports were included which makes comparability with RCTs rather difficult, especially given the different anxiety disorders investigated, and the different amount of treatment sessions in the studies compared, which was not controlled for in the analyses.

2.8 Concluding Remarks

Although the two meta-analyses [11], [12] reported promising effect sizes for VRET generalization across anxiety disorders is hardly possible. Only in two specific phobias (fear of flying and acrophobia) there is now conclusive evidence that VRET indeed is effective in comparison with the state of the art treatment and controlled for the effect of time. With respect to other phobias and PTSD hardly any comparative outcome study has been reported which make any conclusion with respect to clinical relevance of VRET for these disorders premature. Results concerning the treatment of panic disorder are promising, but definite conclusions are precluded since the effects of the VRET component in the package cannot be established in most of these studies.

3 The Role of Presence

As mentioned in the introduction, according to the emotional processing theory of Foa and Kozak [2], [3] two conditions within therapy sessions have to be met for successful emotional processing. The fear structure has to be activated and information incompatible with this existing structure has to be presented and incorporated. To activate the fear structure virtual environments have to be experienced as real enough by subjects (presence) to elicit a sufficient amount of anxiety. Presence refers to the sense of “being there” in the environment depicted by the virtual environment and to the extent to which the virtual environment becomes the dominant one, i.e., that participants will tend to respond to events in the virtual environments rather than to events in the real world [39]. Therefore presence is considered a condition sine qua non for successful virtual reality exposure therapy. VRET is based on the assumption that people feel ‘‘present’’ in the virtual environment. Level of experienced presence is therefore assumed to be an important mediating variable.

Given that presence is considered a basic condition for successful therapy research has focused on the part played by presence on therapy outcome. While for many subjects VRET is less aversive than exposure in vivo, in some subjects VRET cannot elicit presence and therefore anxiety cannot be provoked. These patients tend to drop out of treatment. Until now it remains unclear why some patients can benefit from VRET and others not. Below research concerning technical aspects and the individual capacity to experience presence will be discussed.

3.1 Technical Aspects

According to Slater and Wilbur [40] the term immersion refers to an objective description of the aspects of the system such as field of view and display resolution, while the term presence refers to the subjective phenomenon such as the sensation of being in a virtual environment. Systematic research concerning the different systems has been focused on the hardware most often used: a Computer Animated Virtual Environment (CAVE) and a Head Mounted Display (HMD). Given the more immersive character of the CAVE, it has been suggested that the CAVE would generate a higher sense of presence than presentation through a HMD. In a study of Krijn et al. [18], a higher sense of presence was found in subjects undergoing VRET for acrophobia in the CAVE; however, although the patients experienced significantly more presence in the CAVE than in HMD, this was not related to outcome of treatment: CAVE and HMD presentation of virtual worlds proved to be equally effective.

Contrary to the study of Krijn et al. [18], Juan and Perez [41] found that the CAVE not only generated a higher sense of anxiety in non-phobic subjects but also a higher sense of presence. However, given that it was a student population, the results of Krijn et al. study [18] have more implications for clinical settings. Price and Anderson [42] studied the role of presence on experienced anxiety during VRET. Results supported presence as a factor that contributes to the experience of anxiety in the virtual environment; there was no evidence, however, that there was a relation between presence and treatment outcome, thus corroborating the results of the study of Krijn et al. [18].

3.2 Personality Characteristics

In addition to research into the technical aspects associated with the experience of presence, personality characteristics of subjects undergoing virtual reality exposure therapy may be related to the level of presence experienced as well. One construct that could play an important role in the capability to experience presence is absorption [43]. Absorption refers to the tendency to become immersed in movies, acting, nature, voices, past events, etc. Therefore it could be argued that subjects who have a greater tendency to become immersed in fictional events or have a capacity to dissociate can benefit more from VRET than subjects who do not have this tendency. However, research is still inconclusive [44], [45]. There is some evidence, however, that subjects who are more introvert tend to experience higher levels of presence [46].

Given the few studies investigating individual characteristics related to the experience of presence there is no robust evidence yet that a specific personality trait, may be used to predict potential benefits of VRET for future patients.

4 Process of VRET

Although VRET is regarded as a natural extension of the systematic exposure component of (cognitive) behavior therapy [6], to date hardly any research has examined the underlying mechanisms of change in VRET. In research into the therapeutic process of exposure based treatments, the emphasis has been on the habituation process, using psychophysiological measures, and on changes of anxious thoughts of patients. Further, there is considerable evidence that the quality of the relationship between the therapist and the patient affects treatment outcome. In this paragraph we will discuss research that has been conducted into these processes during VRET.

4.1 Psychophysiology in the Process of VRET

Although extensive research has been done with psychophysiological measures into the process of VRET, results are still inconclusive. Different physiological measures as heart rate (HR), heart rate variability (HRV), or galvanic skin conductance (GSC) have been used to analyze physiological arousal and habituation processes in VRET.

Research in this area was recently reviewed by Meyerbröker and Emmelkamp [14]. Firm conclusions about a pattern of physiological arousal during VRET cannot be drawn since no coherent pattern was found in the studies reviewed. Overall in none of the studies consistent support was found for the emotional processing theory as indicated by changes in heart rate [2]. More support was found for changes in GSC during VRET [47], [48], [49], but this was not corroborated in another study [50]; all three studies, which found support, lacked sufficient statistical power. Studies with more sophisticated research designs, making a direct comparison between VRET and exposure in vivo while keeping all other variables constant are needed before more definite conclusions about physiological processes during VET can be drawn.

4.2 Cognitive Mechanisms in Virtual Reality Exposure Therapy

Research into cognitive processes during VRET is still in its infancy. The few studies addressing cognitions during the process of VRET use a variety of approaches, which shed some light on cognitive processes, but are not yet conclusive. Although there is some evidence that VRET may lead to change on an implicit cognitive measures [51], it is still questionable whether the Stroop task used provides a reliable indication of automatic processing. More promising results were revealed with respect to changes in self-efficacy and self-statements over the course of VRET. In a series of studies by our own research group [19], [28], [52] was found that VRET resulted in significant changes in self-statements (anxious thoughts) and self-efficacy, although the therapy did not focus on these processes directly.

4.3 Therapeutic Relationship

A central process aspect concerning therapy outcome is the therapeutic alliance between therapist and client. Because of its modest but stable ability to predict treatment outcome, the therapeutic alliance has become one of the most studied process variables in psychotherapy research, but the alliance research in technology-based psychological treatment has been neglected [53].

Meyerbröker and Emmelkamp [52] investigated the mediating role of the therapeutic alliance in subjects with fear of flying or acrophobia. Results indicated that the quality of the therapeutic alliance as assessed with the Working Alliance Inventory [54] was positively related to treatment outcome in the fear of flying group but not in the acrophobia group. The discrepancy with respect to the predictive value of the therapeutic relationship between the two groups might be related to differences in challenges within the exposure sessions, which differed for the two groups. In the fear of flying patients exposure was standardized for all patients eliciting moderate anxiety, while exposure in the patients with acrophobia was more challenging in that therapists pushed the patient more to do more difficult exercises. There is a clear need for further studies into the mediating role of the therapeutic relationship in VRET.

5 Concluding Remarks

VRET has been found to be an effective treatment for specific phobias, but more studies are needed to evaluate its effectiveness in social phobia, PTSD, and panic disorder and agoraphobia. Although the two meta-analyses done reveal moderate to high effect sizes for VRET [11], [12], generalization across anxiety disorders is hardly possible. In more complex anxiety disorders as panic disorder and social phobia, which form the core clinical group, first results of VRET are promising. Given that patients with social phobia and panic disorder and agoraphobia are often too scared to refer themselves to treatment, a future aim in research could be to first start treatment at home via an internet port, where patients can login and start first treatment sessions in virtual reality.

As to PTSD it is questionable whether most cases of PTSD can be successfully treated with virtual reality. Treatment for PTSD with virtual reality seems realistic for veterans who have been traumatized in more or less comparable war situations. Other traumatic events/incidents are often too idiosyncratic to be rebuild in virtual environments and such traumatic incidents might be easier and better treated with other state of the art treatments for PTSD.

Although VRET has been found effective in a number of studies, the process how these effects are achieved is still not clear. There is a clear need of studies into the processes involved in VRET. In sum, it would be a valuable addition when research into VRET would not only focus on outcome but also on the underlying processes.

References

[1] Emmelkamp, P.M.G.: Phobic and obsessive-compulsive disorders. Plenum, New York (1982)

[2] Foa, E., Kozak, M.J.: Emotional Processing of Fear: Exposure to Corrective Information. Psychological Bulletin 99, 20–35 (1986)

[3] Foa, E., McNally, R.J.: Mechanisms of change in exposure therapy. In: Rapee, R.M. (ed.) Current controversies in the anxiety disorders, pp. 214–227. Guilford Press, New York (1996)

[4] Emmelkamp, P.M.G.: Behavior therapy with adults. In: Bergin, A., Garfield, S. (eds.) Handbook of Behavior Therapy and Behavior Change. Wiley, New York (1996)
[5] Emmelkamp, P.M.G.: Behavior therapy with adults. In: Lambert, M. (ed.) Bergin & Garfield's Handbook of Behavior Therapy and Behavior Change, pp. 396–448. Wiley, New York (2004)
[6] Krijn, M., Emmelkamp, P.M.G., Olafsson, R.P., Biemond, R.: Virtual reality exposure therapy of anxiety disorders: A review. Clinical Psychology Review 24, 259–281 (2004a)
[7] Emmelkamp, P.M.G., Powers, M.B.: Agoraphobia. In: Thomas, J., Hersen, M. (eds.) Handbook of Clinical Psychology Competencies, pp. 723–758. Springer, New York (2010)
[8] Craske, M.G., Barlow, D.H.: Panic disorder and agoraphobia. In: Barlow, D.H. (ed.) Clinical handbook of psychological disorders, pp. 1–64. Guilford, New York (2008)
[9] Van Hout, W.J.P.J., Emmelkamp, P.M.G., Scholing, A.: The role of negative self-statements during exposure in vivo: A process study of eight panic disorder patients with agoraphobia. Behavior Modification 18, 389–410 (1994)
[10] Van Hout, W.J.P.J., Emmelkamp, P.M.G.: Exposure in vivo. In: Hersen, M., Sledge, W. (eds.) The Encyclopedia of Psychotherapy, vol. I, pp. 761–768. Academic Press, New York (2002)
[11] Parsons, T.D., Rizzo, A.A.: Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. Journal of Behavior Therapy and Experimental Psychiatry 39, 250–261 (2008)
[12] Powers, M.B., Emmelkamp, P.M.G.: Virtual reality exposure therapy for anxiety disorders: A meta-analysis. Journal of Anxiety Disorders 22, 561–569 (2008)
[13] Côté, S., Bouchard, S.: Virtual reality exposure for phobias: A critical review. Journal of CyberTherapy and Rehabilitation 1, 75–91 (2008)
[14] Meyerbröker, K., Emmelkamp, P.M.G.: Virtual reality exposure therapy in anxiety disorders: A systematic review of process- and outcome studies. Depression and Anxiety 27, 933–944
[15] American Psychiatric Association. Diagnostic and statistical manual of mental disorders: Fourth Edition-Text revision. APA, Arlington (2000)
[16] Emmelkamp, P.M.G., Bruynzeel, M., Drost, L., van der Mast, C.P.A.G.: Virtual reality treatment in acrophobia: A comparison with exposure in vivo. CyberPsychology & Behavior 4, 335–339 (2001)
[17] Emmelkamp, P.M.G., Krijn, M., Hulsbosch, A.M., De Vries, S., Schuemie, M.J., Van der Mast, C.A.P.G.: Virtual reality treatment versus exposure in vivo: A comparative evaluation in acrophobia. Behaviour Research and Therapy 40, 509–516 (2002)
[18] Krijn, M., Emmelkamp, P.M.G., Biemond, R., De Wilde de Ligny, C., Schuemie, M.J., Van der Mast, C.A.P.G.: Treatment of acrophobia in virtual reality: The role of immersion and presence. Behaviour Research and Therapy 42, 229–239 (2004b)
[19] Krijn, M., Emmelkamp, P.M.G., Olafsson, R.P., Schuemie, M.J., Van der Mast, C.A.P.G.: Do self-statements enhance the effectiveness of virtual reality exposure therapy? A comparative evaluation in acrophobia. CyberPsychology & Behavior 10, 362–370 (2007a)
[20] Maltby, N., Kirsch, I., Mayers, M., Allen, G.J.: Virtual Reality Exposure Therapy for the Treatment of Fear of Flying: A controlled investigation. Journal of Consulting and Clinical Psychology 70, 1112–1118 (2002)
[21] Rothbaum, B.O., Hodges, L., Smith, S., Lee, J.H.: A controlled study of virtual reality exposure therapy for fear of flying. Journal of Consulting and Clinical Psychology 68, 1020–1026 (2000)

[22] Rothbaum, B.O., Hodges, L., Anderson, P., Price, L., Smith, S.: Twelve-months follow-up of virtual reality and standard exposure therapies for fear of flying. Journal of Consulting & Clinical Psychology 70, 428–432 (2002)

[23] Rothbaum, B.O., Zimand, E., Hodges, L., Lang, D., Wilson, J.: Virtual reality exposure therapy and standard (in vivo) exposure therapy in the treatment of fear of flying. Behavior Therapy 37, 80–90 (2006)

[24] Mühlberger, A., Herrmann, M.J., Wiedemann, G., Ellgring, H., Pauli, P.: Repeated exposure of flight phobics to flights in virtual reality. Behavior Research and Therapy 39, 1033–1050 (2001)

[25] Mühlberger, A., Wiedemann, G., Pauli, P.: Efficacy of a one-session virtual reality exposure treatment for fear of flying. Psychotherapy Research 13, 323–336 (2003)

[26] Mühlberger, A., Weik, A., Pauli, P., Wiedemann, G.: One-session virtual reality exposure treatment for fear of flying: 1-year follow-up and graduation flight accompaniment effects. Psychotherapy Research 16, 26–40 (2006)

[27] Wiederhold, B.K., Wiederhold, M.D.: Three year follow-up for virtual reality exposure for fear of flying. Cyberpsychology & Behavior 6, 441–445 (2003)

[28] Krijn, M., Emmelkamp, P.M.G., Olafsson, R.P., Bouwman, M., van Gerwen, E.J., Spinhoven, P., Schuemie, M.J., Van der Mast, C.A.P.G.: Fear of flying treatment methods: Virtual reality exposure vs. cognitive behavioral therapy. Aviation Space and Environmental Medicine 78, 121–128 (2007b)

[29] American Psychiatric Association. Diagnostic and statistical manual of mental disorders: 4th edn. APA, Arlington (1994)

[30] Powers, M.B., Sigmarsson, S.R., Emmelkamp, P.M.G.: A meta-analytic review of psychological treatments for social anxiety disorder. International Journal of Cognitive Therapy 1, 94–113 (2008)

[31] Klinger, E., Bouchard, S., Legeron, P., Roy, S., Lauer, F., Chemin, I., Nugues, P.: Virtual reality therapy versus cognitive behavior therapy for social phobia: A preliminary controlled study. CyberPsychology & Behavior 8, 76–88 (2005)

[32] Wallach, H.S., Safir, M.P., Bar-Zvi, M.: Virtual reality cognitive behavior therapy for public speaking anxiety; a randomized clinical trial. Behavior Modification 33, 314–338 (2009)

[33] Pertaub, D.P., Slater, M., Barker, C.: An experiment on public speaking anxiety in response to three different types of virtual audience. Presence 11, 68–78 (2002)

[34] Choi, Y.H., Vincelli, F., Riva, G., Wiederhold, B.K., Lee, J.H., Park, K.H.: Effects of group experiential cognitive therapy for the treatment of panic disorder with agoraphobia. CyberPsychology & Behavior 8, 387–393 (2005)

[35] Botella, C., Garcia-Palacios, A., Villa, H., Baños, R.M., Quero, S., Alcaniz, M., Riva, G.: Virtual reality exposure in the treatment of panic disorder and agoraphobia: A controlled study. Clinical Psychology and Psychotherapy 14, 164–175 (2007)

[36] Peñate, W., Pitti, C.T., Bethencourt, J.M., de la Fuente, J., Gracia, R.: The effects of a treatment based on the use of virtual reality exposure and cognitive behavioral therapy applied to patients with agoraphobia. International Journal of Clinical and Health Psychology 8, 5–22 (2008)

[37] Difede, J., Cukor, J., Jayasinghe, N., Patt, I., Jedel, S., Spielman, L., Giosan, C., Hoffman, H.G.: Virtual reality exposure therapy for the treatment of posttraumatic stress disorder following. Journal of Clinical Psychiatry 68, 1639–1647 (2007)

[38] Ready, D.J., Pollack, S., Rothbaum, B.O., Alarcon, R.D.: Virtual reality exposure for veterans with posttraumatic stress disorder. Journal of Aggression, Maltreatment & Trauma 12, 199–220 (2006)

[39] Slater, M.: Measuring Presence: A Response to the Wimer and Singer Presence Questionnaire. Presence: Teleoperators and Virtual Environments 8, 560–565 (1999)
[40] Slater, M., Wilbur, S.: A Framework for immersive virtual environments (five): Speculations on the role of presence in virtual environments. Presence: Teleoperators and Virtual Environments 6, 1–13 (1997)
[41] Juan, C.M., Perez, D.: Comparison of the levels of presence and anxiety in an acrophobic environment viewed via HMD or CAVE. Presence 18, 232–248 (2009)
[42] Price, M., Anderson, P.: The role of presence in virtual reality exposure therapy. Journal of Anxiety Disorders 22, 742–751 (2007)
[43] Tellegen, A., Atkinson, G.: Openness to absorbing and self-altering experiences ("Absorption"), a trait related to hypnotic susceptibility. Journal of Abnormal Psychology 83, 268–277 (1974)
[44] Baños, R.M., Botella, C., Rubio, I., Quero, S., Garcia-Palacios, V.H., Perpina, M., Gallardo, M.: Psychological Variables and Reality jugdement in Virtual Environments: The Role of Absorption and Dissociation. CyberPsychology & Behavior 2, 143–148 (1999)
[45] Murray, C.D., Fox, J., Pettifer, S.: Absorption, dissociation, locus of control and presence in virtual reality. Computers in Human Behavior 23, 1347–1354 (2007)
[46] Alsina-Jurnet, I.A., Carvallo-Beciu, C., Maldonado, J.G.: Individual Differences in the Sense of Presence. Presence, 133–142 (2005)
[47] Wilhelm, F.H., Pfaltz, M.C., Gross, J.J., Mauss, I.B., Kim, S.I., Wiederhold, B.: Mechanisms of Virtual Reality Exposure Therapy: The Role of the Behavioural Activation and Behavioral Inhibition Systems. Applied Psychophysiology and Biofeedback 30, 271–284 (2005)
[48] Moore, K., Wiederhold, B.K., Wiederhold, M.D., Riva, G.: Panic and agoraphobia in a virtual world. CyberPsychology & Behavior 5, 197–202 (2002)
[49] Wiederhold, B.K., Jang, D.P., Kim, S.I., Wiederhold, M.D.: Physiological monitoring as an objective tool in virtual reality therapy. CyberPsychology & Behavior 5, 77–82 (2002)
[50] Mühlberger, A., Bülthoff, H.H., Wiedemann, G., Pauli, P.: Virtual reality for the psychophysiological assessment of phobic fear: responses during virtual driving. Psychological Assessment 19, 340–346 (2007)
[51] Côté, S., Bouchard, S.: Documenting the efficacy of virtual reality exposure with psychophysiological and information processing measures. Applied Psychophysiology and Biofeedback 30, 217–232 (2005)
[52] Meyerbröker, K., Emmelkamp, P.M.G.: Therapeutic processes in virtual reality exposure therapy: The role of cognitions and the therapeutic alliance. Journal of CyberTherapy & Rehabilitation 1, 247–257 (2008)
[53] Emmelkamp, P.M.G.: Technological innovations in clinical assessment and psychotherapy. Psychotherapy & Psychosomatics 74, 336–343 (2005)
[54] Horvath, A.O., Greenberg, L.S.: Development and validation of the Working Alliance Inventory. Journal of Counseling Psychology 36, 223–233 (1989)

Chapter 5
Virtual Reality as a Tool for Cognitive Behavioral Therapy: A Review

Simona Scozzari and Luciano Gamberini

HTLab, Department of General Psychology,
University of Padova, Italy

Abstract. This chapter describes the deployment of Virtual Reality (VR) for Cognitive Behavioral Therapy (CBT) to treat anxiety and other psychological disorders. Regarding anxiety, the most common technique is constituted of Exposure Therapy that, transposed to Virtual Reality, allows the patient to face a digital version of the feared object or situation, instead of a real or imaginal one. Virtual Reality Exposure Therapy (VRET) has proved effective in the treatment of anxiety disorders such as social phobia, Post-Traumatic Stress Disorder (PTSD), and panic disorder with agoraphobia and has shown an efficacy comparable to traditional in-vivo exposure with various specific phobias such as arachnophobia, acrophobia, and fear of flying. Thanks to its versatility, VR has also found an employment within the CBT framework with other psychological disorders, such as substance abuse, eating disorders, and in inducing non-pharmacological analgesia in patients undergoing painful medical procedures. Even when VR-based therapy does not lead to better results than traditional CBT in terms of efficacy, there are several reasons for preferring it over in-vivo exposure, including patient's comfort and safety, as well as the possibility to create complex or delicate scenarios (e.g. PTSD scenarios). In addition, VRET can be employed to facilitate the transition toward fearful objects in the real world in patients who would otherwise refuse to face real stimuli.

1 Introduction

This chapter illustrates the newest applications of Virtual Reality (VR) to psychotherapy, in particular the applications included within the Cognitive Behavioral Therapy (CBT) approach. According to the American National Association of Cognitive Behavioral Therapists, CBT is an educational model to unlearn certain responses with the help of facts and practice; therefore it is briefer than other therapies and not focused on the therapeutic relation (http://www.nacbt.org/whatiscbt.htm). CBT is also an evidence-based therapeutic approach, proven effective by a mass of experimental evidence on a wide range of disorders, and in constant research for improved and innovative methods and techniques to treat people suffering from various disorders. For this reason, CBT is especially apt, compared to other psychotherapeutic approaches, to acknowledge the possibilities offered by VR.

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 63–108.
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In recent years, several literature reviews and meta-analysis have been published to describe the increasing popularity of VR deployment in psychotherapy (among others, [1], [2], [3], [4], [5], [6], [7], [8]). The scope of the present chapter ranges from the first works on VR-based psychological intervention to treat specific phobia in the nineties, to more recent application on anxiety disorders and other psychological and medical conditions. The aim is to provide an up-to-date, wide coverage of VR application to CBT, whereas the abovementioned reviews were mainly focused on one or more specific areas, such as anxiety disorders. About 140 studies are reported, selecting those works that include an assessment of the VR system, either in terms of therapeutic effectiveness, or for the ability to actually induce the psychological condition connected to the disorder. The studies are then grouped according to the psychological or medical condition addressed.

The chapter begins with anxiety disorders. A short description of Exposure Therapy is provided as a start (Section 2.1), since CBT for anxiety disorders through VR relies mainly on this technique; studies of arachnophobia, acrophobia, fear of flying, social phobia, panic and agoraphobia are subsequently presented in Sections 2.2 to 2.6. This section is then completed by a paragraph briefly considering other aspects of the VRET experience besides treatment effectiveness, and highlighting some additional advantages of VRET versus in-vivo exposure (Section 2.7). Section 3 describes the application of VRET to a different anxiety disorder, i.e. Post Traumatic Stress Disorder (PTSD; Section 3.1), and to stress management (Section 3.2).

The illustration of the major deployment of virtual exposure in psychotherapy continues with VR Cue Exposure treatment for substance abuse (Section 4.1) and VR employment in the treatment of eating disorders (Section 4.2). The final part of the chapter is devoted to a different kind of cognitive behavioral intervention, where the VR does not expose the participant/patient to stimuli related to the problematic condition, but to a stimulus distracting from it. This paradigm is used for pain therapy both with children and adults (Sections 5.1 and 5.2 respectively), and sometimes before the painful experience by inducing hypnosis (Section 5.3). In addition to considering the effectiveness of this therapy, the studies considering its possible psychological bases are considered as well (section 5.4). The conclusive section includes some remarks on the role of the specific equipment adopted and on ethics.

2 Virtual Reality Exposure Therapy for Phobia

2.1 Exposure Therapy

Exposure Therapy consists of a gradual approach of the patients to objects and situations they are afraid of. According to Foa and Kozak ([9], p.21) “fear is represented in memory structures that serve as blueprints for fear behavior, and therapy is a process by which these structures are modified”. These structures imply exaggerated physiological and behavioral responses and are quite resistant to modification, both because they have strong structural coherence [10] and because of altered fear-relevant information processing [11]. In fact, patients suffering from anxiety disorders may pay enhanced attention to detect fear-relevant stimuli in the environment, and also interpret the presence of these stimuli as more threatening than they actually are.

According to this model [9], to reduce fear, the memory structure must be activated by fear-relevant elements in the environment, and at the same time, some features of fear-relevant information must be incompatible with the memory structure, promoting the formation of an alternative memory. To produce an emotional change and then reduce fear, this new cognitive and affective information needs to be incorporated into the memory structure.

This change is reached through three steps: first, patients produce an intense physiological response and report intense discomfort during exposure to a fearful stimulus; then physiological reactivity gradually decreases within each session; finally, physiological response to the fear-provoking stimulus decreases across sessions.

Thanks to psycho-physiological habituation, an attenuated response occurs after repeated exposure to the feared stimulus; this information is incompatible with the memorized fear structure and weakens the connection between stimulus and response. Moreover, the exposure to a feared situation promotes the patient's awareness that, despite the presence of the stimulus perceived as a threat, no actual harm is suffered, leading him/her to a more realistic evaluation of its probability. Finally, experiencing a reduced distress and physiological activation in front of the feared stimulus is inconsistent with the belief that avoidance is the only way to decrease anxiety [9].

A considerable amount of evidence on the effectiveness of exposure techniques in the treatment of anxiety disorders has been gathered in the last decades [12], [13], [14], [15] [16].

To date, in-vivo exposure to feared stimuli is considered the golden standard in the treatment of anxiety disorders [17], but there could be several reasons why this procedure might not be undertaken. For example, a patient could consider it as too anxiety provoking. Or some fear-provoking scenarios could be difficult to find in the real world. When this is the case, the exposure can be obtained through pictures, films, or mental imagery elicited by written or verbal descriptions of the fear-inducing stimuli. If these media contain elements matching a fear memory structure, it can be activated [9].

When it is impossible to undergo in-vivo exposure, imagery procedure based on patients' memory has been successfully employed [18], [19], or a mix of imagery and in-vivo exposure to safe trauma-related stimuli [20].

However, other studies confirm that results obtained by in-vivo exposure are somehow superior to results obtained with other forms of exposure, such as imaginal, vicarious, or video exposure [21], [22], [23]: indirect exposure has been confirmed able to produce improvement, but when compared to direct exposure the latter shows better outcomes in some measures and/or better results in the long-term. So, despite the attempts to find a valid alternative to in-vivo exposure, this purpose has probably been accomplished only with the introduction of Virtual Reality Exposure Therapy (VRET).

In the next sections the existing literature on the efficacy of this approach is reviewed, in particular the treatment of specific phobias, social phobias and panic disorder with agoraphobia.

2.2 Arachnophobia

One of the first case report on the treatment of arachnophobia by means of immersive VR was published by Carlin, Hoffmann and Weghorst in 1997 [24]. The patient was a thirty-seven year old woman who suffered from a severe spider phobia. VRET treatment consisted in twelve weekly sessions of fifty-minute duration over three months, delivered by means of a VR system depicting a virtual kitchen seen through a head mounted display (HMD). The position of the cyberhand was controlled by a sensor attached to a glove worn on the right hand, and a second sensor was employed to control the position of a toy spider matching the virtual spider that the patient saw in the virtual kitchen. After one month, the patient began to receive tactile cues: when her cyberhand explored the virtual spider, her real hand touched the toy spider. Patient could feel spider's weight and the sensation of its fur, and the virtual spider moved accordingly to the toy spider the patient manipulated. During the first month in particular, the patient reported, during exposure, physical and subjective symptoms matching her high anxiety ratings, which were collected once a minute on a ten-point scale. Nonetheless, anxiety ratings showed strong evidence of reduction after three months of VRET. At the end of the treatment exaggerated emotional reactions were no longer reported by the patient when exposed to the mixed reality spider. Self-reported fear of spider ratings (modified Fear of Spiders Questionnaire [25]) confirmed the efficacy of the therapy, and, most important, the patient was able to generalize her new coping skills to the spiders she met outside the laboratory.

Garcia-Palacios and colleagues [26] conducted the first controlled study testing VRET intervention on arachnophobia. Twenty-three spider phobics, mean age twenty-nine years, took part in the research, divided into VRET group (N=12) and waiting list control group (N=11). VRET group participants underwent a gradual exposure standardized protocol in immersive VR. During the sessions, participants were immersed in a virtual kitchen ("Spider World" [27], modified from "Kitchen World" [28]) and saw a virtual spider through a HMD, with a tracking system measuring their head and hand position, as well as the virtual spider. During the last sessions tactile augmentation was introduced so that participants could touch the spider and feel it while their real hand touched a toy spider. Treatment ended when participants could handle a big virtual spider reporting low anxiety levels. Results showed that an average of four, one-hour VRET sessions was significantly more effective than the control condition in reducing both objective (Behavioral Avoidance Test) and subjective (Fear of spiders questionnaire [25]; anxiety ratings during Behavioral Avoidance Test) measures of fear. Besides statistical significance, 83% of participants in the treatment condition met also clinical improvement criteria, while participants in the control condition did not show any improvement. Coping skills acquired during treatment showed a generalization to live spiders: in a post-treatment Behavioral Avoidance Test (BAT), participants reported only low to moderate anxiety levels when approaching a big tarantula. BAT is a procedure in which a phobic patient undergoes several approaching steps toward a feared object or animal. The patient rates his/her subjective anxiety at each step, on a 0 to 100 scale (Subjective Units of Discomfort [29]) and the test ends when anxiety is too intense for the patient to go further. It is often used to evaluate patients' pre- to post- treatment performance, and in this study by Garcia-Palacios and colleagues [26] it showed a clear improvement after VR exposure.

With regard to the effectiveness of the introduction of tactile cues in spider phobia VRET, Hoffmann and colleagues [30] compared the outcomes of three groups: VRET, VRET with tactile augmentation, and no treatment control condition, including both clinically phobic (N=8) and non-phobic students (N=28). The virtual world, displayed by HMD, was Spider World [27], described above. The clinically phobic patients in the control condition showed no pre- to post-test improvement in any outcome measure (distance reached from spider and anxiety ratings during BAT; Fear of Spiders Questionnaire [25]). Taken together, clinically phobic participants in the two VR treatment conditions showed statistically significant changes in the pre- to post-test outcome measures, reaching fear of spiders scores similar to the mean score of the non phobic sample. In addition, despite the fact that it was impossible to perform a statistical analysis on the two clinical phobic treatment groups due to the small sample dimension, the pattern indicated that VRET plus tactile augmentation led to better improvement than the ordinary VRET in avoidance and anxiety BAT measures, but not in the Fear of Spiders Questionnaire.

Studies illustrated so far used mostly subjective measures, such as fear questionnaires and anxiety ratings, to evaluate VRET outcome, with the addition of the BAT as the only objective measure. More recent studies collected other objective measures of clinical improvement in spider phobia due to VRET. Côté and Bouchard [31], [32] introduced two objective measures, along with more classical self reports (Spider Beliefs Questionnaire [33]; Fear of Spider Questionnaire [25], Perceived Self- Efficacy Towards Spiders Questionnaire [34]) to assess the efficacy of VR in the treatment of twenty-eight arachnophobic adults: emotional Stroop Task and cardiac response to phobic stimuli. The emotional Stroop Task is a common paradigm often employed to assess information processing of threat-related stimuli. Reaction time (RT) to phobic and non-phobic stimuli is usually measured pre- and post-treatment. In this nonverbal variant, participants stood in front of a pad with four colored buttons. They saw a series of color-filtered pictures and were asked to push the matching button as quickly as possible for each picture. Eight pictures (four for the blank screens) were shown for each category: negative (spiders), positive (rabbits), neutral (cows), and blank screens (baseline). During pre- and post-treatment BAT involving approach to a live spider Heart Rate (HR) was recorded. Treatment consisted of five gradual exposure sessions to virtual spiders in a Virtual Environment (VE) displayed through a HMD. Emotional Stroop Task results showed that after-treatment RT for spider pictures was significantly reduced compared to pre-treatment. A significant reduction in HR was evident between pre- and post-treatment BAT, indicating a decreased anxiety level. So, these arousal and cognitive processes objective measures support the efficacy of VRET in producing therapeutic change, in addition to results on subjective outcome measures highlighted in this and other studies.

Finally, the same research group [35] probed the efficacy of exposure obtained by a modified 3D computer game, as an alternative to more expensive custom VR software, to treat eleven spider phobics. Both BAT and self-reported measures (Spider Beliefs Questionnaire Arntz [33], perceived self-efficacy Towards Spiders Questionnaire [34]) highlighted an improvement after treatment.

2.3 Acrophobia

The first studies on the efficacy of VRET in the treatment of acrophobia (fear of heights) were published in the mid ‘90s. The same authors conducted both a controlled study and a case-report study. In the former [36], [37], acrophobic college students were assigned to VRET (N= 10) or to a waiting-list control condition (N= 7). Treatment consisted in seven individual sessions of immersion in VEs simulating various situations (footbridges, balconies, glass elevator) displayed to participants through a HMD. After the treatment, indices of anxiety, avoidance, distress and attitude toward the feared situation (Acrophobia Questionnaire [38]; Attitude Toward Height Questionnaire, adapted from [39]; other original instruments constructed for the study) were significantly improved in the treatment group, while the measures of the control group did not show any change.

In the latter work, authors documented a case study [40], describing the treatment of one of the phobic students, particularly afraid of elevators, who participated to the control group in the previous research [37]. In this case the VE only encompassed a glass elevator, similar to a real one existing in the town where the participant lived. Ascension in the real elevator was used for pre- and post- treatment BAT assessment. Treatment consisted in five VRET sessions lasting thirty-five to forty-five minutes. Self-reported levels of anxiety and distress, as well as attitude toward heights were assessed pre- and post-treatment with the same instruments employed in the previous study. Avoidance behavior and self-reported measures of anxiety, distress and negative attitude toward height showed an improvement after treatment. Moreover, the participant reported a generalization of this achievement to real life situations.

Schümie and colleagues [41] designed three VEs (a roller coaster, a swimming pool with diving tower and a glass elevator), which were evaluated by six participants suffering from mild to strong acrophobia. Participants’ evaluations indicated the swimming pool VE to be most effective; therefore it was employed for a second experiment, together with a VE reproducing a tower building [42]. Aim of the study was comparing the effectiveness of two sessions of VRET to two sessions of in-vivo exposure in acrophobia treatment. In the patient group (seven females and three males) undergoing both treatments, self-reported measures of anxiety, avoidance and attitude toward heights (Acrophobia Questionnaire [38]; Attitude Toward Heights Questionnaire [39]) showed a comparable improvement between VRET and in-vivo exposure for the anxiety index, and an even better outcome of VRET in improving avoidance index and attitudes toward heights. It has to be taken into account that patients underwent first VRET and then in-vivo exposure, so probably VRET led to a ceiling effect, and further improvement could not be noticed. Emmelkamp and colleagues [43] replicated the study with a between group design in which seventeen acrophobic participants underwent VRET, and sixteen acrophobic participants underwent in-vivo exposure. The VEs were reproductions of the real locations used for the in-vivo exposure: a four-floor mall, a fire escape, and a roof garden at the top of a university building. The VEs were displayed by a HMD. Results showed that both kinds of exposure were effective in improving self-reported measures of anxiety and avoidance (Acrophobia Questionnaire [38]; Attitude Toward Heights Questionnaire [39]), as well as actual avoidance behavior assessed with pre- and post-treatment BAT. Moreover, the six-month follow-up data showed that improvements were maintained after treatment.

It is noticeable that, despite the comparable results, VR exposure elicited a slightly lower anxiety level than in-vivo exposure. This suggests that VR-based treatment leads the patients to overcome their fear experiencing a lower distress degree, thus increasing treatment acceptance.

Coehlo and colleagues [44] tested the persistence of the clinical outcome of VRET in ten acrophobics (four men and six women, mean age thirty-nine years) on one year follow-up after a three-session VRET. The immersive VE employed for treatment consisted in a balcony placed at increasing height. Results showed that improvements were partially maintained: while the Attitude Towards Heights Questionnaire [39] and BAT scores showed to be still significantly better than pre-test scores, Acrophobia Questionnaire [38] did not show any difference, suggesting a lack in generalization to new situations. Anyway, as attitudes towards heights improved, it seems that patients still had some fear, but had more skills to cope with the situation. As the VR system employed in this study recreated a real location, a subsequent study [45] compared the outcomes of VR (N=10) and in-vivo (N=5) exposure to the corrisponding environment after three sessions, using the same measures employed in the previous study. Both groups achieved strong improvements after treatment, but VR sessions were much shorter than in-vivo, session, suggesting an enhanced effectiveness of VR-based treatment.

To assess if addition of cognitive self-statements can enhance VRET effectiveness, Krijn and colleagues [46] compared twenty-six patients randomly assigned to one of two experimental conditions: two sessions of VRET, followed or preceded by two sessions of VRET plus coping self-statements. An intermediate test was held between sessions two and three, a final test was held the week after the last session, and a follow-up test was held six months later. Treatment consisted of three VEs, displayed via HMD in a gradual order: a six-floor fire escape, a roof garden, and an eight-floor building site. In the two sessions of VRET plus coping self-statements, therapist explained the rationale of cognitive therapy, examined patient's anxiety-provoking catastrophic cognitions and helped him/her formulate more neutral self-statements. Moreover, during VR immersion participants were asked questions about their cognitions and instructed to use the new neutral self-statements. In the VRET-only condition no cognitive intervention was provided. Results indicated that the treatment was effective disregarding the addition of coping self-statements. Thus, exposure was confirmed to be an effective component of treatment. Again, the six-month follow-up highlighted that improvement was not completely maintained, but difference between follow-up scores and pre-test scores still showed Cohen's *d* in the substantial range.

2.4 Fear of Flying

Particular effort has been put in the study of VEs for treating fear of flying, as this particular phobia is difficult to treat in-vivo. It is difficult to be allowed into a stationary airplane, and obviously impossible to interrupt the exposure when the plane is flying. Not to mention that continuous travels to and from the airport are money and time consuming. VR is the perfect mean to overcome these difficulties.

Hodges and colleagues [47] recreated a virtual Boeing 737 based on the model used by a flight company to train assistants, to be displayed to patient by means of HMD. Then, they created an immersive world, which could be viewed by the passenger through a window of the aircraft during flight. Variables as sunlight or darkness and weather conditions were taken into account, as well as typical sounds of the various flight stages. A case study [48] with a clinically phobic forty-two year old female patient was conducted to evaluate the design of the virtual airplane and its usefulness for VRET. Treatment consisted of anxiety management training followed by six VRET sessions. The participant's self-reported fear was reduced after treatment (Questionnaire on Attitudes toward Flying, [49];Fear of Flying Inventory [50]). Most important, just days after treatment completion she could actually fly with minimal anxiety. Based on these and other experiences, Rothbaum and colleagues [51] developed a VRET system ("Virtually Better") meant to be part of a comprehensive treatment package addressed to fear of flying. A controlled study [52] on forty-nine patients suffering from fear of flying compared VRET, in-vivo exposure at the airport and on a stationary airplane, and a waiting list control group. Intervention consisted of four sessions of anxiety management training followed by four exposure sessions. VRET outcomes measured by decreasing scores at standardized questionnaires [49], [50] and by actual plane-boarding behavior were statistically identical to in-vivo outcomes, and both were more effective than control condition. These achievements were maintained at a one-year follow up assessment [53]. In a research published in 2006 [54], the research group extended the sample to twenty-five participants per condition: VRET, standard exposure therapy and waiting list control group. After eight treatment sessions the two treatments led to comparable improvements, and outcomes were maintained at six- and twelve-month follow up assessments.

The work of Baños and colleagues [55] focused on other characteristics of fear of flying, such as anticipatory anxiety. The software developed by the authors included immersive VEs encompassing three scenarios from planning the trip to being on board. Trial with four patients suggested that two psychoeducation sessions followed by six sessions of VRET with this software were effective in reducing all measures of fear of flying (Fear Record, reported on a ten-point scale; Danger Expectations and Flying Anxiety Scales [56]; Fear of Flying Questionnaire [57]) and in promoting decision to engage on a real flight. On a subsequent study, Botella, Osma, Garcia-Palacios, Quero and Baños [58] further tested the efficacy of a VR system encompassing anticipatory anxiety scenarios on nine phobic participant undergoing one psychoeducation session followed by six VRET sessions. Participants were assessed pre-, post- and at one-year follow-up. Results showed improvements on self-report measures (Avoidance and Fear Scale, adapted from [59]; Degree of Belief in Catastrophic Thoughts [58], Danger Expectations and Flying Anxiety Scales, [56], Fear of Flying Questionnaire [57]; Maladjustment Scale [60]) which were maintained at follow-up. As a very important outcome index, all participants were able to board on a real flight after treatment.

Wiederhold and colleagues [61] found clearly different psychophysiological reactions in a phobic compared to a non-phobic participant during a twenty-minute exposure to VR flight. After this assessment, a reduction in the phobic participant's physiological reactivity was obtained with four VRET sessions. This results with objective indices support the fact that VR flight simulation can reach enough sense of presence to elicit anxiety comparable to the real situation, and then that it is a valid substitute of in-vivo exposure. A subsequent experiment [62] on thirty phobics (twelve male, eighteen female, mean age forty years) compared three eight-session treatments: Virtual Reality Grades Exposure Therapy (VRGET) with or without physiological feedback and systematic desensitization with imaginal exposure. All treatments were found comparably effective in reducing self-report measures of fear of flying (Questionnaire on Attitudes Toward Flying [63]; The Fear of Flying Inventory [50]; Self-Survey of Stress Responses [64]; State-Trait Anxiety Inventory [65]). Nonetheless, VRGET led to better outcomes (being able to actually fly), especially when coupled with physiological feedback, compared to systematic desensitization with imaginal exposure, at a three-month follow up assessment, suggesting that learning self-control by means of physiological signals feedback may contribute to consolidate treatment outcomes [66].

Positive results on the efficacy of VRET in reducing fear of flying in a pre- to post-treatment comparison were found also by Klein [67] in a case study and by Wallach and Bar-Zvi [68] with four phobics.

Maltby, Kirsch, Mayers and Allen [69] compared the outcomes of forty-five patients (mean age forty-five), randomly divided in a VRET group and a control attention-placebo group. Treatment consisted of five sessions in an immersive VE encompassing ten levels from the airport to a complete flight. Although better outcome measures (Flight Anxiety Situations Questionnaire and Flight Anxiety Modality Questionnaire [70]) were found in the VRET group at post-test, the groups were no more significantly different at a six-month follow-up, due to the fact that placebo condition unexpectedly produced an improvement as well; probably educational and nonspecific factors had somehow an impact on fear of flying. For placebo group, anyway, post-treatment anxiety measures were not related to the ability to be actually engaged in a real flight, while in the VRET group these measures were significantly associated with flying. This differential outcome suggests that VRET participants were confident in their ability to fly without excessive fear, while "placebo participants might have been influenced by other less-specific factors such as loyalty to the therapist, intervention, hope, and self-disclosure" (Forsyth and Corazzini [71], as cited by Maltby and colleagues [69], p. 1117).

Mühlberger, Herrmann, Wiedemann, Ellgring and Pauli [72] investigated the outcomes of one session of VR exposure (N=15) compared to relaxation training (N=15) on flight phobics. VE represented the inside of an airplane during flight and was displayed by HMD to participants in the VRET group. Subjective reports and physiological indices of anxiety assessed with a pre- and post-treatment VR flight test indicated an anxiety reduction in both treatment groups, but a greater reduction for VRET group. Similarly, both treatment reached improvements at self-report questionnaires, but the VRET group showed better outcome measures (General Fear of Flying Questionnaire, constructed by Authors; Fear of Flying Scale [73]). A subsequent experiment [74] conducted with similar apparatus and outcome measures proved that even a VRET single session lasting 140 minutes was effective in reducing fear of flying, and results were maintained over a six-month follow-up period. Patients in the VRET group plus cognitive therapy, disregarding the inclusion of motion and vibration simulation in the VR system (N= 13 with motion simulation, N=13 without motion stimulation) showed greater reductions in fear of flying than those who only received written information about fear of flying (N=10), or information plus one session of cognitive therapy (N=11). Consideration that exposure is effective also without motion simulations is important with regard to the common clinical practice because this VR component is quite expensive and technically demanding.

Krijn and colleagues [75] compared the effectiveness of personalized VRET to personalized CBT, and to bibliotherapy. Treatment with both four sessions of immersive VRET (N=29) or two to four sessions of CBT (N=16) was more effective than of bibliotherapy (N=19), leading to a comparable decrease in the two main measures of fear of flying (Flight Anxiety Situations Questionnaire and Flight Anxiety Modality Questionnaire [70]). It is noteworthy that, however, VRET showed lower effect sizes than CBT, and the latter group profited the most from a subsequent addition of group cognitive-behavioral training, showing the largest decrease in subjective anxiety. A possible explanation for the unclear efficacy of VRET in the present study is that the VEs employed, an airport and an airplane displayed through HMD, were ineffective in inducing anxiety in a considerable number of participants.

In a recent literature review on forty-nine articles containing the keywords “Virtual Reality” and “fear of flying / flying phobia / flight phobia”, Da Costa, Sardinha and Nardi [76] concluded that VRET has been proved effective in clinical trials disregarding the association with CBT and/or psychoeducation, but more studies are needed to clarify the potential differences in these two treatments alone or combined, as the studies considered have many methodological discrepancies.

2.5 Social Phobia

Social phobia is a widespread mental disorder, with a lifetime prevalence of approximately 5% [77]. This kind of anxiety disorder can be observed in two forms: specific social phobia, when an individual experiences excessive anxiety in a circumscribed situation, e.g., public speaking; and a generalized social phobia, occurring when an individual feels uncomfortable in a variety of social situations. Traditional therapeutic approach of choice is CBT; in particular, treatment should be addressed to the modification of anxiety-provoking thoughts and beliefs, the acquisition of social skills, and overcoming avoidance by means of graded exposure to social situations.

Roy and colleagues [78] proposed a clinical protocol to assess the efficiency of VRET compared to CBT for social phobic patients. Four situations considered very distressing by social phobics were reproduced in desktop, non-immersive VR: exposure to public performance, intimacy, scrutiny and assertiveness. In twelve sessions, four patients learnt to employ appropriate cognitions and behaviors when coping with simulated social situations, with the goal to reduce their anxiety in similar real life situations. Results suggested that VRET was able to produce a reduction in social anxiety and avoidance behavior in the real world, according to questionnaires (Liebowitz Social Anxiety Scale [79]; Hospital Anxiety Depression Scale [80]; Beck Depression Inventory [81]; Rathus Assertiveness Schedule [82]), verbal reports, and clinical observations. These outcomes were comparable to results obtained by a six-participant Cognitive Behavioural Group Therapy (CBGT), implying in-vivo exposure. In a subsequent work, conducted with similar equipment, Klinger and colleagues [83] expanded the sample to eighteen participants in VRET condition and eighteen participants in CBGT condition, and the results showed again a comparable effectiveness of the two treatments in reducing the measures of social phobia and in improving social and global functioning.

Horley and colleagues [84] suggested that the avoidance of salient facial features is an important marker of social phobia. Starting from this statement, Grillon, Riquier, Herbelin and Thalmann [85] published a study on eight social phobics, with the aim to evaluate the efficiency of eight sessions of treatment comprising immersion in VR. The VEs employed depicted eight social situations, increasing in anxiety degree, displayed through HMD. Beside common self report questionnaires (Fear Questionnaire, [59]; Liebowitz Social Anxiety Questionnaire [86]; Social Interaction Self-Statement Test [87], Beck Depression Inventory [88]) eye gaze measurement was introduced as a change index. Effectiveness of treatment was supported by both questionnaires and eye gaze results, as a decrease in eye contact avoidance was observed after exposure sessions.

Fear regarding public speaking represents an important aspect of social phobia, because its occurrence is far from being rare, and is difficult to avoid. At school or at work, soon or later almost everyone has to face an audience, and this experience is so distressing also for non-phobic individuals, that public speaking is commonly used as a stress test (Speech test) to elicit psychophysiological activation, for example in hypertensives [89].

North, North and Coble [90] compared a small group (N=6) of students suffering from fear of public speaking undergoing a five-session VRET to a group of phobics in a control no-treatment condition (N=8). The immersive VE used in this study was an auditorium in which the participant had to deliver a speech in front of an audience which could show a variety of reactions. Results indicated that VRET proved effective in reducing anxiety symptoms, as assessed by self-report measures (modified Attitude Towards Public Speaking Questionnaire [39]; modified Subjective Units of Disturbance [29]), and in improving the ability to be engaged in a public speech in the real world with reduced discomfort. This study also comprised a psychophysiological index (heart rate) recorded during exposure, highlighting a physiological activation which can be considered similar to that occurring in real life when facing an audience. This data, as other by Harris, Kemmerling and North [91], suggests that VR is effective in eliciting the same discomfort as a real life public speaking situation, and that a therapy based on VR leads to a reduction of this discomfort.

Anderson, Rothbaum and Hodges [92] published the results of two case studies, one regarding a therapy encompassing four sessions of exposure to immersive VR representing an audience, and one regarding a three-day intensive course of therapy encompassing five sessions in the same VE. Results provided further evidence supporting the employment of VR in social anxiety treatment, as it led to improvements on self-report measures (Personal Report of Confidence as a Speaker [93]; Personal Report of Communication Apprehension [94]; Self-Statements During Public Speaking [95]), reaching levels comparable to public speaking fears reported in the non-phobic population. Moreover, both participants after treatment were able to give a public speech reporting modest anxiety levels. Based on these results, the same research group [96] carried out a clinical trial with ten patients (eight female, two male) suffering from social phobia; they underwent four sessions of anxiety management followed by four sessions of immersive VRET. Results were mixed, as after treatment patients reported diminished anxiety (Personal Report of Confidence as a Speaker [93]; Self-Statements during Public Speaking [95]; Personal Report of Communication Apprehension [94]) but they did not show an increased ability to perform a public speech compared to pre-treatment. This mixed result could be due to the presence among the sample of patients diagnosed with panic disorder.

In a recent work Wallach, Safir and Bar-Zvi [97], compared individuals suffering from public speaking anxiety undergoing three treatment conditions: VR CBT (N=28), traditional CBT (N=30), and a waiting list (N=30). Treatment consisted in twelve sessions, eight of which encompassed exposure. VR CBT group received exposure to an immersive VE representing an audience in various attitudes, CBT group received imaginal exposure. Results showed that both active treatments were more effective than the waiting list condition in reducing self-reported measures of anxiety (Liebowitz Social Anxiety scale [98]; Self-statements during public speaking, [95]) as well as in improving behavioral test performance self-rating, but, despite no difference between treatments were found in the outcomes, the number of participants who dropped out from traditional therapy was twice as much as the number of participants dropped out from VR CBT. This result indicates that VR treatment could be more accepted than traditional (in this case, imaginal) treatment.

Finally, some studies have focused, instead of treatment efficacy, on VE design. For example, Lee and colleagues [99] proposed an immersive VE to be used in treatment of public speaking, alternative to diffused model-based ones. Their VE was designed using simultaneously image-based rendering and chroma keying, in order to make the environment more realistic and to control individually the virtual audience members. Pertaub, Slater and Barker [100] varied the type of audience (with neutral, positive or negative attitude), and the immersion degree of the speaker (HMD or desktop VR presentation) and observed that, as it is easy to imagine, a negative audience response elicited greater anxiety in a sample taken from the general population. Besides, the effect of the HMD greater immersion condition on self-report measures of confidence (modified Personal Report of Confidence as a Speaker [93]) was not generalized, but was higher for women than for men, maybe due to the fact that men are more likely to play computer games and then are more accustomed to VR. The same research group [101] compared phobics (N=16) and confident speakers (N=20) in giving a speech in front of a virtual empty room or in front of a virtual public with a neutral attitude, both displayed through HMD. Phobics speaking to the virtual audience showed significantly higher self-report (Modified Personal Report of Confidence as a Public Speaker [93]) and physiological measures of anxiety compared to phobics speaking to the empty room. Confident speakers did not show any difference between conditions, indicating a specific effect of the audience only in phobic individuals. It is noteworthy that this result with phobics was reached even if the virtual audience had a relatively low degree of representational fidelity, but it was clearly enough to elicit a strong sense of presence in these participants.

2.6 Panic and Agoraphobia

According to the Diagnostic and Statistic Manual IV [102], the essential characteristic of panic disorder is the occurrence of panic attacks, consisting in repeated sudden episodes during which an individual experiences intense fear or discomfort associated with physical and cognitive symptoms. This condition is often associated with phobic disorders, in particular with agoraphobia, which, in more serious cases, can lead to a substantial decrease in the patient's autonomy and quality of life.

Traditional CBT treatment for panic disorder with agoraphobia includes various interventions among which exposure to the feared situation holds an important role. Vincelli and colleagues [103], [104], [105] proposed a new treatment protocol for patients suffering from this disorder, the Experiential Cognitive Therapy (ECT), encompassing VR exposure. During the eight-session treatment, patients have to interact with four immersive virtual scenarios (an elevator, a supermarket, a subway, and a large square, see [105] for description of the protocol). To assess efficacy of this therapeutic protocol, a controlled clinical trial [105] was carried out with three groups, of six patients each: ECT, CBT and waiting list. Both active treatments led to comparable results in reducing the number of panic attacks and levels of depression and anxiety (Beck Depression Inventory [88]; State-Trait Anxiety Inventory [106]; Fear Questionnaire [59]). Yet, ECT needed 33% less sessions than CBT to achieve these results, suggesting an enhanced efficiency of this approach.

Botella and colleagues [107] tried to overcome common limitations of VEs designed VRET, such as limited flexibility. So, they proposed a software taking into account the main features of panic disorder with agoraphobia, such as avoidance, and important anxiety modulators related to interaction with people and trip duration, in order to be flexible and adaptable to different patients. To test the efficacy of this system, first a case study [108] and then a controlled study [109] were carried out. Treatment consisted in a multi-component cognitive-behavioral intervention, comprising six sessions in immersive VR reproducing several panic and agoraphobia-relevant scenarios. In the case study, on a twenty-six year old woman, a reduction in fear, avoidance, and catastrophic thoughts have been observed after treatment, and achievements were maintained at one year follow-up. Then, thirty-seven patients (aged eighteen to seventy-two, 70% female) suffering from panic disorder and agoraphobia were involved in a controlled study, subdivided into VRET group, in-vivo exposure group and waiting-list group. Interventions including VRET and in-vivo exposure led to similar significant improvements in measures of panic and agoraphobia (Panic Disorder Severity Scale [110]; Anxiety Sensitivity Index [111]; Adapted Fear and Avoidance Scales and Agoraphobia Subscale of the Fear Questionnaire [59]; Beck Depression Inventory [88]; Maladjustment Scale [60]; Clinician Global Impression, adapted from [112]) compared to waiting list condition; moreover, the improvements were maintained at twelve-month follow-up.

In a more recent work, Peñate, Pitti, Bethencourt, de la Fuente and Gracia [113] focused on treatment of agoraphobia, comparing VRET combined with CBT (N=15), with traditional CBT comprising in-vivo exposure (N=13). Both treatments comprised eleven sessions, eight of which encompassing exposure. For traditional CBT group all exposure sessions were in-vivo, while for VRET group half exposures were in-vivo and half in VR. Results proved the efficacy of both procedures, and the maintenance of improvements at three-month follow-up assessment. In particular, VRET showed a similar or better outcome that CBT in all measures (Agoraphobic Cognitions Questionnaire and Body Sensations Questionnaire [114]; Beck Depression Inventory II [115]; Beck anxiety Inventory [116]) except for general agoraphobia scores [117], where CBT led to better results, probably due to observed differences between groups at pre-test, although not statistically significant. Finally, subsequent investigation on a combination of VRET, CBT and two psychoactive drugs [118], led to results indicating that all drug treatments and psychological treatments caused significant improvement, but VRET showed better results compared to traditional CBT especially when chronic patients were considered. Moreover, drop-outs number in the CBT group was higher than in VRET group, indicating a better acceptance of the latter treatment.

2.7 Advantages of Virtual Reality Exposure Therapy vs. Other Exposure Treatments for Phobias

Many of the studies presented above compared outcomes achieved by VRET and by in-vivo exposure, highlighting a substantially similar effectiveness of the two techniques. This section is dedicated to the studies specifically addressing the advantages of adopting the VRET technique instead of the traditional in-vivo exposure, going beyond the effectiveness criterion, and than taking into account other aspects such as patients' acceptance, safety, or comfort.

Garcia-Palacios, Hoffman, Kwong See, Tsai, & Botella [119] focused on the greater likelihood for spider phobics to accept VR exposure compared to in-vivo. In the first of the experiments described, they asked eighty-seven students with fear of spiders their preference between in-vivo and virtual exposure therapy, and participants resulted significantly more motivated to engage in a treatment involving VR rather than in-vivo exposure. Taking into account percentage of participants who reported a refusal to undergo treatment, 17.4% would definitely not get involved in the in-vivo exposure treatment, but only 4.6% reported a refusal to get involved in VRET. On the other hand, 31% reported a definite willingness to undergo VRET, but only 7% reported the same for in-vivo exposure. Eighty-one percent of the participants chose VRET when forced to choose between treatments, thus showing a statistically significant preference for VR therapy. In a second experiment, authors investigated students' preferences regarding one three-hour in-vivo single session treatment or three one-hour VR sessions. Despite the high success rate shown in literature, Ost [120] estimated that 90% of patients would have refused the accelerated one-session therapy if told in advance they were going to let live spiders crawl on their arm. In this study, seventy-five participants with high fear of spiders reported again a significantly greater preference toward VRET program, compared to an in-vivo exposure treatment. Thirty-four point seven percent of the participants reported a refuse to be involved in the accelerated, single session in-vivo exposure treatment, while only 8% definitely refused VRET. On the other hand, 27% of participants reported a definite willingness to undergo VR exposure treatment, but only 10.7% reported the same for the in-vivo exposure. Forced to choose between the techniques, 89.2% of participants chose VRET and 10.8% chose in-vivo exposure treatment, showing a statistically significant difference between these proportions.

Given that VR and in-vivo exposure lead to comparable therapeutic results, it is useful to point out the peculiar advantages of choosing VR instead of an in-vivo intervention. Wiederhold and Wiederhold [121] summarized advantages of VRGET compared to in-vivo exposure as follows: "The advantages of VRGET compared to in vivo exposure include:

- There is no loss of patient confidentiality since the treatment sessions can be performed in the therapist's office;
- There are no safety issues because the VRGET can be terminated and the VR system turned off any time the patient requests;

- There is more flexibility in the session. If a patient is only frightened of one aspect of exposure, then this can be practiced over and over in the virtual world. In the real world, a patient may feel conspicuous repeatedly completing the same behavior;
- The experience is just unreal enough that many patients who have resisted therapy due to in-vivo approaches are willing to try treatment; and
- There is less time involved. Because the treatment can be conducted more easily within the "therapeutic hour", it will be more cost effective" (Ibid.p. 5).

Finally, in a recent meta-analysis of studies on specific phobia treatment, Wolitzky-Taylor, Horowitz, Powers and Telch [122] found that in-vivo exposure seems to be more effective than alternative modes of exposure, such as VR exposure, immediately after treatment, but this advantage is often no longer present at follow-up. So, in-vivo may lead to a more rapid improvement, but patients receiving alternative forms of exposure continue to improve after treatment. Then, if VR exposure and in-vivo exposure allow to obtain the same results in the long term, therapists and patients can choose to adopt the solution that requires least money, time and effort to them both.

3 Other Employments of Virtual Reality Exposure Therapy

3.1 Post-Traumatic Stress Disorder

In addition to phobia treatment described in previous sections, VRET has been widely employed to treat a very peculiar anxiety disorder, Post-Traumatic Stress Disorder (PTSD).

PTSD is a serious psychological condition, often associated with significant morbidity, disability and life functions deterioration, which can occur after exposure to a traumatic event [123]. CBT techniques employed in PTSD treatment comprise: psychoeducation, stress management skills training, cognitive therapy and, fundamentally, exposure therapy [124]. For obvious reasons, it is difficult to expose PTSD patients to a traumatic situation in-vivo, so until VRET introduction, exposure has been mainly imaginal.

Wiederhold and Wiederhold published in 2008 [125] an exhaustive review of literature on VR employment in the treatment of PTSD and in Stress Inoculation Training. Here we briefly glance through the works appeared in the last years to describe the employment of this technique on various populations of patients suffering from PTSD.

There are populations at great risk of experiencing traumatic events and develop PTSD, such as civilians living in war theatre and military personnel. Many combat-related experiences can be outside the range of what is considered normal human experience, and then can lead to PTSD, such as witnessing the death of a companion, being attacked and/or wounded, witnessing the death or wounding of civilians. Interestingly, PTSD seems to be more severe and resistant when the critical event is caused by human intervention, such as warfare [126]. In recent years, many governments put great effort in coping with this kind of war consequences.

VRET emerged a few years ago as a new exposure therapy medium for veterans suffering from PTSD. Rothbaum and colleagues [127] were the first to report a case study on a former Vietnam war helicopter pilot suffering from PTSD. The patient was immersed in two VEs, a virtual jungle clearing and a virtual helicopter, both including combat sounds, during fourteen treatment sessions. The results were encouraging, indicating that PTSD scores and other relevant measures taken into account (Clinician-administered PTSD Scale [128]; Impact of Events Scale [129]; Beck Depression Inventory [88]; State-Trait Anger Expression Inventory, [130]) decreased following treatment, even if exposure alone was not resolving, as these patients need a comprehensive treatment in which exposure is one of the components. In a subsequent study, these two VEs were employed in eight to sixteen sessions to treat a group of ten Vietnam war veterans [131]. VRET led to significant reduction in PTSD symptoms and other relevant measures (Clinician-administered PTSD Scale [128]; Impact of Events Scale [129]; Beck Depression Inventory [88]) after treatment and, consistently with other findings on exposure treatment, several measures continued to improve after the end of the treatment as assessed at three and six-month follow-up. In another case study [132], the patient reported a post-treatment reduction of PTSD symptoms, again maintained at three and six-month follow-up. Finally, Ready, Pollack, Rothbaum and Alarcon [133], carried out a study on twenty-one Vietnam veterans suffering from PTSD. Despite the fact that two patients experienced a transitory worsening of symptoms during treatment, after VRET all patients showed a decrease in PTSD symptoms severity, and results were maintained at three and six-month follow-up.

Several VRET protocols have been designed in recent years to address treatment of war veterans suffering from PTSD, taking care of the differences in time, place, climate, etc. of each war theatre. Gamito, Pacheco, Ribeiro, Pablo and Saraiva [134] proposed an immersive VR system to treat veterans from ex Portuguese colonial wars in Africa comprising four scenarios: mine deflagration, ambush, a combination of the two, facing companion's death and/or injury and waiting for casualties evacuation. In a pre-trial case study [135], the patient showed a decrease in physiological activation from the first to the seventh session, but it was not possible to assess PTSD symptoms after treatment due to patient's drop out. In the recently published preliminary results of a controlled study [136], the four patients did not show significant improvements at mid-treatment, even if descriptive analysis suggests a reduction is symptomatology (Impact of Events Scale [129]; Symptom Check-List 90 [137]).

Recently, attention has been drawn by the increasing number of military personnel returning from current war theatres (i.e. Iraq and Afghanistan) suffering from combat-related PTSD. Reger and Gahm [138] published a case study on a thirty-year old infantryman, suffering from PTSD, who underwent six sessions of VRET. The immersive VE employed was a convoy scenario in which events like explosions, firearm shots, etc were guided by the therapist. After treatment the patient reported important improvements at both outcome measures (PTSD Checklist–Military Version [139]; Behavior and Symptom Identification Scale-24 [140]), and subjective reports of improvements in several aspects of his life. The VE employed in this study, together with an middle-east urban VE, were evaluated by ninety-three PTSD-free soldiers returning from Iraq. Eighty-six percent of participants rated convoy VE realism adequate to excellent, and 82% of participants rated the urban VE the same [141].

Rizzo and colleagues developed an application, *Virtual Iraq*, consisting of various virtual scenarios designed to provide PTSD-relevant cues, with additional auditory, vibrotactile and olfactory stimulation, to be delivered through HMD. Results from case studies [142], [143], [144] were encouraging, and results from a clinical trial

[145], [146] showed that 80% of patients who completed the ten-session VRET treatment experienced significant reductions in PTSD, anxiety and depression symptoms (PTSD Checklist-Military Version [147]; Beck Anxiety Inventory [148]; Patient Health Questionnaire-Depression [149]), maintained after three months. Patients also reported perceived improvements in their everyday life. Moreover, a preliminary controlled trial [146] indicated that both VRET group (N=13) and CBT group (N=7) reached a decrease in symptoms, but 62% of VRET participants reached clinically significant amelioration, while only 28% of CBT participants did so. Authors also report a current work on a *Virtual Afghanistan* scenario with a consistent mountainous scenery and building architecture, addressing military personnel returning from Afghanistan war theatre.

Besides military personnel, another population prone to develop PTSD is civilian population suffering terrorist attacks, as in 9/11/2001 attack to the World Trade Center in New York.

Difede and Hoffman [150] treated a twenty-six year old survivor of this attack who developed acute PTSD. They designed an immersive VR scenario reproducing the main features of the attack, to be shown to the patient in a graded exposure VRET. Six sessions were successful in reducing acute PTSD symptoms (Beck Depression Inventory [88]; Post-traumatic Diagnostic Scale [151]). After treatment the patient was able to remember with greater detail the critical event, without experiencing the same degree of terror or other symptoms. In a subsequent controlled study on World Trade Center attack survivors [152], [153], conducted with similar equipment, VRET group (N=13) showed significantly greater post-treatment decrease in PTSD symptoms (Clinician-administered PTSD Scale [128]) compared to the waiting list control group (N=8).

Josman and colleagues [154] developed a VE to treat civil Israel population who survived terrorist suicide bombing attacks on buses, called Bus World. The immersive VR system comprises four levels of increasing seriousness, from simply standing on the sidewalk to assisting to a bus bombing with people screaming and crying, and police sirens. This VR system has been tested with thirty healthy volunteers [155]. Results showed that, as the level of VR exposure increased, participants showed parallel distress increments, as assessed by Subjective Units of Discomfort [29]; this suggests that BusWorld may prove to be a valuable medium to provide graded exposure for bus bombings survivors.

Motorvehicle accident (MVA) survivors often incur in PTSD. Given the substantial number of individuals who are involved in an MVA each year, several hundred thousand individuals a year are subject to develop PTSD.

Several studies assessed the efficacy of VRET in reducing PTSD symptoms related to MVA [156], [157]. Walshe, Lewis, O'Sullivan and Kim [158] tested the efficacy of a driving simulation protocol in eliciting a satisfactory degree of sense of presence in eleven participants suffering from fear of driving following MVA, seven of which suffering from PTSD, in order to allow the treatment to take place. The simulation comprised the reproduction of a car front seat with wheel and pedals, and a large screen on which the driving environments were projected. Ten out of eleven participants gave a subjective (verbal report and Subjective Unit of Discomfort) and/or physiological report of feeling the simulation to be "real".

More recently, Beck, Palyo, Winer, Schwagle and Ang [159] designed a VR system addressed to MVA-related PTSD sufferers. Their VE consisted of several adaptable and customizable driving scenarios where the therapist could manipulate variables such as the amount of traffic, time of day, weather conditions and particular events such as tailgating. The scenarios were displayed on a large screen and viewed with stereoscopic glasses for a three-dimensional perception. Results from six patients undergoing ten VRET sessions indicated significant PTSD symptoms decrease in re-experiencing, avoidance, and emotional numbing (Clinician Administered PTSD Scale [128]), even if measures of anxiety and depression (Beck Depression Inventory [115]; Beck Anxiety Inventory [148]) did not show significant improvements.

Saraiva and colleagues [160] designed a VE to be projected on a large screen, consisting of a four-lane highway in which traffic intensity, field of view and sound cues could be manipulated by therapist. In the case study reported [160], [161], [162], patient's anxiety and depression scores (Hospital Anxiety and Depression Scale [80]) decreased from pre- to post-treatment assessment, after twelve VRET sessions, and the same pattern was observed for PTSD-related symptoms (Impact of Events Scale [129]), even if the patient remained in the severe PTSD range. Moreover, decreased physiological activation from first to last treatment session was observed, and the patient nonverbal behavior showed clear reduction in agitation and rejection behavior as the sessions progressed. Most important, after treatment the patient was able to drive again.

In general, employment of VR in the treatment of PTSD is relatively new, and, although promising, further investigation is needed to assess how it can be used to reach the maximum effectiveness. It has to be taken into account, however, that PTSD needs a complex treatment, in which exposure is one of the components. This observation accounts for the partial improvement obtained in studies mainly focused on exposure.

3.2 Stress Inoculation Training

Stress Inoculation Training (SIT) is an intervention aiming at preventing the impairing effects of possible psychological stressors in healthy individuals, and thus avoiding the aftermaths of excessive stress exposure, such as eventual development of PTSD. This cognitive-behavioral preventive approach has been employed with several populations particularly prone to experience stressful events, such as military population. SIT goal is to enhance and empower an individual's repertoire of coping skills, in order to provide a sort of "immunization" from negative reaction to stress [163]. This technique is based on the assumption that gradual and repeated stress exposure is able to desensitize individuals to stimuli that may impact on performance and lead to psychological trauma [164]. So, during SIT, first the individual learns a new coping skill, and then needs to practice it; VR is a suitable tool for practice, as it is possible to manipulate the stressors in a given scenario until the individual habituates to them [165].

Tarnanas and Manos [166] trained fifty children to a procedure for evacuating school in case of emergency, by means of VR-SIT. For half of the sample the VE was populated by unfamiliar avatars, and for the other half by avatars resembling classmates. Results showed that familiar avatars were more effective for children in eliciting coping skills. The same authors [167] trained a larger group of children (N=209), some of which had already witnessed an earthquake, to coping skills to be employed during an earthquake, in an immersive VE representing a classroom with unfamiliar or familiar avatars. Results showed that training was effective in enhancing children's skills as assessed pre- and post-training with an ad hoc questionnaire. In particular, employment of familiar avatars produced better results than unfamiliar ones.

Tichon, Wallis and Mildred [168] tested the degree of sense of presence felt by twelve train drivers in a train-driving simulator designed for SIT to critical situations. Self-reported measures of presence (Presence Questionnaire [169]; Igroup Presence Questionnaire [170]) were collected covering several aspects of the VE concurring in determining sense of presence. Results were overall positive, but they also highlighted some features of the environment (e.g. color, brightness, sound, lack of physical feedback) that can be improved envisioning a future SIT protocol using this simulator.

Stetz and colleagues [165] conducted a study on twenty-five participants to evaluate the role of VR-SIT in battlefield medical training for soldiers. Participants underwent either VR sessions, coping training sessions, or a combination of both. When immersed in VR, participants could act in immersive virtual Iraqi or Afghan combat scenarios performing several tasks. Preliminary results indicated that participants who only were immersed in VR experienced a higher level of post-training anxiety and dysphoria (Multiple Affect Adjective Check List-Revised [171]) compared to the other conditions, while those receiving coping training in VR showed lower stress level, even though exposed to the same VE. Subsequent study completion [172] saw sixty-three participants from combat medical class undergoing the study protocol. Part of the sample had been previously deployed in the field and part not. Results supported the usefulness of VR-SIT in military personnel training. VR-only group showed higher hostility levels compared to the other groups and VR plus coping training group showed higher sensation-seeking levels compared to the other groups. Participants who had been previously deployed in the field showed higher levels of anxiety and dysphoria compared to those who had not been deployed, both in the VR-only and in the coping training-only condition, while in the VR plus coping training condition dysphoria was lower for those who had been previously deployed. Thus, VR-SIT combined with coping training could be particularly useful for military personnel who had already experienced combat.

4 Other Virtual Reality-Based Exposure Techniques

4.1 Virtual Reality Cue Exposure Treatment for Substance Abuse

Cue exposure is a treatment in which a substance (drug, alcohol, nicotine, etc.) addict is repeatedly exposed to substance-related stimuli (cues) associated with his/her addictive behavior. Reaction (subjective, physiological, and behavioral) to these cues is generally considered a conditioned response, influencing the likelihood of substance self-administration. Repeated exposure to these cues not followed by substance-administration should promote the extinction of the conditioned response, thus removing the primary motivation to continue using drugs, and lowering relapse probability [173], [174], [175].

Recently VR has been employed to provide safe Cue Exposure Therapy (VR CET) to people suffering from various forms of addiction.

Several studies addressed the effectiveness of immersive VEs in eliciting substance craving in addicted people.

Kuntze and colleagues [176] explored the application of VR CET to heroin addiction. They designed an immersive VR bar to present objects related to heroin injection, such as heroin powder, swab, syringe, needle, and used material with and without blood. Results of this pilot study indicated that VR was effective in eliciting physiological activation and subjective craving symptoms in five heroin addicts.

Saladin, Brady, Graap, and Rothbaum [177] developed an immersive virtual "crack house" with crack cocaine related cues, and evaluated its effectiveness in inducing substance craving in eleven crack cocaine addicts. Both subjective ratings of craving on a 0 to 100 scale and physiological measurements suggested a more intense substance craving after "crack house" VR immersion than after immersion in a neutral VE.

Lee and colleagues [178] designed a VE to induce desire for nicotine, based on sixty-four smokers' responses to a nicotine-craving questionnaire. The VE consisted of a virtual bar constituting the craving environment, craving objects (alcoholic drink, pack of cigarettes, lighter, ashtray, glass of beer) and smoking avatars displayed to participants through an HMD. Twenty-two smokers took part to the research. Results indicated that this VR system achieved better results at eliciting nicotine craving, as measured by a 0 to 100 visual-analog scale, than photographs (classical exposure technique).

Several studies [179], [180], [181], [182], [183], [184] compared VR exposure to smoke-relevant cues and to neutral cues, all coming to the conclusion that subjective craving for nicotine was greater after smoke-relevant than neutral cues, thus indicating VR as a reliable medium for CET delivery.

More recent studies focused on the treatment efficacy of VR-based CET. Moon and Lee [185], checked if six sessions of VR CET were able to decrease nicotine craving in eight smokers. The same VE developed for a previous study [178] was employed. Eight late adolescent smokers took part in the research. Besides self-report measures of craving, functional magnetic resonance imaging (fMRI) was employed to assess any modification in craving-related brain region activation following six sessions of VR CET. After treatment, cerebral responses to smoking cues were modified probably as a consequence of reduction in the urge to smoke, despite a lack of modification in self-reported craving.

Another recent study [186], assessed ninety-one smokers assigned to a VR CET in which they had to either crush a virtual cigarette or grasp a virtual ball (control condition) in an immersive VE. Four sessions of virtual cigarettes crushing led to a significantly better improvement in addiction, as measured by Fagerström test for nicotine dependence revised [187], and better abstinence and drop-out rates, compared to control condition.

CET has been widely used to treat alcohol addiction, so, to explore the possible application of VR, Cho and colleagues [188] developed four VEs to assess alcohol craving in different situations: with/without alcohol available and with/without social pressure to engage in drinking behavior. Results on ten healthy participants indicated that VR was able to induce alcohol craving, and that for this purpose, social pressure was more important than alcohol availability.

Bordnick and colleagues [189] designed an immersive VR system constituted of six environments varying in alcohol cues presence and social interaction, encompassing also olfactory cues. Alcohol-related cues presented in this VR system proved effective in eliciting significant increases of subjective alcohol craving compared to neutral cues in non-treatment-seeking drinkers (N=40).

A study on alcohol addiction treatment [190], [191] assessed the effect of eight VR CET sessions in eight drinkers. Cues able to elicit alcohol craving were selected with a preliminary survey. Glass, bottle, food, and a bar resulted as the most drinking behavior-inducing stimuli. Using these materials, authors created a virtual Japanese-style pub and a virtual western bar to be projected on a wide screen. Results highlighted a reduction in self-reported cue-elicited craving at the post-treatment assessment.

Finally, Lee and colleagues [192] compared twenty alcohol addicts exposed to ten sessions of VR CET with eighteen addicts undergoing ten sessions of CBT and fifteen healthy participants undergoing VR CET. VR CET was more effective than CBT in decreasing alcohol craving in patients, as assessed with a ten-point visual-analog scale. Moreover, while patients undergoing CBT showed no electroencephalographic change after treatment, VR CET patients reported an increase in frontal alpha activity, suggesting a decrease in arousal. As this effect was not evident after the first five sessions, it seems that a certain number of sessions are needed to produce the desired change in these patients. In addition, the increase in alcohol craving elicited by cues in VR CET was higher in patients with alcohol dependence than in healthy people, thus indicating that this tool is able to discriminate between high and low-risk individuals.

4.2 Virtual Reality in Eating Disorders Treatment

In recent years, VR has been employed in the treatment of different kinds of eating disorder. Riva, Bacchetta, Baruffi, Rinaldi and Molinari [193] treated a twenty-two year old woman suffering from anorexia nervosa by means of Experiential-Cognitive Therapy (ECT), a relatively short-term approach, based on individual discovery (see [194]). Within this approach, a VE for Body Image Modification was deployed. It was composed by different zones, displayed through HMD and employed in different sessions. The first session assessed abnormal eating behavior. The next four sessions allowed assessment and consequent modification of anxiety symptoms related to food exposure and of patient's body experience. Patient's level of dissatisfaction was reduced as a consequence of modification in her bodily representation; reduction in the avoidance behaviors and in grooming associated with her negative body image was also reported. Moreover, at the end of the treatment, the patient appeared very motivated to continue individual psychotherapy and to apply the acquired skills.

Preliminary clinical trial results [195] on a group of fifty-seven female patients suffering from obesity, binge eating disorder, and eating disorders not otherwise specified showed that employment of VE for Body Image Modification led to an improvement in patients' body satisfaction.

An upgraded system, Virtual Reality for Eating Disorders Modification [196] was employed to support an in-patient weight-reduction program in obesity. The immersive VE was composed by seven zones, called "3D Healing Experiences". Similar to the previous version, the first zone was employed to assess abnormal eating behavior, and the following to assess and modify anxiety symptoms related to food exposure and patient's body experience. This treatment proved more effective, in a group of obese women (N=14), than the traditional low-calorie diet plus cognitive-behavioral nutritional groups (N=14), in improving patients' psychological state and reducing dysfunctional eating behavior (Body Satisfaction Scale [197]; Dieter's Inventory of Eating Temptations [198]; State-Trait Anxiety Inventory [65]; Assertion Inventory [199]; Weight Efficacy Life-Style Questionnaire [200]). Moreover, an improvement in self-efficacy and an increased motivation for change was observed after treatment.

In a subsequent study [201] obese patients were divided in ECT group (N=57), CBT group (N=54), nutritional group (N=52) and waiting list (N=53). Irrespective of the approach (ECT, CBT or nutritional group), patients undergoing intensive treatment showed a significant weight decrease and psychological state improvement (same self-reported measures as in the previous study were employed, plus Body Image Avoidance Questionnaire [202] and Contour Drawing Rating Scale [203]). Even if group effect for weight loss was not significant at six-month follow-up, only the nutritional group showed higher weight at follow-up than at post-treatment, while the ECT group was the best at losing and maintaining weight. Six months after treatment completion, only the ECT group showed a significantly improved body image satisfaction and self-efficacy, and consequently, a reduction in avoidance and an increase in adaptive behaviors.

Similar results (improved body satisfaction, anxiety level and self-efficacy, higher motivation for change) were obtained in a group of patients suffering from binge eating disorder after ECT treatment (N=10), compared to a group of binge-eaters (N=10) undergoing traditional cognitive-behavioral psychonutritional group therapy [204]; unfortunately, no significant differences were found in the occurrence of binge eating behavior. In a subsequent study on binge-eating disorder [205] involving a six-month follow-up assessment after treatment, results showed that 77% of the ECT group quit binging after treatment, whereas only 56% of the participants receiving CBT plus nutritional group and 22% of the participants undergoing only nutritional group did so. ECT also achieved a better result than CBT in improving the psychological state of the patients, with particular regard to body satisfaction and resistance to social pressure, but it did not prove more effective in promoting weight loss.

Perpiñá and colleagues [206], [207] developed an immersive VR system with a 3D figure whose body could be manipulated by patients (i.e. enlarged or thinned); the body was placed in several settings such as a kitchen, an exhibit room, in front of mirrors, etc. Thirteen outpatients, suffering from anorexia nervosa or bulimia nervosa were divided into two treatment conditions: CBT plus VR, or CBT plus relaxation. Results showed that all patients improved significantly after treatment, but CBT plus VR group showed a significantly greater improvement in psychopathology-related indices. This group also showed greater satisfaction with their body, a decrease in body-related negative thoughts and attitudes, a decrease in fear of weighing themselves and of reaching a healthy weight. As found in other studies, treatment group including VR registered fewer drop-outs, indicating an enhanced treatment acceptance and motivation. Twelve-month follow-up assessment showed that achievements had further improved. The same authors carried out a pilot study with a small sample

(N=9) of patients suffering from various eating disorders to test the efficacy of a VR-based system in assessing and treating binge-eating episodes. The VE consisted of a kitchen showing different foods considered 'forbidden' or 'safe'. The patient was required to 'eat' one forbidden food, and subsequently to rate her anxiety, urge to binge, guilt and how she judged the reality of the experience. Then, the patient repeated the experience, with the augmentation of olfactory stimulation, and rated herself again. Results indicated that all patients reported high levels of reality of the experience, and so the VE triggered typical reactions of binge-eating episodes, since patients reported moderate to extreme levels of anxiety, urge to overeat, and guilt. In addition, the odor of food produced an increase in all measures, suggesting that augmented reality helped participants to become deeply immersed in VR.

Ferrer-Garcia and Gutierrez-Maldonado [208], [209] described the emotional responses of thirty female eating disordered patients to six immersive VEs: a high-calorie food kitchen, a low-calorie food kitchen, a high-calorie food restaurant, a low-calorie food restaurant, a swimming-pool, and a neutral situation depicting a living-room. After exposure to each environment self-reported measures of state anxiety and depression (State Anxiety Inventory [65]; Barcelona Depression Questionnaire [210]) were collected. VEs in which patients were confronted with high-calorie food produced significant increases in anxiety and depressed mood compared with the neutral situation. Among social situations, only the swimming-pool significantly increased anxiety level, due to the subjective importance of patients' body image and of others' evaluation, as patients' avatars wore bathing-suits and were surrounded by attractive young people in their bathing-suits. On the other hand, the presence or absence of people had no significant effect in the restaurant situation, as food type was the only variable producing significant effects for both anxiety and depression.

5 Virtual Reality Interventions for Pain Control

Beside VR employment in CBT for various psychological disorders described above, this novel technique has been employed to induce a form of additional analgesia to support or substitute pharmacological intervention, in people undergoing painful medical procedures.

Traditional cognitive-behavioral techniques have already been used as an additional intervention to support analgesic therapy for extremely painful conditions such as, for example, burn wound. Such interventions are mainly addressed to the cognitive component of pain; specifically, attention, beliefs about pain, expectations, and attributions are thought to modulate nociceptive signals [211]. Typical cognitive-behavioral interventions for acute pain include for example hypnosis, mental imagery, mental arithmetic, listening to music, watching a video (see [212] for an overview).

Hoffmann and colleagues [212] proposed immersive VR as a means for distracting patients from painful medical procedures, based on the assumption that, as humans have a limited attention, and pain requires part of its amount, involvement in complex stimulation leaves less resources available to nociceptive input, and patients experience less pain.

5.1 Virtual Reality Analgesia for Pediatric Patients

Children undergoing painful medical procedures often receive inadequate pain treatment [213], so applications of VR analgesia to pediatric medicine has drawn particular attention. Hoffmann and colleagues [212] presented two case studies on adolescent burn wound patients undergoing wound medication; pain perceived during the procedure when immersed in VR was compared to that perceived while playing a video game. VE employed was SpiderWorld, described above [27]. Pain-related variables were rated on 10cm visual-analog scales. The first patient rated pain as much reduced when engaged in VR than when engaged in the video game, especially with regard to sensory pain, affective pain and anxiety, and reported time spent thinking about his pain during the procedure was largely reduced. Anyway, it has been observed that the patient's impossibility to physically see the wound while in VR may have played a role in pain reduction. The second patient showed a greater decrease in perceived pain during VR compared to the video game. Since this patient could not see the wound in either condition, this result ruled out the confound role of wound visibility among conditions. Thus, according to authors, the only effective component was the sense of presence into VE, which was rated by both patients much higher for VR than for videogames.

More recently, controlled studies on burn wound pain control in children and adolescents have been published. Das, Grimmer, Sparnon, McRae and Thomas [214] tested, with a within-subjects design, nine children (five to eighteen years old) undergoing a VR immersive game during half of the wound dressing procedure. They found that combination of VR and analgesics was more effective than analgesics alone in reducing perceived pain, as rated on a 10-point Faces scale [215]. When the same pain level was reported in both treatment condition, the children's behavior was rated by caregivers as calmer during VR immersion.

Chan and colleagues [216], in a within subject study on eight children (mean age six and half years), did not find any statistical difference in the pain, rated on a 0 to 100 scale, in the VR game condition compared to standard procedure, but, as in the previously reported study, the behavior and compliance observed by the nurses were better in the VR condition.

In a recent study, Mott and colleagues [217] studied the employment of an augmented reality system to support analgesia in children burn wound pain control. Forty-two children (three to fourteen years old) were randomly assigned to an augmented reality treatment group (N=20) and a control (basic cognitive therapy) group (N=22). Augmented reality system consisted in a series of plastic figures which could be inserted in a camera unit in order to visualize and manipulate the corresponding character on a screen. Pre-, and post- pain scores plus scores taken at ten-minute intervals during procedure were collected on a visual-analog scale, and physiological measures. Results showed significantly lower pain scores in the augmented reality group compared to control group, but physiological indices showed significant changes over time within but not between the two study groups.

Burn wound care has not been the only condition taken into account for VR pain control with pediatric patients. Gershon and colleagues published a case study [218] and a controlled study [219] assessing the use of VR as a distractor in pediatric cancer patients. The case study (an eight year old patient) compared a no distraction (A), a non-VR computer distraction (B), and head-set displayed VR distraction (C) in an A-B-C-A design. VR employment led to lower perceived pain and anxiety, as reported on a 10 cm visual-analog scale, and reduced physiological and behavioral indices of distress compared to baseline, even if anxiety reported during the VR condition was higher than during non-VR condition. This finding could be due to the fact that when wearing the head set the patient could not see the nurse operating on him, condition that would increase his anxiety. However, VR condition produced the lower pain rating. Remarkably, this benefit was maintained after the VR session, suggesting a reduction in the conditioned anxiety to the procedure. The controlled study [219] was carried out on children aged seven to nineteen, receiving subcutaneous venous port device access. Twenty-two children received VR distraction, twenty-two received no distraction, and fifteen received a non-VR distraction. Both VR and non-VR distraction were provided by a game in which the patient had to play the role of a gorilla interacting with other gorillas. In VR condition, the game was displayed by HMD, in non-VR condition by a simple monitor. VR distraction led to reduced physiological arousal and behavioral indices of distress (CHEOPS [220]), as well as lower nurse's ratings of pain, but no difference in the pain rating between VR and non-VR distraction was observed, probably due to the wide age range of the participants and to the relative mildness of the procedure.

Steele and colleagues [221] tested the effectiveness of VR analgesia on a sixteen year old patient with cerebral palsy, undergoing a post-surgery physiotherapy program. Six physiotherapy sessions were taken into account. For each session, half time was spent in immersive VR, and the other half without VR, in randomized order, while pharmacologic analgesics were administered in both conditions. Patient's pain ratings (Faces scale [215]) in the VR condition resulted 41.2% lower than in the control condition.

Gold, Kim, Kant, Joseph and Rizzo [222] employed VR as a pain distraction during intravenous (IV) placement in children. Twenty children (seven-seventeen years old) were randomly assigned to either an immersive VR game distraction (racing down a hill on a skateboard) or topical anesthetic application with no distraction. Children receiving only topical anesthetic experienced a significant increase in affective pain ratings (Faces pain scale-revised [223]) after IV placement, compared to baseline, when no significant change was detected in the VR condition in this measure.

5.2 Virtual Reality Analgesia for Adult Patients

While mitigating pain in children has been obviously a main interest in research on pain control, VR distraction systems have also been applied to adults in several medical conditions. Again, burn wound have been of primary interest. Hoffman, Patterson and Carrougher [224] published the first study to assess effectiveness of immersive VR in distracting twelve burn wound adult patients (aged nineteen to forty-seven years) undergoing physical therapy. In this within subject study, patients spent, during procedure, three minutes in VR and three minutes with no distraction, in randomized order. VR analgesia was proved effective by patients' report of significantly lower pain, as rated on visual-analog scales, when immersed in VR.

Since the first studies on VR analgesia were conducted mainly on a single trial, Hoffman and colleagues tested the efficacy of multiple-treatment VR analgesia in order to assess possible habituation effects. A case study [225] was carried out on a thirty-two year old male patient with large burns, undergoing physical therapy for various amounts of time across five days. The patient spent half of the therapy time in VR and half without VR, in randomized order. The patient showed a large reduction in several pain scores rated on visual-analog scales during treatment while immersed in VR compared to standard treatment. VR efficacy in inducing pain reduction, as well as the patient's sense of presence in the virtual world as rated on other visual-analog scales, did not show a decrease with repetitions and increased durations, indicating that VR analgesia is suitable to be used repeatedly for extended time periods.

In a controlled study [226] seven burn wound patients aged nine to thirty–two years undergoing at least three physical therapy sessions were tested. Sessions time was equally divided between immersive VR and no-distraction control condition. Pain ratings on visual-analog scales resulted statistically lower during immersion in VR, and, again, this effect did not decrease with repeated VR immersions.

As burn wounds are often treated in a hydrotank, especially in the early, more painful, stage of recovery, the same research group built and tested a custom VR helmet to be used in the hydrotank. This system proved effective, both on a clinical and a technical perspective in a case study [227] and in a controlled study [228].

Van Twillert, Bremer and Faber [229] compared immersive VR game to standard intervention and other distraction methods (chosen by individual patients among television, music, conversation, etc.) during wound care in nineteen burn wound pediatric and adult patients (aged eight to sixty-five years). Both VR and television engagement during the procedure led to significant reductions in pain, rated on visual-analog scales. Sixteen participants reported to some extent a reduction in perceived pain during VR immersion. Sixty-eight percent of the participants reported a clinically relevant (i.e., 33% or greater) pain reduction, while only 50% of the participants reported the same during TV distraction. It is noteworthy that the three adult participants who reported an increase of pain during VR immersion also reported problems related to control of the situation during the procedure, as the helmet impeded their view of the wound care, inducing greater anxiety (State-Trait Anxiety Inventory-Y [106]) and pain scores. This result could be attributed to individual coping style or personality traits that could influence success of VR intervention [230].

To assess individual factors implied in efficacy of VR analgesia, Sharar and colleagues [231] tested eighty-eight patients, ranging from six to sixty-five years of age, undergoing post-burn physical therapy with the aid of standard analgesic only and standard analgesic combined with VR immersion. Patients reported a significant reduction in several indices of pain, rated on visual-analog scales, during VR immersion. Most important, this effect was present regardless of patients' age, sex, ethnicity, burn size and duration of the therapy session, indicating a wide generalizability of VR analgesia usefulness.

Finally, Maani and colleagues [232] published outcomes from two cases of combat-related burn injury where part of the wound care was administered during VR immersion and part not, in order to compare conditions. The particular system used in this study was constituted of an articulated robotic-like arm, on a VR goggle system. Though the first patient reported less pain during VR immersion, he reported no reduction in worst pain rating. The second patient reported a generally reduced pain during procedure when immersed in VR, and also a reduction in the worst perceived pain rating.

As for children treatment, VR analgesia for adult patients has not been limited to burn wound care. Hoffman and colleagues [233] tested whether immersive VR can be useful to reduce dental pain in two patients (fifty-one and fifty-six years old) with adult periodontitis. In this within-subjects design, patients received immersive VR distraction, movie distraction, and no-distraction (control condition) during nonsurgical dental treatment. The first patient's mean pain ratings, on a 0 to 100 scale, were in the severe range during the movie, and when he was not receiving any kind of distraction, but in the mild pain range when immersed in VR. The second patient reported a progessive decrease of pain from moderate pain with no distraction, to mild pain during the movie, to reach essentially no pain in VR. A more recent research [234] on thirty-eight patients undergoing a painful dental procedure, with a similar within subject procedure, showed that during VR immersion patients' pain ratings were lower than during the movie and the no-distraction condition.

One study investigated the effects of VR distraction on chemotherapy-related symptom distress levels in sixteen middle-aged or older women suffering from breast cancer [235]. A within subject design showed that immersive VR intervention reduced treatment-related anxiety [106], but no reduction was achieved in symptom distress and fatigue levels (Symptom Distress Scale [236], Revised Piper Fatigue Scale [237]) probably because of the novelty of the intervention and the low baseline of symptom distress.

VR analgesia has been applied also to phantom limb pain [238], [239]. In this research, authors used immersive VR not to distract patients from their pain, but to "transpose the movements made by an amputee's remaining anatomical limb into movements of a virtual limb in the phenomenal space occupied by their phantom limb" ([238], p. 1466). Three participants (sixty-three, sixty and sixty-five years old) who experienced phantom limb pain underwent two to five immersive VR sessions. All participants reported somehow a transferal of sensations to the phantom limb and a pain reduction, but it was impossible to rule out that this analgesic effect was attributable to simple distraction due to the lack of a control group.

Another study probed the usefulness of VR distraction during a painful procedure such as transurethral microwave thermotherapy [240], used for treatment of benign prostatic hypertrophy. In this case report, a sixty-seven years old patient rated his pain and anxiety during treatment without distraction and when playing an immersive VR game. When immersed in VR, the patient reported decreased pain and anxiety (Pain Questionnaire [241]), and, moreover, described the treatment as "extremely fun". Furthermore, as a decrease in prostatic blood flow was observed during VR immersion, it is suggested that VR distraction actually induced physiological changes in the patient.

Finally, Hoffman and colleagues [242] conducted a case study on a thirty-two year old male patient undergoing passive range of motion exercises after a road accident. During two sessions, the patient spent half-time (ten minutes) immersed in VR, and the other half without distraction. Pain self ratings, obtained on 0 to 10 graphic rating scales showed a reduction in pain severity during VR immersion in all the pain components taken into account, namely, cognitive, affective and sensory.

5.3 Hypnosis Induction by Means of Virtual Reality

A peculiar application of VR is hypnosis induction. Since patients can comfortably remain immersed in VR only for limited amounts of time, VR analgesia can be considered more suitable to relief procedural than chronic pain. VR-induced hypnosis can be instead a more useful tool to treat chronic pain.

Evidence has been reported on analgesic effects of hypnosis for clinical chronic and acute pain, as well as for experimentally induced pain [243], [244]. According to Patterson, Tininenko, Schmidt and Sharar [245], clinical hypnosis could reach far greater number of patients if interventions did not require the actual presence of a trained hypnotist. The employment of automated stimuli to guide patient's attention might be a way to allow a less effortful induction than self-generating the scenarios and imagining the objects cued by the hypnotist, which require considerable concentration. Patterson, Tininenko, Schmidt and Sharar [245] reported a case study on a thirty-seven year old burn wound patient, undergoing computerized hypnosis using immersive VR. The rationale was that VR might increase patient's disposition toward hypnotic suggestion for relaxation and analgesia. VR conveyed the stimuli that the patient usually has to imagine guided by the therapist. In this case the patient went into VR prior but not during wound care. The patient was not allowed to interact with the VE as in the previously described studies, but he could only look around while listening to audiotaped hypnosis instructions. Two hours after VR hypnosis, the patient underwent a one hour and half long wound care session. Afterwards, the patient filled in questionnaires to rate pain and anxiety levels (Graphic Rating Scales, [246], Burn Specific Pain Anxiety Scale [247]) during the wound care session. In a subsequent session, patient only listened to the audiotaped instruction, without visual cues provided by VR, and after one hour he underwent wound care and filled in the pain and anxiety questionnaires. After the VR hypnosis intervention, patient indicated that the worst pain perceived was 40% lower, average pain levels was reduced by 60% and anxiety was 50% lower than pre-intervention. Additional reduction in pain and anxiety was observed after the subsequent audiotape-only induction, but pain ratings and medication usage returned almost to baseline level on the third day, when he did not receive hypnotic induction. According to Authors, this result is inconsistent with previous findings suggesting that the analgesic effects of one or two days of hypnosis continue to be effective for subsequent medical procedures [248], [249], [250], and seems due to peculiar patient's condition and mental status.

In a recent case report, Oneal, Patterson, Soltani, Teeley, and Jenses [251] tested the employment of VR hypnosis to treat chronic neuropathic pain in a thirty-six year old patient, using material and procedure very similar to those employed in the previous study. This patient underwent thirty-three VR hypnosis sessions over six months. Though VR hypnosis analgesia did not produce lasting decreases in pain perception, an immediate 36% reduction in average pain intensity rating and a 33% reduction in average pain unpleasantness rating on a 0 to 10 scale were obtained post-treatment. When compared to traditional hypnosis experienced by the patient previously of VR hypnosis treatment, VR hypnosis showed a greater pain intensity and unpleasantness reduction. Moreover, the patient was free from pain for an average of 3.86 hours, and experienced a reduction of pain for an average of 12.21 hours after VR hypnosis sessions. These results suggest that hypnosis can provide a valuable mean for managing chronic pain daily, similar to medications use, but without the negative side effects of medications.

To test the hypothesis that the amount of pain reduction obtained by VR post-hypnotic suggestions is modulated by hypnotizability, in contrast with VR distraction analgesia, primarily mediated by attentional mechanisms (which would not be modulated by hypnotizability), Patterson, Hoffman, Garcia-Palacios and Jensen [252] experimentally induced thermal pain in one-hundred and three student volunteers (forty men and sixty-three women, mean age nineteen years). After assessment of baseline thermal pain, participants were randomly assigned to the four experimental conditions: No post-hypnotic suggestions/ No VR distraction (control), VR distraction only, post-hypnotic suggestions only, post-hypnotic suggestions and VR distraction. Hypnotizability was assessed (Stanford Hypnotic Clinical Scale [253]) by a researcher blind to participants' condition. Results show that only posthypnotic analgesia was moderated by hypnotizability, while it had no effect on VR distraction analgesia. This result is consistent with the hypothesis that the two kinds of analgesia work via different mechanisms.

5.4 Studies on Virtual Reality Analgesia Mechanisms

To further investigate the mechanisms upon which VR analgesia works, and to assess factors implied in its success, several studies have been carried out not on patients but on healthy participants with experimentally induced pain. Hoffman, Garcia-Palacios, Kapa, Beecher and Sharar [254] induced ischemic arm pain in fourteen female and eight male students via a blood pressure cuff to assess gender differences in VR-induced analgesia. Pain ratings on visual-analog scales increased along time during the no distraction phase and were suddenly and significantly reduced when participants were immersed in the VE, both for women and for men. A second experiment with the same sample was then conducted to investigate the mechanism by which VR immersion works in reducing pain. The hypothesis was that, as VR immersion draws a significant amount of attention, an impaired performance on a working memory–divided attention task would be observed. Experimental task consisted in paying attention to an auditorily presented string of numbers for 2 minutes while engaged in VR, and then performing the same task with no distraction (control condition). Results showed that participants performed a significantly more accurate task in the control condition than in the VR condition. This result is consistent with the assumption that VR absorbs attentional resources and pain reduction is reached via an attentional mechanism.

Magora, Cohen, Shochina and Dayan [255] investigated if VR immersion through HMD can prolong the amount of time twenty participants (ten males, ten females, mean age thirty-two point five years) can tolerate ischemic arm pain. VR game immersion and a control condition were evaluated in a within-subject design. Time amount during which ischemic pain was tolerated was significantly longer for VR condition than for control condition. Also, immersion in a VE led to significantly lower ratings of unpleasantness and of time participants spent thinking about pain on ten-point visual-analog scales.

Hoffman and colleagues [256] assessed the neural correlates of VR analgesia with fMRI. Each of the eight male participants aged eighteen to forty-three underwent thermal pain-related brain activity assessment during immersive VR distraction and in a control condition. As expected, VR significantly reduced pain-related brain activity in all the regions of interest: the anterior cingulate cortex, primary and secondary somatosensory cortex, insula, and thalamus. Both subjective and objective measures revealed a VR-induced decrease in pain, gained via modulation of both the sensory and the emotional aspects of pain processing. In a subsequent experiment, the same research group [257] used subjective pain ratings on 0-10 graphic rating scale and fMRI to measure pain and pain-related brain activity in participants receiving opioid and/or immersive VR distraction. Thermal pain was induced in nine healthy participants (eight men and one woman) aged twenty to thirty-eight years, while exposed to four analgesia conditions in a within-subjects design: control (no analgesia), opioid administration, VR distraction, opioid plus VR distraction. Both subjective pain ratings and pain-related brain activity indicated an effect of opioids alone and VR distraction alone, but combined use of the two reduced pain ratings and pain-related brain activity more effectively than opioid alone. These data support the use of combined pharmacological and nonpharmacological interventions in analgesic therapies.

6 Conclusion

Far from being exhaustive, this chapter gathered together several evidence of the usefulness of Virtual Reality in CBT-based techniques addressing a variety of psychological and medical conditions. The emphasis has been put on the studies that tried to validate this technique through specific assessment procedures. The results is that, overall, VR-based CBT has proven effective in reducing both self-reported and physiological correlates of anxiety in various specific and social phobias, in reducing PTSD symptoms, in inducing safe cue exposure in patients suffering from various forms of substance addiction. Moreover, VR has effectively been included within eating disorder treatments and as a non-pharmacological analgesic for painful medical conditions. Taken together, these results testify the role, value and versatility of this technological tool at the service of the human well-being.

Is expensive VR equipment necessary to the success of the therapy? The answer is more articulated than a simple yes or no. On the one side, it seems that some equipment is more effective than other, and that this difference is mediated by the sense of presence experienced by the user. Hoffman and colleagues [258], [259] conducted two studies testing VR analgesia to thermal pain in healthy students induced by means of High Tech HMD vs Low Tech HMD. Participants in the High Tech group reported significantly more ‘fun’, and a significantly stronger sense of presence, compared to participants in the Low Tech group. Moreover, a significant positive correlation was observed between sense of presence ratings and amount of pain reduction, and more pain reduction was evident in the High Tech group than in the Low Tech group. Riva, Manzoni, Villani, Gaggioli, Molinari [260] compared a VR Condition with a DVD condition in a stress management protocol. They found that more present the users felt, the higher the reduction in anxiety and the increase in positive emotions. Also, Hoffman, Garcia-Palacios, Patterson, Jensen, Furness, Ammons [233] compared an immersive virtual reality depicting an icy 3D virtual canyon with a river and waterfalls, versus a movie relative to a no-distraction control. Patients had the illusion of flying through the virtual world. On a scale of 0–100 with 100=high, the patients, in a within subjects design, rated their sense of presence much higher in VR than in the movie condition (60 vs. 0, respectively), and the realism of objects higher in VR than for the movie (30 vs. 0, respectively).

On the other hand, it seems that the sense of presence experienced is not necessarily dependent on the sophistication of the equipment, nor is the success of the therapy per se. Schümie and colleagues [41], similarly to Jang and colleagues [261], found that it is possible to provide an effective VRET even without expensive equipment, as long as some basic guidelines are followed in the VE design. Expensive equipment is not necessary to induce a phobic reaction to heights. Krijn and colleagues [262] observed no differences between VRET for acrophobia administered via CAVE or HMD, and improvements remained stable up to six-month follow-up. Three rear-projected images formed the CAVE walls, while a fourth image was projected on the floor. To be immersed in the CAVE, patients wore LCD shutterglasses synchronized with the images on the screen. This result has the practical implication that a cheaper equipment based on HMD is able to achieve the same results than a CAVE, which is more expensive and more difficult to be installed in the therapist's office. Juan and Pérez [263] found that immersion with both equipments induces a sense of presence and provokes anxiety, but the CAVE was more effective than the HMD visualization in eliciting both. Probably the difference between this outcome and the results of the previous study can be explained by the different samples taken into account: it is possible that when phobic patients are involved, HMD visualization is enough to elicit a phobic reaction and then to allow successful treatment.

Therefore, even affordable and simple VR equipment can effectively induce the desired psychological state and a sense of presence in cybertherapy. However, it is recommended that the literature is checked before embarking in building a specific system for a specific treatment in order to include the features that have proven more successful or that pilot studies are deviced in order to find out those features. It is also recommended to consider the ethical implications of cybertherapy and their specific deontological demands, in order to outline a proper, safe procedure [264].

References

1. Botella, C., Quero, S., Baños, R.M., Perpiñá, C., García-Palacios, A., Riva, G.: Virtual Reality and Psychotherapy. In: Riva, G., Botella, C., Légeron, P., Optale, G. (eds.) Cybertherapy: Internet and Virtual Reality as Assessment and Rehabilitation Tools for Clinical Psychology and Neuroscience. IOS Press, Amsterdam (2004)
2. Krijn, M., Emmelkamp, P.M.G., Olafsson, R.P., Biemond, R.: Virtual Reality Exposure Therapy of Anxiety Disorders: A Review. Clinical Psychology Review 24, 259–281 (2004)
3. Riva, G.: Virtual Reality in Psychotherapy: Review. CyberPsychology & Behavior 8, 220–230 (2005)
4. Gregg, L., Tarrier, N.: Virtual Reality in Mental Health: A Review of the Literature. Social Psychiatry and Psychiatric Epidemiology 42, 343–354 (2007)
5. Bush, J.: Viability of Virtual Reality Exposure Therapy as a Treatment Alternative. Computers in Human Behavior 24, 1032–1040 (2008)

6. Côté, S., Bouchard, S.: Virtual Reality Exposure for Phobias: A Critical Review. Journal of CyberTherapy & Rehabilitation 1, 75–91 (2008)
7. Parsons, T.D., Rizzo, A.A.: Affective Outcomes of Virtual Reality Exposure Therapy for Anxiety and Specific Phobias: A Meta-Analysis. Journal of Behavior Therapy and Experimental Psychiatry 39, 250–261 (2008)
8. Powers, M.B., Emmelkamp, P.M.G.: Virtual Reality Exposure Therapy for Anxiety Disorders: A Meta-Analysis. Journal of Anxiety Disorders 22, 561–569 (2008)
9. Foa, E.B., Kozak, M.J.: Emotional Processing of Fear: Exposure to Corrective Information. Psychological Bulletin 99, 20–35 (1986)
10. Lang, P.J.: Imagery in Therapy: An Information Processing Analysis of Fear. Behavior Therapy 8, 862–886 (1977)
11. Foa, E.B., Kozak, M.J.: Treatment of Anxiety Disorders: Implications for Psychopathology. In: Tuma, A.H., Maser, J. (eds.) Anxiety and the Anxiety Disorders, pp. 451–452. Erlbaum, Hillsdale (1985)
12. Marks, I.M.: Behavioral Psychotherapy of Adult Neurosis. In: Garfield, S.L., Bergin, A.E. (eds.) Handbook of Psychotherapy and Behavior Change, 2nd edn., pp. 493–589. Wiley, New York (1978)
13. Gelder, M.G.: Psychological Treatment for Anxiety Disorders: a Review. Journal of the Royal Society of Medicine 79, 230–233 (1986)
14. de Beurs, E., van Balkom, A.J., Lange, A., Koele, P., van Dyck, R.: Treatment of Panic Disorder with Agoraphobia: Comparison of Fluvoxamine, Placebo, and Psychological Panic Management Combined with Exposure and of Exposure In Vivo Alone. The American Journal of Psychiatry 152, 683–691 (1995)
15. Fava, G.A., Rafanelli, C., Grandi, S., Conti, S., Ruini, C., Mangelli, L., Belluardo, P.: Long-Term Outcome of Panic Disorder With Agoraphobia Treated by Exposure. Psychological Medicine 31, 891–898 (2001)
16. Heldt, E., Gus Manfro, G., Kipper, L., Blaya, C., Isolan, L., Otto, M.W.: One-Year Follow-Up of Pharmacotherapy-Resistant Patients with Panic Disorder Treated with Cognitive-Behavior Therapy: Outcome and Predictors of Remission. Behaviour Research and Therapy 44, 657–665 (2006)
17. Emmelkamp, P.M.G.: Behavior Therapy With Adults. In: Lambert, M.J. (ed.) Bergin & Garfields Handbook of Psychotherapy and Behavior Change, 5th edn., pp. 393–446. Wiley, New York (2004)
18. Frueh, B.C.: Exposure Therapy for Combat-Related PTSD: A Critical Review. Clinical Psychology Review 15, 799–817 (1995)
19. Arntz, A., Tiesema, M., Kindt, M.: Treatment of PTSD: A Comparison of Imaginal Exposure With and Without Imagery Rescripting. Journal of Behavior Therapy and Experimental Psychiatry 38, 345–370 (2007)
20. Taylor, S., Thordarson, D.S., Maxfield, L., Fedoroff, I.C., Lovell, K., Ogrodniczuk, J.: Comparative Efficacy, Speed, and Adverse Effects of Three PTSD Treatments: Exposure Therapy, EMDR, and Relaxation Training. Journal of Consulting and Clinical Psychology 71, 330–338 (2003)
21. Richards, D.A., Lovell, K., Marks, I.M.: Post-Traumatic Stress Disorder: Evaluation of a Behavioral Treatment Program. Journal of Traumatic Stress 7, 669–680 (1994)
22. Götestam, K.G.: One Session Group Treatment of Spider Phobia by Direct or Modeled Exposure. Cognitive Behaviour Therapy 31, 18–24 (2002)
23. Tuschen-Caffier, B., Vögele, C., Bracht, S., Hilbert, A.: Psychological responses to body shape exposure in patients with bulimia nervosa. Behaviour Research and Therapy 41, 573–586 (2003)

24. Carlin, A.S., Hoffman, H.G., Weghorst, S.: Virtual Reality and Tactile Augmentation in the Treatment of Spider Phobia: a Case Report. Behavior Research and Therapy 35, 153–158 (1997)
25. Szymanski, J., O'Donohue, W.: Fear of spiders questionnaire. Journal of Behavior Therapy and Experimental Psychiatry 26, 31–34 (1995)
26. Garcia-Palacios, A., Hoffman, H., Carlin, A., Furness III, T.A., Botella, C.: Virtual Reality in the Treatment of Spider Phobia: a Controlled Study. Behaviour Research and Therapy 40, 983–993 (2002)
27. Hoffman, H.G., Hollander, A., Rousseau, S., Hendrickson, D.: SpiderWorld. University of Washington. Human Interface Technology Labs, Seattle (1996)
28. Hamilton, A.: Kitchen World. Division Ltd., England (1992)
29. Wolpe, J.: The Practice of Behavior Therapy. Pergamon Press, New York (1969)
30. Hoffman, H.G., Garcia-Palacios, A., Carlin, A., Furness III, T.A., Botella-Arbona, C.: Interfaces That Heal: Coupling Real and Virtual Objects to Treat Spider Phobia. International Journal of Human–Computer Interaction 16, 283–300 (2003)
31. Côté, S., Bouchard, S.: Documenting the Efficacy of Virtual Reality Exposure with Psychophysiological and Information Processing Measures. Applied Psychophysiology and Biofeedback 30, 217–232 (2005)
32. Côté, S., Bouchard, S.: Cognitive Mechanisms Underlying Virtual Reality Exposure. CyberPsychology & Behavior 12, 121–129 (2009)
33. Arntz, A., Lavy, E., van der Berg, G., van Rijsoort, S.: Negative Beliefs of Spider Phobics: A Psychometric Evaluation of the Spider Phobia Beliefs Questionnaire. Advances in Behaviour Research and Therapy 15, 257–277 (1993)
34. Côté, S., Bouchard, S.: The Perceived Self-Efficacy Towards Spiders Questionnaire: A Psychometric Evaluation. In: Poster Presented at the Advancement of Behavior Therapy Convention, Boston (2003)
35. Bouchard, S., Côté, S., St-Jacques, J., Robillard, G., Renaud, P.: Effectiveness of Virtual Reality Exposure in the Treatment of Arachnophobia Using 3D games. Technology and Healthcare 14, 19–27 (2006)
36. Hodges, L.F., Kooper, R., Meyer, T.C., Rothbaum, B.O., Opdyke, D., de Graaff, J.J., Williford, J.S., North, M.M.: Virtual Environments for Treating the Fear of Heights. IEEE Computer 28, 27–34 (1995)
37. Rothbaum, B.O., Hodges, L.F., Kooper, R., Opdyke, D., Williford, J.S., North, M.: Effectiveness of Computer-Generated (Virtual Reality) Graded Exposure in the Treatment of Acrophobia. American Journal of Psychiatry 152, 626–628 (1995)
38. Cohen, D.C.: Comparison of Self-Report and Behavioral Procedures for Assessing Acrophobia. Behavior Therapy 8, 17–23 (1977)
39. Abelson, J.L., Curtis, G.C.: Cardiac and Neuroendocrine Responses to Exposure Therapy in Height Phobics: Desynchrony with the Physiological Response System. Behavior Research & Therapy 27, 556–561 (1989)
40. Rothbaum, B.O., Hodges, L.F., Kooper, R., Opdyke, D., Williford, J.S., North, M.: Virtual Reality Graded Exposure in the Treatment of Acrophobia: A Case Report. Behavior Therapy 26, 547–554 (1995)
41. Schümie, M.J., Bruynzeel, M., Drost, L., Brinckman, M., de Haan, G., Emmelkamp, P.M.G., van der Mast, C.A.P.G.: Treatment of Acrophobia in Virtual Reality: a Pilot Study. In: Proceedings of Euromedia Conference, Antwerp, Belgium, May 8-10, pp. 271–275. SCS Publishing House, Erlangen (2000)

42. Emmelkamp, P.M.G., Bruynzeel, M., Drost, L., Van Der Mast, C.A.P.G.: Virtual Reality Treatment in Acrophobia: A Comparison with Exposure in Vivo. CyberPsychology & Behavior 4, 335–339 (2001)
43. Emmelkamp, P.M.G., Krijn, M., Hulsbosch, A.M., de Vries, S., Schuemie, M.J., Van der Mast, C.A.P.G.: Virtual Reality Treatment Versus Exposure in Vivo: a Comparative Evaluation in Acrophobia. Behaviour Research and Therapy 40, 509–516 (2002)
44. Coelho, C.M., Santos, J.A., Silvèrio, J., Silva, C.F.: Virtual Reality and Acrophobia: One-Year Follow-Up and Case Study. CyberPsychology & Behavior 9, 336–341 (2006)
45. Coelho, C.M., Silva, C.F., Santos, J.A., Tichon, J., Wallis, G.: Contrasting the Effectiveness and Efficiency of Virtual Reality and Real Environments in the Treatment of Acrophobia. PsychNology Journal 6, 203–216 (2008)
46. Krijn, M., Emmelkamp, P.M.G., Ólafsson, R.P., Schümie, M.J., Van Der Mast, C.A.P.G.: Do Self-Statements Enhance the Effectiveness of Virtual Reality Exposure Therapy? A Comparative Evaluation in Acrophobia. CyberPsychology & Behavior 10, 362–370 (2007)
47. Hodges, L.F., Watson, B.A., Kessler, G.D., Rothbaum, B.O., Opdyke, D.: Virtually Conquering Fear of Flying. IEEE Computer Graphics and Applications 16, 42–49 (1996)
48. Rothbaum, B.O., Hodges, L., Watson, B.A., Kessler, G.D., Opdyke, D.: Virtual Reality Exposure Therapy in the Treatment of Fear of Flying: a Case Report. Behavior Research and Therapy 34, 477–481 (1996)
49. Howard, W.A., Murphy, S.M., Clarke, J.C.: The Nature and Treatment of Fear of Flying: a Controlled Investigation. Behavior Therapy 14, 557–567 (1983)
50. Scott, W.: A Fear of Flying Inventory. In: Kellar, P., Hayman, S. (eds.) Innovation of Clinical Practices, vol. 7, Professional Resource Exchange, Sarasota (1987)
51. Rothbaum, B.O., Hodges, L., Smith, S.: Virtual Reality Exposure Therapy Abbreviated Treatment Manual: Fear of Flying Application. Cognitive and Behavioral Practice 6, 234–244 (1998)
52. Rothbaum, B.O., Hodges, L., Smith, S., Lee, J.H., Price, L.: A Controlled Study of Virtual Reality Exposure Therapy for the Fear of Flying. Journal of Consulting and Clinical Psychology 68, 1020–1026 (2000)
53. Rothbaum, B.O., Hodges, L., Anderson, P.L., Lee, J.H., Price, L.: Twelve-Month Follow-Up of Virtual Reality and Standard Exposure Therapies for the Fear of Flying. Journal of Consulting and Clinical Psychology 70, 428–432 (2002)
54. Rothbaum, B.O., Anderson, P., Zimand, E., Hodges, L., Lang, D., Wilson, J.: Virtual Reality Exposure Therapy and Standard (in Vivo) Exposure Therapy in the Treatment of Fear of Flying. Behavior Therapy 37, 80–90 (2006)
55. Baños, R.M., Botella, C., Perpiñá, C., Alcañiz, M., Lozano, J.A., Osma, J., Gallardo, M.: Virtual Reality Treatment of Flying Phobia. IEEE Transactions on Information Technology in Biomedicine 6, 206–212 (2002)
56. Sosa, C.D., Capafons, J.I., Viña, C., Herrero, M.: Evaluación del Miedo a Viajar en Avión: Un Estudio Psicométrico de Dos Escalas de Autoinforme. Psicología Conductual 3, 133–158 (1995)
57. Bornas, X., Tortella-Feliu, M.: Descripción y Análisis Psicométrico de un Instrumento de Autoinforme Para la Evaluación del Miedo a Volar. Psicología Conductual 1, 67–86 (1995)
58. Botella, C., Osma, J., Garcia-Palacios, A., Quero, S., Baños, R.M.: Treatment of Flying Phobia using Virtual Reality: Data from a 1-Year Follow-up Using a Multiple Baseline Design. Clinical Psychology and Psychotherapy 11, 311–323 (2004)

59. Marks, I.M., Mathews, A.M.: Brief Standard Self-Rating for Phobic Patients. Behaviour Research and Therapy 17, 263–267 (1979)
60. Echeburúa, E., Corral, P., Fernández-Montalvo, J.: Escala de Inadaptación (EI): Propiedades Psicométricas en Contextos Clínicos. Análisis y Modificación de Conducta 107, 325–338 (2000)
61. Wiederhold, B.K., Gevirtz, R., Wiederhold, M.D.: Fear of Flying: A Case Report Using Virtual Reality Therapy with Physiological Monitoring. CyberPsychology & Behavior 1, 97–103 (1998)
62. Wiederhold, B.K., Jang, D.P., Gevirtz, R.G., Kim, S.I., Kim, I.Y., Wiederhold, M.D.: The Treatment of Fear of Flying: A Controlled Study of Imaginal and Virtual Reality Graded Exposure Therapy. IEEE Transactions on Information Technology in Biomedicine 6, 218–223 (2002)
63. Howard, W.A., Mattick, R.P., Clarke, J.C.: The Nature of Fears of Flying. University of New South Wales Press, Adelaide (1982)
64. Forgione, A.G., Bauer, F.M.: Fearless Flying: The Complete Program for Relaxed Air Travel. Houghton Miffin, Boston (1980)
65. Spielberger, C.D., Gorsuch, R.L., Lushene, R.E.: Manual for the State-Trait Anxiety Inventory (Self-Evaluation Questionnaire). MindGarden, Palo Alto (1970)
66. Wiederhold, B.K., Wiederhold, M.D.: Three-Year Follow-Up for Virtual Reality Exposure for Fear of Flying. CyberPsychology & Behavior 6, 441–445 (2003)
67. Klein, R.A.: Virtual Reality Exposure Therapy in the Treatment of Fear of Flying. Journal of Contemporary Psychotherapy 30, 195–207 (2000)
68. Wallach, H.S., Bar-Zvi, M.: Virtual-Reality-Assisted Treatment of Flight Phobia. Israel Journal of Psychiatry and Related Science 44, 29–32 (2007)
69. Maltby, N., Kirsch, I., Mayers, M., Allen, G.J.: Virtual Reality Exposure Therapy for the Treatment of Fear of Flying: A Controlled Investigation. Journal of Consulting and Clinical Psychology 70, 1112–1118 (2002)
70. Van Gerwen, L.J., Spinhoven, P., Van Dyck, R., Diekstra, R.F.: Construction and Psychometric Characteristics of Two Self-Report Questionnaires for the Assessment of Fear of Flying. Psychological Assessment 11, 146–158 (1999)
71. Forsyth, D.R., Corazzini, J.G.: Groups as Change Agents. In: Snyder, C.R., Ingram, R.E. (eds.) Handbook of Psychological Change: Psychotherapy Processes and Practices for the 21st Century, pp. 309–336. Wiley, New York (2000)
72. Mühlberger, A., Herrmann, M.J., Wiedemann, G., Ellgring, H., Pauli, P.: Repeated Exposure of Flight Phobics to Flights in Virtual Reality. Behaviour Research and Therapy 39, 1033–1050 (2001)
73. Haug, T., Brenne, L., Johnsen, B.H., Berntzen, D., Gotestam, K.G., Hugdahl, K.: A Three-Systems Analysis of Fear of Flying: a Comparison of a Consonant Vs a Non-Consonant Treatment Method. Behaviour Research and Therapy 25, 187–194 (1987)
74. Mühlberger, A., Wiedemann, G., Pauli, P.: Efficacy of a One-Session Virtual Reality Exposure Treatment for Fear of Flying. Psychotherapy Research 13, 323–336 (2003)
75. Krijn, M., Emmelkamp, P.M.G., Ólafsson, R.P., Bouwman, M., Van Gerwen, L.J., Spinhoven, P., Schuemie, M.J., Van Der Mast, C.A.P.G.: Fear of Flying Treatment Methods: Virtual Reality Exposure Vs. Cognitive Behavioral Therapy. Aviation, Space, and Environmental Medicine 78, 121–128 (2007)
76. da Costa, R.T., Sardinha, A., Nardi, A.E.: Virtual Reality Exposure in the Treatment of Fear of Flying. Aviation, Space, and Environmental Medicine 79, 899–903 (2008)
77. Veale, D.: Treatment of Social Phobia. Advances in Psychiatric Treatment 9, 258–264 (2003)

78. Roy, S., Klinger, E., Légeron, P., Lauer, F., Chemin, I., Nugues, P.: Definition of a VR-Based Protocol to Treat Social Phobia. CyberPsychology & Behavior 6, 411–420 (2003)
79. Liebowitz, M.R.: Social phobia. Modern Problems in Pharmacopsychiatry 22, 141–173 (1987)
80. Zigmond, A.S., Snaith, R.P.: The Hospital Anxiety and Depression Scale. Acta Psychiatrica Scandinavian 67, 361–370 (1983)
81. Beck, A.T., Beamesderfer, A.: Assessment of Depression: the Depression Inventory. Psychological Measurements in Psychopharmacology. Modern Problems in Pharmacopsychiatry 7, 151–159 (1974)
82. Rathus, S.A.: A Thirty Items Schedule for Assessing Assertive Behaviors. Behavior Therapy 4, 298–306 (1973)
83. Klinger, E., Bouchard, S., Légeron, P., Roy, S., Lauer, F., Chemin, I., Nugues, P.: Virtual Reality Therapy Versus Cognitive Behavior Therapy for Social Phobia: A Preliminary Controlled Study. CyberPsychology & Behavior 8, 76–88 (2005)
84. Horley, K., Williams, L.M., Gonsalvez, C., Gordon, E.: Social Phobics Do Not See Eye to Eye: A Visual Scanpath Study of Emotional Expression Processing. Journal of Anxiety Disorders 17, 33–44 (2001)
85. Grillon, H., Riquier, F., Herbelin, B., Thalmann, D.: Virtual Reality as Therapeutic Tool in the Confines of Social Anxiety Disorder Treatment. International Journal of Disability and Human Development 5, 243–250 (2006)
86. Yao, S.N., Note, I., Fanget, F., Albuisson, E., Bouvard, M., Jalenques, I., Cottraux, J.: L'Anxiété Sociale chez les Phobiques Sociaux: Validation de l'Échelle d'Anxiété Sociale de Liebowitz. Encephale 25, 429–435 (1999)
87. Yao, S.N., Cottraux, J., Mollare, E., Albuisson, E., Note, I., Jalenques, I., Fanget, F., Robbe-Grillet, P., Dechassey, M., Ektmedjian, N., Bouvard, M., Coudert, A.J.: The French Version of the Social Interaction Self-Statement Test (SISST): a Validation and Sensitivity Study in Social Phobics. Behavioral Cognitive Psychotherapy 26, 247–259 (1998)
88. Beck, A.T., Ward, C.H., Mendelson, M., Mock, J., Erbaugh, J.: An Inventory for Measuring Depression. Archieves of General Psychiatry 4, 561–571 (1961)
89. Bonso, E., Palomba, D., Perkovic, D., Palatini, P.: Effect of a Biofeedback System Using an Auto-Shaping Method on Blood Pressure at Rest and During Stress in Mild Hypertension. American Journal of Hypertension 18(Suppl. 1), 211A–211A (2005)
90. North, M.M., North, S.M., Coble, J.R.: Virtual Reality Therapy: an Effective Treatment for the Fear of Public Speaking. The International Journal of Virtual Reality 3, 1–6 (1998)
91. Harris, S.R., Kemmerling, R.L., North, M.M.: Brief Virtual Reality Therapy for Public Speaking Anxiety. CyberPsychology & Behavior 5, 543–550 (2002)
92. Anderson, P., Rothbaum, B.O., Hodges, L.E.: Virtual Reality Exposure in the Treatment of Social Anxiety. Cognitive and Behavioral Practice 10, 240–247 (2003)
93. Paul, G.: Insight Vs. Desensitization in Psychotherapy. Stanford University Press, Stanford (1966)
94. McCroskey, J.C.: Validity of the PRCA as an Index of Oral Communication Apprehension. Communication Monograph 45, 192–203 (1978)
95. Hoffmann, S.G., DiBartolo, P.M.: An Instrument to Assess Self-Statements During Public Speaking: Scale Development and Preliminary Psychometric Properties. Behavioral Therapy 31, 499–515 (2000)

96. Anderson, P.L., Zimand, E., Hodges, L.F., Rothbaum, B.O.: Cognitive Behavioral Therapy for Public-Speaking Anxiety Using Virtual Reality for Exposure. Depression and Anxiety 22, 156–158 (2005)
97. Wallach, H.S., Safir, M.P., Bar-Zvi, M.: Virtual Reality Cognitive Behavior Therapy for Public Speaking Anxiety: A Randomized Clinical Trial. Behavior Modification 33, 314–338 (2009)
98. Fresco, D.M., Coles, M.E., Heimberg, R.G., Liebowitz, M.R., Hami, S., Stein, M.B., Goetz, D.: The Liebowitz Social Anxiety Scale: A Comparison of the Psychometric Properties of Self-Report and Clinician-Administered Formats. Psychological Medicine 31, 1025–1035 (2001)
99. Lee, J.M., Ku, J.H., Jang, D.P., Kim, D.H., Choi, Y.H., Kim, I.Y., Kim, S.I.: Virtual Reality System for Treatment of the Fear of Public Speaking Using Image-Based Rendering and Moving Pictures. CyberPsychology & Behavior 5, 191–195 (2002)
100. Pertaub, D.P., Slater, M., Barker, C.: An Experiment on Public Speaking Anxiety in Response to Three Different Types of Virtual Audience. Presence, Teleoperators and Virtual Environments 11, 68–78 (2002)
101. Slater, M., Pertaub, D.P., Barker, C., Clark, D.M.: An Experimental Study on Fear of Public Speaking Using a Virtual Environment. CyberPsychology & Behavior 9, 627–633 (2006)
102. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders, 4th edn., text rev. Washington, DC (2000)
103. Vincelli, F., Choi, Y.H., Molinari, E., Wiederhold, B.K., Riva, G.: Experiential Cognitive Therapy for the Treatment of Panic Disorder with Agoraphobia: Definition of a Clinical Protocol. CyberPsychology & Behavior 3, 375–385 (2000)
104. Vincelli, F., Choi, Y.H., Molinari, E., Wiederhold, B.K., Riva, G.: A VR-Based Multicomponent Treatment for Panic Disorders with Agoraphobia. Studies in Health Technology and Informatics 81, 544–550 (2001)
105. Vincelli, F., Anolli, L., Bouchard, S., Wiederhold, B.K., Zurloni, V., Riva, G.: Experiential Cognitive Therapy in the Treatment of Panic Disorders with Agoraphobia: A Controlled Study. CyberPsychology & Behavior 6, 321–328 (2003)
106. Spielberger, C.D., Gorsuch, R.L., Lushene, R.E., Vagg, R., Jacobs, G.A.: State-Trait Anxiety Inventory. Self-evaluation questionnaire (form Y). In: Manual for the State-Trait Anxiety Inventory. Consulting Psychologists Press, Palo Alto (1983)
107. Botella, C., Villa, H., Garcìa-Palacios, A., Baños, R.M., Perpiñá, C., Alcañiz, M.: Clinically Significant Virtual Environments for the Treatment of Panic Disorder and Agoraphobia. CyberPsychology & Behavior 7, 527–535 (2004)
108. Villa Martin, H., Botella, C., García-Palacios, A., Osma, J.: Virtual Reality Exposure in the Treatment of Panic Disorder With Agoraphobia: A Case Study. Cognitive and Behavioral Practice 14, 58–69 (2007)
109. Botella, C., García-Palacios, A., Villa, H., Baños, R.M., Quero, S., Alcañiz, M., Riva, G.: Virtual Reality Exposure in the Treatment of Panic Disorder and Agoraphobia: A Controlled Study. Clinical Psychology and Psychotherapy 14, 164–175 (2007)
110. Shear, M.K., Brown, T.A., Sholomskas, D.E., Barlow, D.H., Gorman, J.M., Woods, S., Cloitre, M.: Panic Disorder Severity Scale (PDSS). Department of Psychiatry. University of Pittsburgh School of Medicine, Pittsburgh (1992)
111. Reiss, S., Peterson, R., Gursky, D.M., McNally, R.J.: Anxiety Sensitivity, Anxiety Frequency and the Prediction of Fearfulness. Behaviour Research and Therapy 24, 1–8 (1986)

112. Guy, W.: ECDEU. Assessment Manual for Psychopharmacology-Revised. DHEW Publ. No. ADM 76-338 (1976)
113. Peñate, W., Pitti, C.T., Bethencourt, J.M., de la Fuente, J., Gracia, R.: The Effects of a Treatment Based on the Use of Virtual Reality Exposure and Cognitive-Behavioral Therapy Applied to Patients With Agoraphobia. International Journal of Clinical and Health Psychology 8, 5–22 (2008)
114. Chambless, D.L., Caputo, G.C., Bright, P., Gallagher, R.: Assessment of Fear in Agoraphobics: the Body Sensations Questionnaire and the Agoraphobic Cognitions Questionnaire. Journal of Consulting and Clinical Psychology 52, 1090–1097 (1984)
115. Beck, A.T., Steer, R., Brown, G.: Manual for the Beck Depression Inventory II. Psychological Corporation, San Antonio, Texas (1996)
116. Beck, A.T., Steer, R.: Manual for the Beck Anxiety Inventory. Psychological Corporation, San Antonio, Texas (1990)
117. Echeburúa, E., Corral, P.: Agorafobia. In: Caballo, V., Buela-Casal, G., Carrobles, J.A. (eds.) Manual de Psicopatología y Trastornos Psiquiátricos, vol. 1, pp. 344–345. Siglo XXI, Madrid (1995)
118. Pitti, C.T., Peñate, W., de la Fuente, J., Bethencourt, J.M., Acosta, L., Villaverde, M.L., Gracia, R.: Agoraphobia: Combined Treatment and Virtual Reality. Preliminary Results. Actas Española de Psiquiatria 36, 94–101 (2008)
119. Garcia-Palacios, A., Hoffman, H., See, S.K., Tsai, A., Botella, C.: Redefining Therapeutic Success with Virtual Reality Exposure Therapy. Cyber Psychology & Behavior 4, 341–348 (2001)
120. Ost, L.-G.: One-Session Treatment for Specific Phobias. Behaviour Research and Therapy 27, 1–7 (1989)
121. Wiederhold, B.K., Wiederhold, M.D.: A New Approach: Using Virtual Reality Psychotherapy in Panic Disorder With Agoraphobia. Psychiatric Times XX (2004), `http://www.psychiatrictimes.com/display/article/10168/47086`
122. Wolitzky-Taylor, K.B., Horowitz, J.D., Powers, M.B., Telch, M.J.: Psychological Approaches in the Treatment of Specific Phobias: A Meta-Analysis. Clinical Psychology Review 28, 1021–1037 (2008)
123. Foa, E.B., Keane, T.M., Friedman, M.J., Cohen, J.A. (eds.): Effective Treatments for PTSD. Practice Guidelines from the International Society for Traumatic Stress Studies, 2nd edn. Guilford Press, New York (2009)
124. Keane, T.M., Barlow, D.H.: Posttraumatic Stress Disorder. In: Barlow, D. (ed.) Anxiety and its Disorders: the Nature and Treatment of Anxiety and Panic, 2nd edn., pp. 418–453. Guilford Press, New York (2002)
125. Wiederhold, B.K., Wiederhold, M.D.: Virtual Reality for Posttraumatic Stress Disorder and Stress Inoculation Training. Journal of CyberTherapy & Rehabilitation 1, 23–35 (2008)
126. Spira, J.L., Pyne, J.M., Wiederhold, B., Wiederhold, M., Graap, K., Rizzo, A.: Virtual Reality and Other Experiential Therapies for Combat-Related Posttraumatic Stress Disorder. Primary Psychiatry 13, 43–49 (2006)
127. Rothbaum, B.O., Hodges, L.F., Alarcon, R., Ready, D., Shahar, F., Graap, K., Pair, J., Hebert, P., Gotz, D., Wills, B., Baltzell, D.: Virtual Reality Exposure Therapy for PTSD Vietnam Veterans: A Case Study. Journal of Traumatic Stress 12, 263–271 (1999)
128. Blake, D.D., Weathers, F., Nagy, L.M., Kaloupek, D.G., Klauminzer, G., Charney, D.S., Keane, T.M.: A Clinician Rating Scale for Assessing Current and Lifetime PTSD: The CAPS-1. The Behavior Therapist 13, 187–188 (1992)
129. Horowitz, M.J., Wilner, N., Alvarez, W.: Impact of Event Scale: A Measure of Subjective Distress. Psychosomatic Medicine 41, 207–218 (1979)

130. Spielberger, C.D.: State-Trait Anger Expression Inventory. STAXI Professional Manual. Psychological Assessment Resources (1996)
131. Rothbaum, B.O., Hodges, L.F., Ready, D., Shahar, F., Graap, K., Alarcon, R.: Virtual Reality Exposure Therapy for Vietnam Veterans with Posttraumatic Stress Disorder. Journal of Clinical Psychiatry 62, 617–622 (2001)
132. Rothbaum, B.O., Ruef, A.M., Litz, B.T., Han, H., Hodges, L.: Virtual Reality Exposure Therapy of Combat-Related PTSD: a Case Study Using Psychophysiological Indicators of Outcomes. Journal of Cognitive Psychotherapy 17, 163–178 (2003)
133. Ready, D.J., Pollack, S., Rothbaum, B.O., Alarcon, R.D.: Virtual Reality Exposure for Veterans with Posttraumatic Stress Disorder. Journal of Aggression, Maltreatment and Trauma 12, 199–220 (2005)
134. Gamito, P., Pacheco, J., Ribeiro, C., Pablo, C., Saraiva, T.: Virtual War PTSD – a Methodological Thread. Annual Review of Cyber Therapy and Telemedicine 3, 173–178 (2005)
135. Gamito, P., Oliveira, J., Morais, D., Saraiva, T., Rosa, J., Leal, A., Pacheco, J., Ribeiro, C., Neto, D., Pablo, C., Gamito, L., Anastácio, M.: Annual Review of Cyber Therapy and Telemedicine, vol. 5, pp. 191–198 (2007)
136. Gamito, P., Oliveira, J., Morais, D., Oliveira, S., Duarte, N., Saraiva, T., Pombal, M., Rosa, P.: Virtual Reality Therapy Controlled Study for War Veterans with PTSD. Preliminary Results. Studies in Health Technology and Informatics 144, 269–272 (2009)
137. Derogatis, L.R.: SCL-90: Administration, Scoring, and Procedure Manual-I. Johns Hopkins University School of Medicine, Baltimore (1977)
138. Reger, G.M., Gahm, G.A.: Virtual Reality Exposure Therapy for Active Duty Soldiers. Journal of Clinical Psychology 64, 940–946 (2008)
139. Weathers, F.W., Litz, B.T., Herman, J.A., Huska, J.A., Keane, T.M.: The PTSD Checklist (PCL): Reliability, Validity and Diagnostic Utility. In: Paper Presented at the 9th Annual Conference of the International Society for Traumatic Stress Studies, San Antonio, TX, October 24-27 (1993)
140. McLean Hospital: Behavior and Symptom Identification Scale: BASIS-24 Instruction Guide, Belmont (2006)
141. Reger, G.M., Gahm, G.A., Rizzo, A.A., Swanson, R., Duma, S.: Soldier Evaluation of the Virtual Reality Iraq. Telemedicine and e-Health 15, 101–104 (2009)
142. Rizzo, A.A., Graap, K., Mclay, R.N., Perlman, K., Rothbaum, B.O., Reger, G., Parsons, T., Difede, J., Pair, J.: Virtual Iraq: Initial Case Reports from a VR Exposure Therapy Application for Combat-Related Post Traumatic Stress Disorder. Virtual Rehabilitation, 124–130 (2007)
143. Wood, D.P., Murphy, J., Center, K., Mclay, R., Reeves, D., Pyne, J., Shilling, R., Wiederhold, B.K.: Combat-Related Post-Traumatic Stress Disorder: A Case Report Using Virtual Reality Exposure Therapy with Physiological Monitoring. CyberPsychology & Behavior 10, 309–315 (2007)
144. Gerardi, M., Rothbaum, B.O., Ressler, K., Heekin, M., Rizzo, A.A.: Virtual Reality Exposure Therapy Using a Virtual Iraq: Case Report. Journal of Traumatic Stress 21, 209–213 (2008)
145. Rizzo, A.A., Graap, K., Pearlman, K., McLay, R.N., Rothbaum, B.O., Reger, G., Parsons, T., Difede, J., Pair, J.: Virtual Iraq: Initial Results from a VR Exposure Therapy Application for Combat-Related PTSD. In: Westwood, J.D., Haluck, R.S., Hoffman, H.M., Mogel, G.T., Phillips, R., Robb, R.A., Vosburgh, K.G. (eds.) Medicine Meets Virtual Reality 16. Studies in Health Technology and Informatics, vol. 132, pp. 420–425. IOS Press, Amsterdam (2008)

146. Rizzo, A., Newman, B., Parsons, T., Difede, J., Reger, G., Holloway, K., Gahm, G., McLay, R., Johnston, S., Rothbaum, B., Graap, K., Spitalnick, J., Bordnick, P.: Development and Clinical Results from the Virtual Iraq Exposure Therapy Application for PTSD. In: Proceedings of Virtual Rehabilitation International Conference, Haifa, Israel, June 29-July 2, pp. 8–15 (2009)
147. Blanchard, E.B., Jones-Alexander, J., Buckley, T.C., Forneris, C.A.: Psychometric Properties of the PTSD Checklist (PCL). Behaviour Research and Therapy 34, 669–673 (1996)
148. Beck, A.T., Epstein, N., Brown, G., Steer, R.A.: An Inventory for Measuring Clinical Anxiety: Psychometric Properties. Journal of Consulting and Clinical Psychology 56, 893–897 (1988)
149. Kroenke, K., Spitzer, R.L.: The PHQ-9: A New Depression and Diagnostic Severity Measure. Psychiatric Annals 32, 509–521 (2002)
150. Difede, J., Hoffman, H.G.: Virtual Reality Exposure Therapy for World Trade Center Post-traumatic Stress Disorder: A Case Report. CyberPsychology & Behavior 5, 529–535 (2002)
151. Foa, E.B.: Posttraumatic Stress Diagnostic Scale Manual. National Computer Systems Inc. (1995)
152. Difede, J., Cuckor, J., Patt, I., Giosan, C., Hoffman, H.G.: The Application of Virtual Reality to the Treatment of PTSD Following the WTC Attack. Annals of New York Academy of Science 1071, 500–501 (2006)
153. Difede, J., Cuckor, J., Jayasinghe, N., Patt, I., Jedel, S., Spielman, L., Giosan, C., Hoffman, H.G.: Virtual Reality Exposure Therapy for the Treatment of Posttraumatic Stress Disorder Following. Journal of Clinical Psichiatry 68, 1639–1647 (2007)
154. Josman, N., Somer, E., Reisberg, A., Weiss, P.L.T., Garcia-Palacios, A., Hoffman, H.: BusWorld: Designing a Virtual Environment for Post-Traumatic Stress Disorder in Israel: A Protocol. CyberPsychology & Behavior 9, 241–244 (2006)
155. Josman, N., Reisberg, A., Weiss, P.L.T., Garcia-Palacios, A., Hoffman, H.: BusWorld: An Analog Pilot Test of a Virtual Environment Designed to Treat Posttraumatic Stress Disorder Originating from a Terrorist Suicide Bomb Attack. CyberPsychology & Behavior 11, 775–777 (2008)
156. Wald, J., Taylor, S.: Preliminary Research on the Efficacy of a Virtual Reality Exposure Therapy to Treat Driving Phobia. CyberPsychology & Behavior 6, 459–465 (2003)
157. Walshe, D.G., Lewis, E.J., Kim, S.I., O'Sullivan, K., Wiederhold, B.K.: Exploring the Use of Computer Games and Virtual Reality in Exposure Therapy for Fear of Driving Following a Motor Vehicle Accident. Cyber Psychology & Behavior 6, 329–334 (2003)
158. Walshe, D., Lewis, E., O'Sullivan, K., Kim, S.I.: Virtually Driving: Are the Driving Environments "Real Enough" for Exposure Therapy with Accident Victims? An Explorative Study. CyberPsychology & Behavior 8, 532–537 (2005)
159. Beck, J.G., Palyo, S.A., Winer, E.H., Schwagler, B.E., Ang, E.J.: Virtual Reality Exposure Therapy for PTSD Symptoms After a Road Accident: An Uncontrolled Case Series. Behavior Therapy 38, 39–48 (2007)
160. Saraiva, T., Gamito, P., Oliveira, J., Morais, D., Pombal, M., Gamito, L., Anastácio, M.: The Use of VR Exposure in the Treatment of Motor Vehicle PTSD: A Case-Report. Annual Review of CyberTherapy and Telemedicine 5, 199–205 (2007)
161. Gamito, P., Saraiva, T., Oliveira, J., Morais, D., Rosa, P., Pombal, M., Gamito, L., Leal, A.: Physiological Assessment During VR PTSD Treatment of a Motor Vehicle Accident Patient. Journal of CyberTherapy & Rehabilitation 1, 258–266 (2008)

162. Saraiva, T., Gamito, P., Oliveira, J., Morais, D., Pombal, J., Rosa, P., Pablo, C., Gamito, L., Leal, A., Lopes, F.: Road Civil War: Treating a MVA Victim with Virtual Reality-— A Case Study. Abstracts from CyberTherapy 13, San Diego, California (June 23-25, 2008); CyberPsychology & Behavior 12, 111 (2009)
163. Meichenbaum, D.: Stress Inoculation Training for Coping With Stressors. The Clinical Psychologist 49, 4–7 (1996)
164. Wiederhold, B.K., Bullinger, A.H., Wiederhold, M.D.: Advanced Technologies in Military Medicine. In: Roy, M.J. (ed.) Novel Approaches to the Diagnosis and Treatment of Posttraumatic Stress Disorder, pp. 148–160. IOS Press, Amsterdam (2006)
165. Stetz, M.C., Long, C.P., Schober Jr., W.V., Cardillo, C.G., Wildzunas, R.M.: Stress Assessment and Management while Medics Take Care of the VR Wounded. Annual Review of CyberTherapy and Telemedicine 5, 165–171 (2007)
166. Tarnanas, I., Manos, G.: Using Virtual Reality to Teach Special Population how to Cope with Crisis: The Case of a Virtual Hearthquake. Studies in Health Technology and Informatics 81, 495–501 (2001)
167. Tarnanas, I., Manos, G.: A Clinical Protocol for the Development of a Virtual Reality Behavioral Training in Disaster Exposure and Relief. Annual Review of CyberTherapy and Telemedicine 2, 71–84 (2004)
168. Tichon, J., Wallis, G., Mildred, T.: Virtual Training Environments to Improve Train Driver's Crisis Decision Making. In: Proceedings of SimTecT, Melbourne, Australia, May 29-June 1 (2006)
169. Witmer, B.G., Singer, M.J.: Measuring Presence in Virtual Environments: A Presence Questionnaire. Presence 7, 225–240 (1998)
170. Schubert, T., Friedmann, F., Regenbrecht, H.: The Experience of Presence: Factor Analytic Insights. Presence: Teleoperators & Virtual Environments 10, 266–282 (2001)
171. Zuckerman, M., Lubin, B.: Multiple Affect Adjective Check List-Revised: Manual. Educational and Industrial Testing Service, San Diego (1985)
172. Stetz, M.C., Long, C.P., Wiederhold, B.K., Turner, D.D.: Combat Scenarios and Relaxation Training to Harden Medics Against Stress. Journal of CyberTherapy & Rehabilitation 1, 239–246 (2008)
173. Drummond, D.C., Tiffany, S.T., Glautier, S., Remington, B.: Cue Exposure in Understanding and Treating Addictive Behaviours. In: Drummond, D.C., Tiffany, S.T., Glautier, S., Remington, B. (eds.) Addictive Behaviour: Cue Exposure Theory and Practice, pp. 1–17. Wiley, Chichester (1995)
174. Havermans, R.C., Jansen, A.T.M.: Increasing the Efficacy of Cue Exposure Treatment in Preventing Relapse of Addictive Behavior. Addictive Behaviors 28, 989–994 (2003)
175. Jansen, A.: A Learning Model of Binge Eating: Cue Reactivity and Cue Exposure. Behaviour Research and Therapy 36, 257–272 (1998)
176. Kuntze, M.F., Stoermer, R., Mager, R., Roessler, A., Mueller-Spahn, F., Bullinger, A.H.: Immersive Virtual Environments in Cue Exposure. CyberPsychology & Behavior 4, 497–501 (2001)
177. Saladin, M., Brady, K.T., Graap, K., Rothbaum, B.O.: A Preliminary Report on the Use of Virtual Reality Technology to Elicit Craving and Cue Reactivity in Cocaine Dependent Individuals. Addictive Behaviors 31, 1881–1894 (2006)
178. Lee, J.H., Ku, J., Kim, K., Kim, B., Kim, I.Y., Yang, B.H., Kim, S.H., Wiederhold, B.K., Wiederhold, M.D., Park, D.W., Lim, Y., Kim, S.I.: Experimental Application of Virtual Reality for Nicotine Craving through Cue Exposure. CyberPsychology & Behavior 6, 275–280 (2003)

179. Baumann, S.B., Sayette, M.A.: Smoking Cues in a Virtual World Provoke Craving in Cigarette Smokers. Psychology of Addictive Behaviors 20, 484–489 (2006)
180. Bordnick, P.S., Graap, K.M., Copp, H., Brooks, J., Ferrer, M., Logue, B.: Utilizing Virtual Reality to Standardize Nicotine Craving Research: A Pilot Study. Addictive Behaviors 29, 1889–1894 (2004)
181. Bordnick, P.S., Graap, K.M., Copp, H.L., Brooks, J., Ferrer, M.: Virtual Reality Cue Reactivity Assessment in Cigarette Smokers. CyberPsychology & Behavior 8, 487–492 (2005)
182. Bordnick, P.S., Traylor, A.C., Graap, K.M., Copp, H.L., Brooks, J.: Virtual Reality Cue Reactivity Assessment: A Case Study in a Teen Smoker. Applied Psychophysiology and Biofeedback 30, 187–193 (2005)
183. Carter, B.L., Bordnick, P., Traylor, A., Day, S.X., Paris, M.: Location and Longing: The Nicotine Craving Experience in Virtual Reality. Drug Alcohol Dependence 95, 73–80 (2008)
184. Traylor, A.C., Bordnick, P.S., Carter, B.L.: Assessing Craving in Young Adult Smokers Using Virtual Reality. The American Journal on Addictions 17, 436–440 (2008)
185. Moon, J., Lee, J.H.: Cue Exposure Treatment in a Virtual Environment to Reduce Nicotine Craving: A Functional MRI Study. CyberPsychology & Behavior 12, 43–45 (2009)
186. Girard, B., Turcotte, V., Bouchard, S., Girard, B.: Crushing Virtual Cigarettes Reduces Tobacco Addiction and Treatment Discontinuation. CyberPsychology & Behavior 12, 477–483 (2009)
187. Heatherton, T.F., Kozlowski, L.T., Frecker, R.B., Fagerström, K.-O.: The Fagerström Test for Nicotine Dependence: a Revision of the Fagerström Tolerance Questionnaire. British Journal of Addiction 86, 1119–1127 (1991)
188. Cho, S., Ku, J., Park, J., Han, K., Lee, H., Choi, Y.K., Jung, Y.C., Namkoong, K., Kim, J.J., Kim, I.Y., Kim, S.I., Shen, D.F.: Development and Verification of an Alcohol Craving–Induction Tool Using Virtual Reality: Craving Characteristics in Social Pressure Situation. CyberPsychology & Behavior 11, 302–308 (2008)
189. Bordnick, P.S., Traylor, A., Copp, H.L., Graap, K.M., Carter, B., Ferrer, M., Walton, A.P.: Assessing Ractivity to Virtual Rality Acohol Based Cues. Addictive Behaviors 33, 743–756 (2008)
190. Kwon, H., Choi, J., Roh, S., Yang, B.-H., Lee, J.-H.: Application of Virtual Reality-Cue Exposure Therapy for Reducing Alcohol Craving. Annual Review of CyberTherapy and Telemedicine 4, 161–166 (2006)
191. Lee, J.-H., Kwon, H., Choi, J., Yang, B.-H.: Cue-Exposure Therapy to Decrease Alcohol Craving in Virtual Environment. CyberPsychology & Behavior 10, 617–623 (2007)
192. Lee, S.H., Han, D.H., Oh, S., Lyoo, I.K., Lee, Y.S., Renshaw, P.F., Lukas, S.E.: Quantitative Electroencephalographic (qEEG) Correlates of Craving During Virtual Reality Therapy in Alcohol-Dependent Patients. Pharmacology, Biochemistry and Behavior 91, 393–397 (2009)
193. Riva, G., Bacchetta, M., Baruffi, M., Rinaldi, S., Molinari, E.: Virtual Reality Based Experiential Cognitive Treatment of Anorexia Nervosa. Journal of Behavior Therapy and Experimental Psychiatry 30, 221–230 (1999)
194. Riva, G., Bacchetta, M., Baruffi, M., Rinaldi, S., Molinari, E.: Experiential Cognitive Therapy: A VR Based Approach for the Assessment and Treatment of Eeating Disorders. In: Riva, G., Wiederhold, B., Molinari, E. (eds.) Virtual Environments in Clinical Psychology and Neuroscience: Methods and Techniques in Advanced Patient-Therapist Interaction, pp. 120–135. IOS Press, Amsterdam (1998)
195. Riva, G., Bacchetta, M., Baruffi, M., Cirillo, G., Molinari, E.: Virtual Reality Environment for Body Image Modification: A Multidimensional Therapy for the Treatment of Body Image in Obesity and Related Pathologies. CyberPsychology & Behavior 3, 421–431 (2000)

196. Riva, G., Bacchetta, M., Baruffi, M., Molinari, E.: Virtual Reality–Based Multidimensional Therapy for the Treatment of Body Image Disturbances in Obesity: A Controlled Study. CyberPsychology & Behavior 4, 511–526 (2001)
197. Slade, P.D., Dewey, M.E., Newton, T., Brodie, D., Kiemle, G.: Development of the Body Satisfaction Scale (BSS). Psychology and Health 4, 213–226 (1990)
198. Schlundt, D.G., Zimering, R.T.: The Dieter's Inventory of Eating Temptations: a Measure of Weight Control Competence. Addictive Behavior 13, 151–164 (1988)
199. Gambrill, E.D., Richey, C.A.: An Assertion Inventory for Use in Assessment and Research. Behavior Therapy 6, 550–561 (1975)
200. Clark, M.M., Abrams, D.B., Niaura, R.S., Eaton, C.A., Rossi, J.: Self-Efficacy in Weight Management. Journal of Consulting and Clinical Psychology 59, 739–744 (1991)
201. Riva, G., Bacchetta, M., Cesa, G., Conti, S., Castelnuovo, G., Mantovani, F., Molinari, E.: Is Severe Obesity a Form of Addiction?: Rationale, Clinical Approach, and Controlled Clinical Trial. CyberPsychology & Behavior 9, 457–479 (2006)
202. Rosen, J.C., Srebnik, D., Saltzberg, E., Wendt, S.: Development of a Body Image Questionnaire. Psychological Assessment 1, 32–37 (1991)
203. Thompson, M.A., Gray, J.J.: Development and Validation of a New Body-Image Assessment Scale. Journal of Personality Assessment 2, 258–269 (1995)
204. Riva, G., Bacchetta, M., Baruffi, M., Molinari, E.: Virtual-Reality-Based Multidimensional Therapy for the Treatment of Body Image Disturbances in Binge Eating Disorders: A Preliminary Controlled Study. IEEE Transactions on Information Technology in Biomedicine 6, 224–234 (2002)
205. Riva, G., Bacchetta, M., Cesa, G., Conti, S., Molinari, E.: Six-Month Follow-Up of In-Patient Experiential Cognitive Therapy for Binge Eating Disorders. CyberPsychology & Behavior 6, 251–258 (2003)
206. Perpiñá, C., Botella, C., Baños, R., Marco, J.H., Alcañiz, M., Quero, S.: Body Image and Virtual Reality in Eating Disorders: Exposure by Virtual Reality Is More Effective Than the Classical Body Image Treatment? CyberPsychology & Behavior 2, 149–159 (1999)
207. Perpiñá, C., Botella, C., Baños, R.M.: Virtual Reality in Eating Disorders. European Eating Disorders Review 11, 261–278 (2003)
208. Ferrer-Garcia, M., Gutiérrez-Maldonado, J.: Assessment of Emotional Reactivity Produced by Exposure to Virtual Environments in Patients with Eating Disorder. Annual Review of CyberTherapy and Telemedicine 3, 123–128 (2005)
209. Gutiérrez-Maldonado, J., Ferrer-Garcia, M., Caqueo-Urízar, A., Letosa-Porta, A.: Assessment of Emotional Reactivity Produced by Exposure to Virtual Environments in Patients with Eating Disorders. CyberPsychology & Behavior 9, 507–513 (2006)
210. Gutiérrez-Maldonado, J., Mora-Bello, M.: Cuestionario de Depresión Barcelona. In: Pérez, B., Gutiérrez-Maldonado, J., Ferrer-Garcia, M. (eds.) VII European Conference on Psychological Assessment, Málaga, Spain, April 1-4 (2004) (not published manuscript)
211. Turk, D.C., Meichenbaum, D., Genest, M.: Pain and Behavioral Medicine: a Cognitive-Behavioral Perspective. Guilford Press, New York (1983)
212. Hoffman, H.G., Doctor, J.N., Patterson, D.R., Carrougher, G.J., Furness III, T.A.: Virtual Reality as an Adjunctive Pain Control During Burn Wound Care in Adolescent Patients. Pain 85, 305–309 (2000)
213. Weisman, S.J., Bernstein, B., Schechter, N.L.: Consequences of Inadequate Analgesia During Painful Procedures in Children. Archives of Pediatric & Adolescent Medicine 152, 147–149 (1998)

214. Das, D.A., Grimmer, K.A., Sparnon, A.L., McRae, S.E., Thomas, B.H.: The Efficacy of Playing a Virtual Reality Game in Modulating Pain for Children With Acute Burn Injuries: A Randomized Controlled Trial. BMC Pediatrics 5 (2005), http://www.biomedcentral.com/1471-2431/5/1
215. LeBaron, S., Zeltzer, L.: Assessment of Acute Pain and Anxiety in Children and Adolescents by Self-Reports, Observer Reports, and a Behavior Checklist. Journal of Consulting and Clinical Psychology 52, 729–738 (1984)
216. Chan, E.A., Chung, J.W.Y., Wong, T.K.S., Lien, A.S.Y., Yang, J.Y.: Application of a Virtual Reality Prototype for Pain Relief of Pediatric Burn in Taiwan. Journal of Clinical Nursing 16, 786–793 (2007)
217. Mott, J., Bucolo, S., Cuttle, L., Mill, J., Hilder, M., Miller, K., Kimble, R.M.: The Efficacy of an Augmented Virtual Reality System to Alleviate Pain in Children Undergoing Burns Dressing Changes: A Randomised Controlled Trial. Burns 34, 803–808 (2008)
218. Gershon, J., Zimand, E., Lemos, R., Rothbaum, B.O., Hodges, L.: Use of Virtual Reality as a Distractor for Painful Procedures in a Patient with Pediatric Cancer: A Case Study. CyberPsychology & Behavior 6, 657–661 (2003)
219. Gershon, J., Zimand, E., Pickering, M., Rothbaum, B.O., Hodges, L.: A Pilot and Feasibility Study of Virtual Reality as a Distraction for Children With Cancer. Journal of American Academy of Child & Adolescent Psychiatry 43, 1243–1249 (2004)
220. McGrath, P.J., Johnson, G., Goodman, J.T., Schillinger, J., Dunn, J., Chapman, J.-A.: CHEOPS: a Behavioral Scale for Rating Postoperative Pain in Children. Advances in Pain Research and Therapy 9, 395–402 (1985)
221. Steele, E., Grimmer, K., Thomas, B., Mulley, B., Fulton, I., Hoffman, H.: Virtual Reality as a Pediatric Pain Modulation Technique: A Case Study. Cyber Psychology & Behavior 6, 633–638 (2003)
222. Gold, J.I., Kim, S.H., Kant, A.J., Joseph, M.H., Rizzo, A.: Effectiveness of Virtual Reality for Pediatric Pain Distraction during IV Placement. CyberPsychology & Behavior 9, 207–212 (2006)
223. Hicks, C.L., von Baeyer, C.L., Spafford, P., van Korlaar, I., Goodenough, B.: The Faces Pain Scale–Revised: Toward a Common Metric in Pediatric Pain Measurement. Pain 93, 173–183 (2001)
224. Hoffman, H.G., Patterson, D.R., Carrougher, G.J.: Use of Virtual Reality for Adjunctive Treatment of Adult Burn Pain During Physical Therapy: A Controlled Study. The Clinical Journal of Pain 16, 244–250 (2000)
225. Hoffman, H.G., Patterson, D.R., Carrougher, G.J., Nakamura, D., Moore, M., Garcia-Palacios, A., Furness, T.A.: The Effectiveness of Virtual Reality Pain Control With Multiple Treatments of Longer Durations: A Case Study. International Journal of Human–Computer Interaction 13, 1–12 (2001)
226. Hoffman, H.G., Patterson, D.R., Carrougher, G.J., Sharar, S.R.: Effectiveness of Virtual Reality–Based Pain Control With Multiple Treatments. The Clinical Journal of Pain 17, 229–235 (2001)
227. Hoffman, H.G., Patterson, D.R., Magula, J., Carrougher, G.J., Zeltzer, K., Dagadakis, S., Sharar, S.R.: Water-Friendly Virtual Reality Pain Control During Wound Care. Journal of Clinical Psychology 60, 189–195 (2004)
228. Hoffman, H.G., Patterson, D.R., Seibel, E., Soltani, M., Jewett-Leahy, L., Sharar, S.R.: Virtual Reality Pain Control During Burn Wound Debridement in the Hydrotank. Clinical Journal of Pain 24, 299–304 (2008)

229. Van Twillert, B., Bremer, M., Faber, A.W.: Computer-Generated Virtual Reality to Control Pain and Anxiety in Pediatric and Adult Burn Patients During Wound Dressing Changes. Journal of Burn Care & Research 28, 694–702 (2007)
230. Wismeijer, A.A., Vingerhoets, A.J.: The Use of Virtual Reality and Audiovisual Eyeglass Systems as Adjunct Analgesic Techniques: a Review of the Literature. Annuals of Behavioral Medicine 30, 268–278 (2005)
231. Sharar, S.R., Carrougher, G.J., Nakamura, D., Hoffman, H.G., Blough, D.K., Patterson, D.R.: Factors Influencing the Efficacy of Virtual Reality Distraction Analgesia During Postburn Physical Therapy: Preliminary Results from 3 Ongoing Studies. Archives of Physical Medicine & Rehabilitation 88(Suppl. 2), S43–S49 (2007)
232. Maani, C., Hoffman, H.G., DeSocio, P.A., Morrow, M., Galin, C., Magula, J., Maiers, A., Gaylord, K.: Pain Control During Wound Care for Combat-Related Burn Injuries Using Custom Articulated Arm Mounted Virtual Reality Goggles. Journal of CyberTherapy & Rehabilitation 1, 193–198 (2008)
233. Hoffman, H.G., Garcia-Palacios, A., Patterson, D.R., Jensen, M., Furness, T.A., Ammons, W.F.: The Effectiveness of Virtual Reality for Dental Pain Control: A Case Study. CyberPsychology & Behavior 4, 527–535 (2001)
234. Furman, E., Jasinevicius, T.R., Bissada, N.F., Victoroff, K.Z., Skillicorn, R., Buchner, M.: Virtual Reality Distraction for Pain Control During Periodontal Scaling and Root Planing Procedures. Journal of American Dental Association 140, 1508–1516 (2009)
235. Schneider, S.M., Ellis, M., Coombs, W.T., Shonkwiler, E.L., Folsom, L.C.: Virtual Reality Intervention for Older Women with Breast Cancer. CyberPsychology & Behavior 6, 301–307 (2003)
236. McCorkle, R., Young, K.: Development of a Symptom Distress Scale. Cancer Nursing 1, 373–378 (1978)
237. Piper, B.F., Dibble, S.L., Dodd, M.J., Weiss, M.C., Slaughter, R.E., Paul, S.M.: The Revised Piper Fatigue Scale: Psychometric Evaluation in Women With Breast Cancer. Oncology Nursing Forum 25, 677–684 (1998)
238. Murray, C.D., Patchick, E., Pettifer, S., Caillette, F., Howard, T.: Immersive Virtual Reality as a Rehabilitative Technology for Phantom Limb Experience: A Protocol. CyberPsychology & Behavior 9, 167–170 (2006)
239. Murray, C.D., Pettifer, S., Howard, T., Patchick, E., Caillette, F., Kulkarni, J., Bamford, C.: The Treatment of Phantom Limb Pain Using Immersive Virtual Reality: Three Case Studies. Disability and Rehabilitation 29, 1465–1469 (2007)
240. Wright, J.L., Hoffman, H.G., Sweet, R.M.: Virtual Reality as an Adjunctive Pain Control During Transurethral Microwave Thermotherapy. Urology 66, 1320.e1–1320.e3 (2005)
241. Gracely, R.H., McGrath, F., Dubner, R.: Ratio Scales of Sensory and Affective Verbal Pain Descriptors. Pain 5, 5–18 (1978)
242. Hoffman, H.G., Patterson, D.R., Soltani, M., Teeley, A., Miller, W., Sharar, S.R.: Virtual Reality Pain Control During Physical Therapy Range of Motion Exercises for a Patient with Multiple Blunt Force Trauma Injuries. CyberPsychology & Behavior 12, 47–49 (2009)
243. Montgomery, G.H., DuHamel, K.N., Redd, W.H.: A Meta-Analysis of Hypnotically Induced Analgesia: How Effective Is Hypnosis? International Journal of Clinical and Experimental Hypnosis 48, 138–153 (2000)
244. Patterson, D.R., Jensen, M.: Hypnosis for Clinical Pain Control. Psychological Bulletin 129, 495–521 (2003)
245. Patterson, D.R., Tininenko, J.R., Schmidt, A.E., Sharar, S.R.: Virtual Reality Hypnosis: A Case Report. The International Journal of Clinical and Experimental Hypnosis 52, 27–38 (2004)

246. Scott, J., Huskisson, E.C.: Graphic Representation of Pain. Pain 2, 175–184 (1976)
247. Taal, L.A., Faber, A.W.: The Burn Specific Anxiety Scale: Introduction of a Reliable and Valid Measure. Burns 23, 147–500 (1997)
248. Ohrbach, R., Patterson, D.R., Carrougher, G., Gibran, N.: Hypnosis After an Adverse Response to Opioids in an ICU Burn Patient. Clinical Journal of Pain 14, 167–175 (1998)
249. Patterson, D.R., Everett, J.J., Burns, G.L., Marvin, J.A.: Hypnosis for the Treatment of Burn Pain. Journal of Consulting and Clinical Psychology 60, 713–717 (1992)
250. Patterson, D.R., Ptacek, J.T.: Baseline Pain as a Moderator of Hypnotic Analgesia for Burn Injury Treatment. Journal of Consulting and Clinical Psychology 65, 60–67 (1997)
251. Oneal, B.J., Patterson, D.R., Soltani, M., Teeley, A., Jensen, M.P.: Virtual Reality Hypnosis In The Treatment Of Chronic Neuropathic Pain: A Case Report. International Journal of Clinical and Experimental Hypnosis 56, 451–462 (2008)
252. Patterson, D.R., Hoffman, H.G., Garcia Palacios, A., Jensen, M.J.: Analgesic Effects of Posthypnotic Suggestions and Virtual Reality Distraction on Thermal Pain. Journal of Abnormal Psychology 115, 834–841 (2006)
253. Hilgard, E.R., Hilgard, J.R.: Hypnosis in the Relief of Pain. Kaufmann, Los Altos (1975)
254. Hoffman, H.G., Garcia-Palacios, A., Kapa, V., Beecher, J., Sharar, S.R.: Immersive Virtual Reality for Reducing Experimental Ischemic Pain. International Journal of Human–Computer Interaction 15, 469–486 (2003)
255. Magora, F., Cohen, S., Shochina, M., Dayan, E.: Virtual Reality Immersion Method of Distraction to Control Experimental Ischemic Pain. The Israel Medical Association Journal 8, 261–265 (2006)
256. Hoffman, H.G., Richards, T.L., Coda, B., Bills, A.R., Blough, D., Richards, A.L., Sharar, S.R.: Modulation of Thermal Pain-Related Brain Activity With Virtual Reality: Evidence From fMRI. Neuroreport 15, 1245–1248 (2004)
257. Hoffman, H.G., Richards, T.L., Van Oostrom, T., Coda, B.A., Jensen, M.P., Blough, D.K., Sharar, S.R.: The Analgesic Effects of Opioids and Immersive Virtual Reality Distraction: Evidence from Subjective and Functional Brain Imaging Assessments. Anesthesia & Analgesia 105, 1776–1783 (2007)
258. Hoffman, H.G., Sharard, S.R., Codad, B., Everetta, J.J., Ciol, M., Richards, T., Patterson, D.R.: Manipulating Presence Influences the Magnitude of Virtual Reality Analgesia. Pain 111, 162–168 (2004)
259. Hoffman, H.G., Seibel, E.J., Richards, T., Furness, T.A., Patterson, D.R., Sharar, S.R.: Virtual Reality Helmet Display Quality Influences the Magnitude of Virtual Reality Analgesia. The Journal of Pain 7, 843–850 (2006)
260. Riva, G., Manzoni, M., Villani, D., Gaggioli, A., Molinari, E.: Why You Really Eat? Virtual Reality in the Treatment of Obese Emotional Eaters. Studies in Health Technology and Informatics 132, 417–419 (2008)
261. Jang, D.P., Ku, J.H., Choi, Y.H., Wiederhold, B.K., Nam, S.W., Kim, I.Y., Kim, S.I.: The Development of Virtual Reality Therapy (VRT) System for the Treatment of Acrophobia and Therapeutic Case. IEEE Transactions on Information Technology in Biomedicine 6, 213–217 (2002)
262. Krijn, M., Emmelkamp, P.M.G., Biemond, R., de Wilde de Ligny, C., Schümie, M.J., van der Mast, C.A.P.G.: Treatment of Acrophobia in Virtual Reality: The Role of Immersion and Presence. Behaviour Research and Therapy 42, 229–239 (2004)
263. Juan, M.C., Pérez, D.: Comparison of the Levels of Presence and Anxiety in an Acrophobic Environment Viewed via HMD or CAVE. Presence 18, 232–248 (2009)
264. Botella, C., Garcia-Palacios, A., Baños, R.M., Quero, S.: Cybertherapy: Advantages, Limitations, and Ethical Issues. PsychNology Journal 7, 77–100 (2009)

Chapter 6

Virtual Reality and the Training of Military Personnel to Cope with Acute Stressors

Stéphane Bouchard[1], Tanya Guitard[2], François Bernier[3], and Geneviève Robillard[1]

[1] Université du Québec en Outaouais, Québec, Canada
{stephane.bouchard,genevieve.robillard}@uqo.ca
http://www.uqo.ca/cyberpsy
[2] Université du Québec à Montréal, Québec, Canada
tanya.guitard@uqo.ca
[3] Defence Research and Development Canada - ValCartier, ValCartier, Québec, Canada
Francois.Bernier@drdc-rddc.gc.ca

Abstract. Virtual reality is used in psychotherapeutic applications, but also as a training tool to practice stress management techniques and, hopefully, in the long term reduce the likelihood of developing posttraumatic stress disorder. This chapter begins with an overview of posttraumatic stress disorder and virtual reality technologies used in clinical research. The core of the chapter is dedicated to review studies using virtual reality to learn and practice stress coping skills or preparing military personnel to deal with stressful situations. Our analyses revealed that virtual reality is a promising training tool but more studies are clearly needed. Issues such as realism and the sense of presence are discussed and their role appears more complicated than initially thought.

1 Introduction

Posttraumatic stress disorder (PTSD) is the most frequent mental disorder that may develop when an individual encounters life-threatening events. In order to make that diagnostic one must, first and foremost, have experienced a traumatic event. According to the Diagnostic and Statistical Manual of Mental disorders (fourth edition – text revision) or DSM-IV-TR [1], an event is considered traumatic when it meets the following criteria: "the person has experienced, witnessed or was confronted with an event or events that involved actual or threatened death or serious injury, or a threat to the physical integrity of self or others" and is accompanied by a response involving either intense fear, horror or helplessness [1]. Thus, there are two dimensions to a traumatic event: an objective criterion relating to the characteristics of the event, and a subjective criterion involving the individual response to the event; the latter one can be peritraumatic and/or posttraumatic. Other criteria include symptoms of anxiety, arousal, dissociation, or flashbacks and affects between 1% and 14% of the general population. At-risk individuals (e.g. combat veterans, victims of natural disasters or criminal violence) have an exceedingly high prevalence rate of PTSD symptoms, ranging from 3% to 58% within three months of a trauma [1].

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 109–128.
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According to Hoge et al. [2], epidemiological data, the number for soldiers at risk for mental disorders increased from 9% to 16.6% for those who have returned 3-4 months post-deployment in the Middle-East, often experiencing symptoms of anxiety and flashback caused by their active duties. In a further study through a U.S. Department of Defence screening, 20.3% of soldiers and 42.2% of reserve soldiers returning from Iraq required mental health treatment [3]. The fifth report of the Mental Health Advisory Team (MHAT) [4], using self-report measures, states that 6.9% of the Iraq-deployed sample scored positive for depression, 7.3% for anxiety, 15.2% for PTSD and 17.9% for any behavioral problem. Other U.S. studies report similar estimates of PTSD, with slightly different cohorts, ranging from 14% to 16.6% [2,4]. Rates of PTSD may differ from one country to another, depending on the nature of the work performed by the soldiers (e.g., 4% for UK's 2003 deployment in Iraq [5]).

The rates of mental health disorders assessed with reliable structured interviews, as opposed to estimations based on using self-report measures, have been reported by Sareen, Cox, et al. [6] based on information collected in 2002 on 5155 regular Canadian Forces members and 3286 reserve Canadian Forces. However, their data were not gathered specifically with deployed or recently deployed personnel but rather reflect the mental health of military personnel in the last 12 months as measured while they were on their base in Canada (only 34% had been in combat or peacekeeping mission) [6]. The one-year prevalence of the four most common mental disorders in their sample was 6.9% for major depression, 4.8% for alcohol dependence, 3.2% for social phobia, and 2.3% for PTSD. PTSD is the mental disorder which prevalence is most increased by exposure to combat, to peacekeeping operation and to seeing atrocities / massacres, with increases in the magnitude of 2.1, 1.15 and 4.33 fold, respectively. Sareen, Belik, et al. [7] added that the diagnosis of PTSD in their sample is essentially the only mental disorder significantly associated with combat and/or peacekeeping missions, and that most other mental health problems found in this sample are attributable to a wide range of putative risk factors. Furthermore, participating in both combat and peacekeeping missions appears to have the worse impact on mental health, as opposed to being exposed to combat or peacekeeping only.

In addition to direct life-threatening events such as being shot at, other stressors are involved in theater of operation, such as participation in the killing of enemy soldiers, living under the constant threat of identifiable and unidentifiable combatants (such as booby-trapped children or infants), witnessing horrifying maiming and slaughter of fellow soldiers or civilians (grotesque death, dismemberment, disfigurement), failing to act against (or participating in) the commission of atrocities, isolation, ambiguity (of the mission or command structure), powerlessness and boredom [2,8-11].

2 Stress Management Techniques for Military Personnel

Training in stress management is important, and not only because it might reduce the risk of PTSD and other psychological injuries. Stress and anxiety also reduces operational effectiveness [12]. Anxiety, acute stress or operational stress affect information processing, including focus of attention, sensitivity to certain peripheral cues, memory recall and encoding. It also directly influences physiology (e.g., trembling) and emotion regulation, and thus has a strong impact on performance in situations requiring emotional, cognitive and behavioral control such a military operations [13]. Chronic stress also exacerbates the impact of acute stressors.

Guidelines have been developed to deal with combat stress (e.g., U.S. Marine Corps, [14]) and include coping strategies to implement before deployment to a combat zone, during deployment and when returning home. Some of these strategies have also been implemented in structured programs to build resilience and prevent psychological injuries, including PTSD, such as Battlemind Training developed at the Walter Reed Army Institute of Research [15] or the Military Resilience Training Program (MRTP) developed by for the Canadian Forces by Routhier [16]. MHAT-V data collected during deployment of military personnel who had received Battlemind Training and were deployed in Iraq, suggests that 54.4% of those who received it felt the training was adequate [15]. This program may have reduced from 20.35% to 12% the rate of soldiers deployed in Iraq scoring positive on mental health problem. The data on the impact of the Battlemind Training does not come from a randomized control trial and may be biased or inflated by the concomitant implementation of other effective behavioral health prevention and interventions strategies implemented before, during and after deployment in the Middle East [17-19].

The stress management techniques of the MRTP are more elaborated than the Battlemind Training. It is grounded in a cognitive-behavioral / bio-psychosocial approach and also includes a spiritual dimension. The portion of the program developed specifically for soldiers unfolds in 13 modules delivered in workshops and lectures cumulating in 13 hours of training pre-deployment. The program remains active during the mission, in the form of peer-support. Additional sessions are also delivered post-deployment. Pre-deployment, SMT skills are taught over a period of six to nine months and the vocabulary is adapted to the culture and attitude of military personnel towards stress and coping skills. Some coping strategies address primary appraisal of stressful stimuli (e.g., self-talk, thought stopping), other allow building a realistic but more reassuring secondary appraisal coping (autogenic training and meditation, visualization, listening to music, signing or reading, humor), and some can be used to sustain acute stress associated with objective life-threatening stressors (e.g., listening to silence, focusing, breathing, de-identification). Preliminary data on the use of the MRTP are encouraging [20]. Out of 640 respondents who completed the post-deployment survey, 58% felt the training was useful and 85% considered the program well adapted to the military reality.

The stress management and coping skills mentioned above have been modified to fit with what is referred to as Mental Readiness Training, where the classical cognitive-behavior strategies are adapted to the military culture and context, and delivered by people with operational experience and credibility [13,16]. Unfortunately, there is no data on how socially acceptable it may be for military personnel to actually practice stress management skills in programs such as the MRTP. Because of virility or potential "Army Strong" mentality, some soldiers may be reluctant to practice emotion regulation techniques. In addition, further research is needed to document whether programs such as these can reduce the amount of deployment-related mental health concerns experienced by military personnel.

Yet, simply teaching general coping skills during lectures, even in a 13-hour workshop, is not sufficient. Like any behavioral skill, learning in theory how to use coping strategies will transfer poorly to actual behavior change in stressful operational situations. Practice under stressful situations is needed, and virtual reality appears to offer interesting possibilities to facilitate this practice within the general context of enhancing mental readiness [13,21], in order to allow training military personnel to be more efficient in psychological coping skills to control their emotions, cognitions and behaviour.

The current chapter focuses on the scientific literature on stress management strategies and proposes solutions using virtual reality. Basic information on the use of this technology in mental health will first be briefly addressed (e.g., the technology frequently used, the potential to induce useful levels of anxiety), followed by an overview of PTSD treatments using virtual reality and a detailed description of its use in stress management training of military personnel.

3 Virtual Reality and Its Potential to Induce Anxiety

By definition, virtual reality (VR) is "an application that lets users navigate and interact with a three-dimensional computer-generated (and computer-maintained) environment in real time" [22]. The key concept that differentiates VR from the use of other audio-visual media is interactivity. Even if stressful stimuli are presented on slides, computer or IMAX theatre screen, this is not sufficient to be considered as VR. The mediated experience becomes a virtual reality when participants can interact and explore the surroundings (e.g., open a door, walk out of a room) and the displayed images are changing accordingly.

Different technologies can immerse the user to different degrees in the virtual environments, from a simple presentation on a computer screen to the use of head-mounted displays and motion trackers, and even to a full-size 10 by 10 by 10-foot room with stereoscopic images projected on walls, floor and ceiling.

The most affordable immersive technology is often referred to as HMD, because of its reliance on head mounted displays (see Figure 1). With this type of technology, the user can be immersed in virtual reality through the use of a virtual reality helmet that allows either monoscopic or stereoscopic display. In addition, a motion tracker tracks, at least, the head rotations (refined system offer more complete tracking solutions, including 6dof for the head and the use of more than one tracker) and the computer adapts the virtual images according to the user's head movements. Room-size systems, often referred to by the trade name of CAVE[1] (C-Automatic Virtual Environment™, Fakespace Technology), are very attractive mediums to deliver virtual stimuli. They are very appreciated in the research community. As the user stands up in the middle of stereoscopic 3D projected images (see Figure 2), objects are seen as literally there, perceived as if they were in the middle of the room surrounding the user. The field of view is much wider than the majority of HMDs and the user can actually see his physical body. Immersive rooms are often considered the gold standard of immersive technology because of their power to induce the illusion of presence. But they are also extremely costly to build and require a fairly large amount of physical space.

[1] Since CAVE is a trademark, similar systems not built by Fakespace are often referred to as CAVE-like systems. The C in the acronym CAVE was added to Automatic Virtual Environment to create a recursive acronym that would provide a meaning to the acronym.

Fig. 1. A therapist (right) and (left) his patient immersed in virtual reality using a HMD.

Fig. 2. A user immersed in the kitchen of a virtual reality apartment in a 6-wall retro-projected immersive room (often referred to as a CAVE™).

The military, medical and entertainment industries were instrumental in the early development of VR applications. The technology really gained popularity in clinical psychology in the early 1990's, with VR being used to treat anxiety disorders. Initially, VR was used with specific phobias [23,24], which was useful for researchers in need of well defined mental disorders, circumscribed treatments and easily available objective and behavioral outcome measures. The field is now moving towards more appealing applications for clinicians [25; see also chapters 4, 5, and 7, in this volume], such as complex anxiety disorders like PTSD.

The potential of VR to elicit genuine fear reaction when people are exposed to stressful virtual stimuli is a prerequisite for using VR in stress management training (SMT). The capacity of VR to reliably produce stress reactions has been repeatedly documented. For example, Robillard et al. [26] have demonstrated that the presentation of frightening virtual stimuli to non-phobics participants can elicit subjective fear reactions, and these reactions are significantly more intense among phobic participants. Renaud et al. [27] have shown using eye-tracking that presenting frightening virtual stimuli can lead to behavioral avoidance patterns that are significantly more pronounced in phobics than in normal controls. Looking at physiological measures, Moore et al. [28] have shown that non-phobics encountering potentially stressful virtual situations such as elevators, grocery stores or avatars (virtual copies of people) manifest significant changes in heart rate and skin conductance. Meehan [29] and Zimmons [30] have assessed participants' reaction under a variety of conditions while immersed in a virtual environment and confirmed that VR can produce strong and significant changes in heart rate, skin conductance and skin temperature when exposed to phobogenic cues.

People's reactions to virtual stimuli also apply to virtual humans. For example, James et al. [31] have immersed non-phobics in various virtual social environments and observed an increase in anxiety when participants had to interact with virtual humans who appeared disinterested by their presence. Later on, the same research team [32] compared the impact of giving a speech in an empty seminar room or to a virtual audience on phobics and non-phobics. The level of anxiety, measured subjectively and physiologically, was low among non-phobics in both conditions, but it was significantly higher among phobics in the empty room condition and even higher when the phobics delivered their speech to the virtual humans. Pursuing their research on autonomous agents, Pertaub et al. [33] compared the reaction of 43 people suffering of fear of public speaking when they delivered two speeches to an audience of autonomous agents that were programmed to respond neutrally (no reaction), positively (leaning forward, eyes wide open, etc.) or negatively (leaning back, discussing among themselves, etc.) to the speeches. Delivering a speech to the negative audience was significantly more anxiety inducing and rated as less satisfying than delivering a speech to a neutral audience. Interestingly, all these studies used virtual environments and virtual representations of humans that were far from perfectly realistic. They also found significant correlations between stress and the feeling of presence (the illusion of being in the virtual environment), which might give us clues to explain why VR can elicit strong emotions.

However, it is not clear whether physiological responses to virtual environments show a consistent pattern across individuals. Wiederhold and Wiederhold [34] found that participants do not show consistent changes in peripheral skin temperature or heart rate when being exposed to virtual environments. Similarly, Jang et al. [35] exposed eleven non-phobic individuals for fifteen minutes to virtual environments depicting a flying or driving scenario. Analyses of heart rate variability showed no significant differences between an interactive driving condition and passively exploring a flying environment. Within environments, however, baseline and immersion heart rates were significantly different in the driving but not the flying environment. Consistent with extinction principles, participants initially showed an increased skin conductance in the driving environment that dissipated after seven minutes.

4 VR in the Treatment of PTSD

Two potential approaches to reduce PTSD are treatment and prevention. The current chapter focuses on the second option, preventing psychological injuries by increasing resilience, but it seems important to overview what information is presently available in the treatment of PTSD using VR technologies.

VR has made substantial advancements in the field of PTSD, improving and enhancing treatment efficacy for this disorder in the survivors of several types of trauma. Cognitive-behavior therapists use VR-based exposure therapy to create a safe, virtual environment with the ability to allow a patient to stop avoiding the intrusive flashbacks associated with PTSD and “relive” their experiences in a thorough and efficient method, by slowly exposing themselves to events that trigger memories of the traumatic event. In some treatment protocols, the patient is first taught coping skills, and can then use those skills while exposed to the traumatic events in VR. The patient can then, at their own pace, move through the traumatic scenarios and experience the corresponding emotional responses [36,37].

For example, Rothbaum et al. [38] used HMD technology to immerse 16 Vietnam veterans suffering from PTSD in environments including a helicopter and jungle terrain. Patients experienced a 34% decrease in clinician-rated PTSD symptoms and a 45% decrease in self-ratings. Using scenarios depicting stressors commonly experienced in Iraq, Wood et al. [39] showed that after VR-based exposure therapy, two-third of their sample of Iraq war veterans no longer met the diagnostic criteria for PTSD. Applications of VR to the treatment of PTSD for military personnel are recent and a popular topic in the field, as shown by the frequent publications from ongoing randomized clinical trials [40-42]. Based on the Wiederhold and Wiederhold [43] review and recently published work, we were able to find 19 studies published on the use of VR to treat PTSD, for a total of 413 patients and five types of trauma (war, car accidents, earthquakes, September 11th / Word Trade Center incident, and terrorist attacks). The war-related traumas include Vietnam [38], Angola [44] and Iraq [45; also see chapters 2, 3, 4, and 5 for additional studies].

5 The Use of VR in Stress Management Training

VR can also be used as a way of preventing PTSD in militaries by preparing individuals to deal with stressful situations. A key publication comes from researchers at the Virtual Reality Medical Center, led by Mark and Brenda Wiederhold, who published in 2005 their final report on studies performed with a total of 612 members[2] of elite units of the United States Navy, United States Marine Corps and United States Coast Guard [46]. Their aim was to document the effectiveness of VR training to increase performance in applying tactical and trauma care skills as well as practicing combat breathing. They also purposefully conducted all their immersions using a (yet powerful for the time) laptop computer and no HMD in order to test a low-cost solution. They replicated the same experimental design for most study, with less than half of the participants receiving one session of VR training where they practiced performing their duties while their stress and arousal were monitored. Participants in the control

[2] This number is based on the actual number of participants reported in the five studies (with only 332 having received VR training).

condition did not receive any VR training. It is assumed that participants were not randomly assigned to the experimental conditions in the first four studies. The authors describe their key outcome measures as actual response time in “real world” physical environments, subjective and rated assessments from training officers and psycho-physiological assessment during VR training (e.g., heart rate, skin conductance, and breathing rate).

In Study 1, 90 U.S. Marine Corps navigated a virtual shoothouse for approximately 15 minutes and feedback was provided on their performance after the immersion. The tasks were to take down and secure the "objective" (shoothouse) as quickly as possible, conduct sensitive site exploitation and exfiltrate a crisis sight in a village. The authors compared on a variety of parameters the performance of the 90 participants trained in VR with 120 Marines that did not receive any training at all. Results, based on mostly subjective information, suggest an increased efficiency of those who received prior training. The few data subjected to statistical analyses revealed that: (a) averaged over 60 trials, participants trained in VR took 9 seconds to clear the physical room, as opposed to 11 seconds in the control group who never had any training ($p < .001$); (b) those receiving VR training took (averaged over 35 trials) 21 minutes to secure the objective as opposed to 23 minutes (averaged over 32 trials only) for those in the control group. When it comes to conducting site sensitive exploration, receiving VR training significantly ($p < .001$) reduced the time to sketch the layout of the house to 4 minutes as opposed to 6 minutes in the control group. A host of other data are reported, notably higher accuracy for Marines who benefited from the VR training and the accompanying feedback, but no statistical analyses are reported to confirm whether these differences occur above chance level.

Study 2 was conducted with United States Navy SEAL, with 30 team members receiving the same VR training as Study 1, and 90 team members being in the control condition. No empirical data or statistical analyses are reported for this sample but, as suggested by authors, VR training might have been helpful according to qualitative observations.

The third study from Wiederhold [46] report was conducted with 30 U.S.M.C. Marine Expeditionary Unit but with no control condition. Participants’ task was to conduct “Visit, Board, Search, and Seize” procedures on a ship. The VR training consisted of taking a virtual ship under custody and search for hidden cargo and contraband within 10 minutes. No empirical data or statistical analyses are reported for Study 3 but the authors considered that VR training was helpful based on several observations, such as reduction in 14.2% of time needed to search the ship. The same comments can be formulated for Study 4 conducted with United States Coast Guards' Pacific Tactical Law Enforcement Detachment. They report encouraging descriptive and qualitative data gathered on 20 participants receiving VR training and 80 participants in the control condition.

The last study was conducted with 152 members of the Light Armored Reconnaissance battalion. They were midway through their pre-deployment work up and the focus of their training was on military operations in urban terrain and house clearing in the shoothouse (as in Study 1 and 2). The study aimed at several objectives at the same time: (a) compare whether training with the VR scenario was more effective that simply playing a computer game (in which one links chains of identical sparkling jewels), and to no training at all, (b) compare if training on the laptop was less effective than projecting the image on a screen from approximately 15 feet away (note, there is no indication that stereoscopy was used), and (c) whether multiple performance in the physical reality has an impact on time it takes to clear the physical house. For the first research question, it took 9.42 seconds for those trained in VR to perform their task as opposed to the 12.07 and 12.15 seconds it took by participants the two control conditions. For the second research question, participants performed their task in 8.42 seconds when they received training with the large screen, in 9.42 seconds when the training was done on the desktop and 12.07 seconds when had no training at all. Finally, repeating four times the clearing of the physical house improved performance time from 12.19 seconds to 9.85 while those who received the desktop training took 9.42 seconds. Sadly, no statistical analyses were reported so it is impossible to confirm if the differences found in this study were significant.

In their review on stress management training, Wiederhold and Wiederhold [43] report a few additional studies where VR was used. One study was conducted by Tarnanas and Manos [47] where they used VR to train pre-school children and children suffering from Down syndrome to evacuate their classroom in the case of an earthquake. Although this may resemble more stress inoculation than stress management training and the study was not conducted with military personnel, their results are interesting as they show that participants were able to learn to better perform under a stressful virtual situation. In a preliminary phase of the larger study mentioned above [46], Wiederhold and Wiederhold [48] tested whether practicing in VR tending to a wounded virtual person while being shot at, or without being shot at, had an impact on performance. According to the information reported in Wiederhold and Wiederhold [43], results were positive.

Another line of research in stress inoculation / management straining of military personnel is the training of medical personnel. In 2008, Stetz et al. [49] published the conclusion of a project whose results were progressively released in 2006 [50] and 2007 [51]. The final sample was composed of 63 military volunteers who were attending combat medical class (for flight medic, ranger's first responders, mountain medics and medical personnel). Two tasks were available and performed over two or four sessions. One task consisted in providing care to a wounded team member and within about three minutes to triage, stop life threatening bleeding, treat casualties, administer intravenous fluids and pain medication, chest seals, call for medical help, etc. The other task consisted in treating a similar casualty inside a helicopter. The immersion in VR was created with the use of a HMD (z800 by eMagin) and its built-in tracker, a low frequency set of speakers (to reproduce vibrations) and olfactive cues produced with a scent machine (Scentpalette). The stress management training consisted in practicing progressive muscle relaxation and controlled breathing while performing the task. Participants were assigned to the following four conditions: (a) control with no training at all, (b) no training with the VR tasks but training in stress management, (c) training with the VR tasks with no stress management, and (d), combined training with the VR tasks plus stress management. Condition (b) actually constitutes a second control condition as it provides a baseline upon which the other two experimental conditions can be compared. The goal of the study was to induce stress during the task, and is therefore presented by the authors as an approach to harden soldiers against the stressors they will encounter in the battlefield.

The analyses could not find any difference between the three experimental conditions and the control group, maybe because of the small size of this group (n=9) compared to the experimental groups (each n = 18). When performing the analyses with the three experimental groups and taking into account whether participants have been deployed or not in the past, two results stand out. First, those immersed in the VR only and those immersed in the VR combined with stress management felt more hostility during the sessions than those in the stress management only condition. Second, participants who had been deployed in the past felt more anxiety during the sessions in the VR only condition than those in the same condition who had never been deployed before. The impact of previous deployment on anxiety was not significant in the other two conditions, where stress management was applied. Other statistically significant findings were reported for sensation seeking and dysphoria, but they are difficult to meaningfully interpret given the pattern of results and the analyses performed.

Stetz et al.'s [49] findings on hostility revealed that their VR environment increased the hostility level in all participants who were immersed. Participants scored higher on a scale measuring the extent to which they felt annoyed, critical, disagreeable, disgusted, furious, hostile, etc. It shows that the content of the VR environment and the tasks performed may have been quite effective in inducing frustration. In addition, the use of the stress management strategies was ineffective in buffering the level of hostility, probably because of the strength of the hostility induced by the environment and because participants learned to apply the strategies during the immersion, as opposed to progressively mastering the techniques before applying it to highly engaging situations [6,52]. However, these can only be tentative conclusions given the lack of random assignment and control of pre-experiment levels of hostility (e.g., pre-experiment comparisons or repeated measures analyses).

Findings on anxiety are interesting as well because anxiety was induced only in those who meet three conditions: having been deployed in the past, being immersed in the VR environment, and not applying the stress management techniques. This suggests that the content of the VR environment and the task were anxiogenic for people who may have been sensitized to emotionally related to it because of past experience, and also that the stress management techniques may have been effective in buffering the level of anxiety. However, since the analyses did not control for pre-intervention levels of anxiety, it is impossible to state whether the results among those who received stress management are due to individual differences prior to the experiment among participant's ability to regulate stress or to the acquisition of new and effective skills. Findings on dysphoria, which is a global score combining anxiety, depression and hostility, further question the impact of prior individual differences. Indeed, significantly more dysphoria was found in those who had been previously deployed, as compared with those who have not, both in the participants that were immersed in the VR only and in those who received stress management, but opposite results were found in those in the combined condition. Nevertheless, we concur with Stetz et al. [49] that the study suggests VR may increase negative affect in those who have previously been deployed and that it is a promising tool to harden military personnel for future operations.

In a recent yet unpublished study, Stetz et al. [53] assessed sixty soldiers to document their receptivity to stress management techniques. Given the potential negative impact of a culture favouring virility in the military personnel, this research question seemed especially timely. For three days the experimental group practiced progressive muscle relaxation and controlled breathing while listening to a script embedded in a video of an isolated beautiful 3D island developed for VR. In the mornings, they would practice these techniques while watching the video projected on a screen. In the evening, they would watch the same video but via a portable play station. Preliminary results show they prefer the controlled breathing technique but they all liked both techniques. About half of the sample also said they would consider practicing these techniques after the study. More results are expected from this study based on analyses of additional objective data [54]. These results concur with those reported by Routhier [20] with the MRTP that stress management is well accepted. What remains to be documented is whether they actually practice stress management strategies until they master it.

In sum, the interactivity and possibility to create virtual scenarios that resemble physical reality are significant assets for using VR in SMT training. Wiederhold [46] reported some data suggesting that having military personnel practicing a house clearing and other similar tasks using a 3D software on a desktop, along with receiving feedback, may improve actual performance by a few seconds. Stetz et al.'s work suggests that being immersed in a VR environment to perform a simulated, low interactivity, medical task can possibly increase psychological stress, especially hostility and anxiety among people who have been previously deployed. For the moment, most of the VR research in the field of psychological application for stress related problems focuses on the treatment of PTSD, with less than a handful of studies on SMT.

6 The Feeling of Presence

It is intriguing that VR may be effective given the fact that virtual reality does not perfectly replicate physical reality. The impression that the virtual reality is "the real reality"[3] has been defined as the subjective impression of being *there* in the virtual environment [55]. Presence is also thought to be related to the suspension of

[3] The expression "real reality" is used here only to introduce the concept of presence because reality is a subjective construction, hence the need to use a more adequate term such as physical reality instead of real reality.

disbeliefs [56], or when the user fails to perceive the existence of a medium in his interactions with the environment (the illusion of non-mediation; [57]). Presence may occur when a person interacting with a virtual environment reports a greater degree of interactivity with the virtual environment than with their physical environment [34].

Presence should be distinguished from immersion, the latter being related to the technology used to provide multimodal sensory input to users [55]. Immersion is an objective and quantifiable description of what any particular system provides, compared the subjective feeling of being transported in VR.

Sadowski and Stanney [55] and Slater and Usoh [58] proposed to organize the known factors influencing the level of presence experienced in a virtual environment in seven categories: (a) ease of interaction (presence is reduced when user have difficulties navigating in the virtual environment); (b) user-initiated control (the greater the level of control a user has regarding their action, the higher the presence); (c) pictorial realism (the quality of the visual display is related to presence, although it is much less influential than other factors, see the second paragraph below); (d) length of exposure (presence level raises during the first few minutes of immersion and usually remain stable until influenced by specific stimuli or events); (e) social factors (the feeling of presence is increased when communicating with virtual or physical people); (f) system factors (the better the technology and multimodal sensory input replicate the objective reality, the stronger the feeling of presence); and (g) internal factors (individual differences in how individuals cognitively and emotionally process the information).

In 2006 and 2007, Youngblut [59,60] submitted to the Institute of Defence Analyses reports where she performed a comprehensive analysis of system factors influencing presence. She reviewed 301 studies, looking at details like methodology and factors such as technical characteristics, interfaces, tasks performed by users, etc. Her results (see Figure 3) represent the best and most comprehensive synthesis of studies published in peer-reviews journals and conference proceedings. She confirmed that stronger presence is associated with using: (a) more immersive technologies, (b) better textures, more realistic light maps, higher polygon count, (c) visual displays with higher resolution, wider field of views and foreground occlusion, (d) peripherals providing more interactivity, (e) more efficient navigation methods and computer performances, and (f) high quality and spatialized audio stimuli. It is important to highlight here the conclusion that CAVE-like system reliably produces more presence than HMD technology, which are superior to desktop display [61-63]. Her review also support the growing notion among researchers that an increase in all the factors cited above do not necessarily lead to corresponding increases in presence. There may be a ceiling effect where beyond a certain point it is not cost effective to invest money, time and energy to reach for higher sense of presence.

Youngblut's reviews did not address specifically internal factors such as emotions, which also play a role in presence. Judgment about the perceived realism of VR environments is significantly affected by stress and anxiety. The Robillard et al. [26] study mentioned earlier is an example where the comparison between phobics and non-phobics revealed significantly stronger anxiety, presence, and sense of realism among phobics. Taking the realism to a minimum, Herbelin et al. [64] asked social anxious participants to deliver a speech in a virtual room filled with images of just

Audio display:	Aural rendering quality	▲	Sound rotation, velocity	▲
	HRTF	▲	Spatialized audio	■ ●
	Sound rotation, direction	▲		
Avatars & Agents:	Agency	○	Relation to user	▲
	Behavioral realism	●	Role, interacting	●
	Form realism	○	Role, passive	●
Interaction:	Audio interaction aid	▲	Latency, end-to-end	▲
	Collision detection, audio	▲	Latency, visual	▲
	Collision detection, haptic	▲	Level of	●
	Collision detection, tactile	▲	Moving between worlds	▲
	Collision detection, visual	▲	Number of	▲
	Haptic force feedback	●	Passive haptics	○
Navigation:	Control of	○▲	Navigation method	■ ●▲
	Device	▲		
Self-representation:	Fidelity of body	■ ○	Fidelity of hand	○
User movement:	Cross-modal illusions	▲	Seated or standing	▲
	Head movement, bending	▲	Vection	○
	Hand reaching	▲		
Visual detail:	Color	▲	Scene realism	□ ●
	Dynamic shadows	○	Texture mapping, use of	●▲
	Rendering quality	○	Texture mapping, quality	●
Visual display:	Device, Cave-HMD-monitor	■ ●	Frame rate	▲
	Device, HMD-monitor	■ ○	Resolution	▲
	Device, HMD-p/screen-monitor	○	Stereopsis	●
	Device, proj screen-monitor	●	Tracking, face	○
	Device, other	▲	Tracking, head	○
	Field of view	●▲	Update rate	■ ●
	Foreground occlusion	■ ●		
World characteristics:	Audio cues	○▲	Olfactory cues	▲
	Audio sources, nature of	▲	Presentation quality	■ ●
	Audio sources, number of	■	Scene detail	■ ●[2]
	Manipulation, presence	▲	Speed of user movement	▲
	Manipulation, social presence	▲	Tactile cues	○

Key:
■ Replicated experiments with consistent findings
□ Replicated experiments with inconsistent findings
▲ Single experiment
● Other experiment(s) with consistent findings
○ Other experiment(s) with inconsistent findings

Fig. 3. Reproduction of Younglut's (2007) summary of the analyses of factors associated with presence. Reproduced with permission from the Institute for Defense Analyses.

and only eyes staring at them. Even in this unrealistic condition, participants reported significantly higher subjective anxiety and heart rate.

Zimmons [30] immersed 42 non-phobics in a virtual height simulation (throwing balls down a pit) and, in an attempt to assess whether the texture or the lighting quality of the image played a role in the experience felt in VR, used a simple black and white grid representation of the virtual pit as a control condition. Interestingly, there was a statistically significant increase in anxiety, as measured with heart rate, even in the black and white environment. These are only a few examples reminding us that emotions are not logical and that anxiety can be triggered by the simple perception of a threat, even if the stimuli are virtual, cartoonish and not really dangerous.

The relationship between presence and the level of anxiety felt in the VR environment may be more complex than it appears at first glance. As mentioned earlier, there is a strong relationship between anxiety and presence. For example, Robillard et al. [26] reported a significant correlation (r = .74, p < .001) between anxiety and presence. In order to document the direction of the causal relationship between anxiety and presence, two studies were conducted by Bouchard and his colleagues. In a first randomized single-blind study conducted with snake phobics, participants were told that the virtual environments were either infested or not infested with snakes [65]. Since the VR environments were exactly the same, changing the instructions allowed the researchers to manipulate experimentally the level of anxiety and assess its impact on presence. Using a counter-balanced design, they found that inducing anxiety lead to a significant increase in presence. To test the inverse relationship, Michaud et al. [66] asked acrophobics to do a stressful task (i.e., riding a glass elevator up to a selected floor, crawling outside the building while looking down to the streets, walking on wooden scaffolds toward a building across the street, etc.) while immersed in VR with conditions that were favourable or unfavourable to presence (lights turned on in the laboratory, surrounding physical environment visible in the participant's field of view, etc.). Interestingly, the randomized single-blind and crossover trial showed that levels of anxiety were higher in the immersions conducted when presence was higher, and vice versa. Taken together, these two studies suggest that there is a reciprocal determinism between anxiety and presence; increasing anxiety leads to more presence, and more presence leads to increase in anxiety. What remains to be tested is whether this relationship is linear and if it holds if only a minimal level of stress, or presence, is reached.

The relationship between stress (more precisely, anxiety) and presence has been studied to a limited extent, yet this is significantly more than what had been done with performance in the physical world. For learning to perform new tasks [67] or new academic [68] or educational [69] concepts, researchers have not thoroughly addressed the question. Some authors [67] even confess explicitly that attaining high degrees of realism is not essential in creating a virtual environment.

We found one study by Youngblut and Huie [70] where presence in the virtual environment and performance in a physical environment was examined. A group of 35 students were randomly assigned to three conditions: a control group (with no VR training), and Immersive VR training group (with one rear large projection screen) and a Desktop VR training group (non-immersive interface). The VR task had been developed for the special nuclear, biological and chemical response team and involved two training missions for basic procedures in searching for weapons of mass destruction (e.g., identify hazardous material, suspicious objects and casualties, position alarms, etc.). Participants in the control group only studied a manual describing mission's procedures. Those in the VR groups received, in addition to the manual, two training missions using the interactive 3D software. Coaching and feedback was also provided during the VR training. A performance score was derived based on audio and video recordings of a survey mission conducted in the physical reality, as well as an inspection of the searched areas. The analysis showed a significant effect of training condition on knowledge of mission procedures ($p < .001$), with participants in the Immersive VR condition achieving higher mission scores. There was no difference in presence ratings in both VR training conditions, probably due to the limited immersiveness of both systems. Correlations with performance yielded mix results, with a significant correlation with the Slater and Usoh Scale ($r = .42$, $p < .04$) but not with the Presence Questionnaire ($r = .39$, $p = .059$). However the non-significant correlation with the Presence Questionnaire may be related to limitations inherent to this instrument.

It is important to differentiate the role of presence in the transfer of skills from the virtual to the physical reality, and skills' transfer itself. It is not because the contribution of presence is understudied that generalization of learning should be questioned. There is a wealth of evidences showing that what is learned in a virtual reality is real and can be generalized *in vivo* to the physical reality (see Stanney [24] for reviews). For example, in the field of anxiety disorders (see Bouchard et al. [71] for a review), several randomized control trials have demonstrated that successfully learning to face feared stimuli in virtual reality transfers in the patient's day to day life, and up to many years post treatment. Studies in the area of motor and cognitive rehabilitation (see Holden [72] for a review) demonstrate that people can learn, or reacquire, motor and cognitive skills thanks to virtual reality.

7 Conclusion

VR has already proven to be effective in the treatment of a variety of mental health disorders, ranging from specific phobias [24] to more complex disorders like PTSD. Preliminary work is also presently being done on the utilization of VR in the prevention of disorders such as PTSD. To further this work, virtual reality could be used to provide a context where military personnel can practice newly learned coping strategies.

The basic principle for effective learning of a coping skill is to first teach and explain the strategies. That can be done in a group format and can be formulated in different ways that target various audiences, from policy makers to soldiers. However, the next step is to practice coping skills in simple situations, and then progress to more and more stressful (and potentially traumatic) events, using virtual reality. The user can, at his or her own pace, move through the stressful scenarios and learn to master the required stress management strategies. Trainers could also better tailor the training situations to the specific needs of each soldier. It is then expected that soldiers will transfer these skills and apply more efficiently the stress management strategies while facing stressful and potentially traumatic situations during deployment. As suggested by Stetz et al. [73] and Thompson and McCreary [74] virtual reality based training would offer the opportunity for the infusion of mental readiness training principles as the scenario unfolds and reinforce the lessons learned in courses, videos and classroom simulations.

Further research is of course necessary to materialize this line of work with VR. Nevertheless, virtual reality could prove to be a tool with endless possibilities to train different populations in stress management to ultimately augment their efficacy and even, hopefully, prevent possible negative outcome such as PTSD in the military.

Acknowledgement

This project was supported by a grant from the Canada Research Chairs program awarded to the first author and stems from a contract from the Canadian Forces. Portions of this paper were included in an internal research report presented by the first author to the Canadian Forces [Bouchard, S. (2009). *Foundations for Stress Management Training of Traumatic Stressors Using Virtual Reality*. Defence R & D Canada – ValCartier. Contract report CR 2009-170]. Corresponding address: Stéphane Bouchard, Dept de Psychoéducation et de psychologie, Université du Québec en Outaouais, C.P. 1250 Succ. "Hull", Gatineau, Québec, J8X 3X7. E-mail: stephane.bouchard@uqo.ca. The opinions expressed in this publication reflect those of the authors and do not necessarily represent the opinion of the Canadian Forces or the Department of National Defence.

References

1. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders, 4th ed. Text Revision. APA, Washington (2000)
2. Hoge, C.W., Castro, C.A., Messer, S.C., McGurk, D., Cotting, D.I., Koffman, R.L.: Combat Duty in Iraq and Afghanistan, Mental Health Problems, and Barriers to Care. New Eng. J. of Med. 351, 13–22 (2004)
3. Milliken, C.S., Auchterlonie, J.L., Hoge, C.W.: Longitudinal Assessment of Mental Health Problems Among Active and Reserve Component Soldiers Returning From the Iraq War. JAMA 298, 2141–2148 (2007)
4. Mental Health Advisory Team (MHAT) V.: Operation Iraqi Freedom 06-08: Iraq / Operation Enduring Freedom 8: Afghanistan. Department of Defense, the United States of America (2008)
5. Hotopf, M., Hull, L., Fear, N.T., Browne, T., Horn, O., Iversen, A., et al.: The Health of UK Military Personnel Who Deployed to the 2003 Iraq War: A Cohert Study. Lancet. 367, 1731–1741 (2006)
6. Sareen, J., Cox, B.J., Afifi, T.O., Stein, M.B., Belik, S.-L., Meadows, G., et al.: Combat and Peacekeeping Operations in Relation to Prevalence of Mental Disorders and Perceived Need for Mental Health Care. Arch. Gen Psych. 64, 843–852 (2007)
7. Sareen, J., Belik, S.-L., Afifi, T.O., Asmundson, G.J.G., Cox, B.J., Stein, M.B.: Canadian Military Personnel's Population Attributable Fractions of Mental Disorders and Mental Health Service Use Associated with Combat and Peacekeeping Operations. American J. Public Health 98, 2191–2198 (2008)
8. Bartone, P.T., Adler, A.B., Vaitkus, M.A.: Dimension of Psychological Stress in Peacekeeping Operations. Military Medecine 163, 587–593 (1998)
9. Callers, J., Foy, D.W., Donahue, C.P., Goldfarb, J.: Post-Traumatic Stress Disorder in Vietnam Combat Veterans: Effects of Traumatic Violence Exposure and Military Adjustment. J. Trauma. Stress 1, 181–192 (1998)
10. Flack Jr., W.F., Litz, B.T., Keane, T.M.: Cognitive-Behavioral Treatment of War-Zone-Related Posttraumatic Stress Disorder - A Flexible, Hierarchical Approach. In: Follette, V.M., Ruzek, J.I., Abues, F.R. (eds.) Behavioral Therapies for Trauma, pp. 77–99. The Guilford Press, New York (1998)
11. Karnow, S.: Vietnam: A History. Viking Press, New York (1983)
12. Britt, T.W.: The Psychology of Serving in Peace and Combat. Praeger Security Intl. (2006)
13. Thompson, M.M., McCreary, D.R.: Enhancing Mental Readiness in Military Personel. Military Life. In: Britt, T.W. (ed.) The Psychology of Serving in Peace and Combat. Praeger Security Intl., pp. 54–79 (2006a)

14. U.S. Marine Corps: Combat Stress. Marine Corps Reference Publication 6-11C (NTTP 1-15M). Dept of the Navy, Washington DC (2000)
15. Adler, A.B., Bliese, P.D., Hoge, C.W., McGurk, D., Castro, C.A.: Early Interventions during Reintegration with Soldiers Returning from Iraq: Randomization by Platoon. Cited in the MHAT-C report, 55 (2008) (in preparation)
16. Routhier, C.: Programme d'Entraînement à la Résilience Militaire (PERM). Unpublished document : SQFT (2007)
17. Warner, C.H., Appenzeller, G.N., Barry, M.J., Morton, A., Grieger, T.: The Evolving Role of the Division Psychiatrist. Military Med. 172, 918–924 (2007)
18. Warner, C.H., Breibach, J.E., Appenzeller, G.N., Yates, V., Grieger, T., Webster, W.G.: Division Mental Health in the New Brigade Combat Team Structure; Part I Predeployment and Deployment. Military Med. 172, 907–911 (2007a)
19. Warner, C.H., Breibach, J.E., Appenzeller, G.N., Yates, V., Grieger, T., Webster, W.G.: Division Mental Health in the New Brigade Combat Team Structure; Part II Redeployment and Postdeployment. Military Med. 172, 912–917 (2007b)
20. Routhier, C.: Military Resilience Training Program: Executive Report. Presented at the MH & OSI JSB Harmonization of MH Education Initiative (Feburary 2009)
21. Armfield, F.: Preventing Posttraumatic Stress Disorders Resulting from Military Operations. Military Med. 159, 739–746 (1994)
22. Pratt, D.R., Zyda, M., Kelleher, K.: Virtual Reality: In the Mind of the Beholder. Computer 28, 17–19 (1995)
23. North, M.M., North, S.M., Coble, J.R.: Virtual Reality Therapy. An Innovative Paradigm. IPI Press, Colorado Springs (1996)
24. Stanney, K.M.: Handbook of Virtual Environments. Design, Implementation, and Applications. Lawrence Erlbaum Associates, Mahwah (2002)
25. Côté, S., Bouchard, S.: Virtual Reality Exposure for Phobias: A critical review. J. Cyber Therapy and Rehab. 1, 75–91 (2008)
26. Robillard, G., Bouchard, S., Fournier, T., Renaud, P.: Anxiety and Presence during VR Immersion: A Comparative Study of the Reactions of Phobic and Non-Phobic Participants in Therapeutic Virtual Environments Derived from Computer Games. Cyber Psych. and Behav. 6, 467–476 (2003)
27. Renaud, P., Bouchard, S., Proulx, R.: Behavioral Dynamics in the Presence of a Virtual Spider. IEEE Transactions on Information Technology in Biomedecine 6, 235–243 (2002)
28. Moore, K., Wiederhold, B.K., Wiederhold, M.D., Riva, G.: Panic and Agoraphobia in a Virtual World. Cyberpsych. and Behav. 5, 197–202 (2002)
29. Meehan, M.: Physiological Reaction as an Objective Measure of Presence in Virtual Environments. Ph.D. Dissertation. Chapel Hill, U.S.A (2001)
30. Zimmons, S.: Anxiety and Image Characteristics in Virtual Environments. The Virtual-Pit Experiment. Dissertation. Preliminary Results. Chapel Hill, USA (2004)
31. James, L.K., Lin, C.-Y., Steed, A., Swapp, D., Slater, M.: Social Anxiety in Virtual Environments: Results of a Pilot Study. Cyberpsych. and Behav. 6, 237–243 (2003)
32. Slater, M., Pertaub, D.-P., Barker, C., Clark, D.: An Experimental Study on Fear of Public Speaking in a Virtual Environment. In: IWVR 2004, Lausanne, Switzerland (2004)
33. Pertaub, D.-P., Slater, M., Barker, C.: An Experiment on Public Speaking Anxiety in Response to Three Different Types of Virtual Audience. Presence: Teleoperators and Virtual Environments 11, 68–78 (2002)
34. Wiederhold, B.K., Wiederhold, M.: Lessons Learned from 600 Virtual Reality Sessions. Cyberpsych. and Behav. 3, 393–400 (2000)

35. Jang, D.P., Kim, I.Y., Nam, S.W., Wiederhold, B.K., Wiederhold, M.D., Kim, S.I.: Analysis of Physiological Response to Two Virtual Environments: Driving and Flying Simulation. Cyberpsych. and Behav. 5, 11–18 (2002)
36. Richard, D.S., Lauterbach, D.: Handbook of Exposure. Academic Press, New York (2007)
37. Wiederhold, B.K., Bouchard, S.: Comprehensive Handbook of Virtual Reality and Anxiety Disorders. Kluewer, Toronto (in preparation, 2011)
38. Rothbaum, B.O., Hodges, L.F., Ready, D., Graap, K., Alarcon, R.D.: Virtual Reality Exposure Therapy for Vietnam Veterans with Posttraumatic Stress Disorder. Journal of Clinical Psychiatry 62, 617–622 (2001)
39. Wood, D.P., Murphy, J.A., Center, K., Russ, C., McLay, R.N., Reeves, D., et al.: Combat Related Post Traumatic Stress Disorder: A Multiple Case Report Using Virtual Reality Graded Exposure Therapy with Physiological Monitoring. Studies in Health Technology and informatics 132, 556–561 (2008)
40. Reger, G.M., Gahm, G.A.: Virtual Reality Exposure Therapy for Active Duty Soldiers. J. Clin. Psych.: In session 64, 940–946 (2008)
41. Rizzo, A.A., Graap, K., Mclay, R.N., Perlman, K., Rothbaum, B.O., Reger, G., et al.: Virtual Iraq: Initial Case Reports from a VR Exposure Therapy Application for Combat-Related Post Traumatic Stress Disorder. In: Paper presented at the 2007 Virtual Rehabilitation Conference, Venice, Italy (2007)
42. Rizzo, A., Parsons, T., Pair, J., McLay, R., Johnston, S., Perlman, K., et al.: Clinical Results from the Virtual Iraq Exposure Therapy Application for PTSD. In: Proceedings of the Army Science Conference, Orlando, FL (November 2008)
43. Wiederhold, B.K., Wiederhold, M.: Virtual Reality for Posttraumatic Stress Disorder and Stress Inoculation Training. J. CyberTherapy and Rehab. 1, 23–35 (2008)
44. Gamito, P., Oliveira, J., Morais, D., Saraiva, T., Rosa, P., Leal, A., et al.: War PTSD: A VR Pre-Trial Case Study. In: Widederhold, B.K., Bouchard, S., Riva, G. (eds.) Annual Review of CyberTherapy and Telemedicine, vol. 5, pp. 191–198. Interactive Media Institute, San Diego (2007)
45. Rizzo, A.A., Difede, J., Rothbaum, B.O., Johnston, S., McLay, R.N., Reger, G., et al.: VR PTSD Exposure Therapy Results with Active Duty OIF/OEF combatants. Studies in Health Technology and Informatics, vol. 142, pp. 277–282 (2009)
46. Wiederhold, M.D.: Psychological Monitoring during Simulation Training and Testing (Final Report). Issued by U.S. Army Aviation and Missile Command Under contract no. DAA01-03-C-R301 (2005)
47. Tarnanas, I., Manos, G.: Using Virtual Reality to Teach Special Populations how to Cope in Crisis: The Case of a Virtual Earthquake. Studies in Health Technology and Informatics 81, 495–550 (2001)
48. Wiederhold, M.D., Wiederhold, B.K.: Training Combat Medics using VR. Cyberpsych. and Behav. 7, 319 (2004)
49. Stetz, M.C., Long, C.P., Wiederhold, B.K., Turner, D.D.: Combat Scenarios and Relaxations Training to Harden Medics Against Stress. J. Cyber Therapy and Rehab. 1, 239–246 (2008)
50. Stetz, M.C., Wildzunas, R.M., Wiederhold, B.K., Stetz, T.A., Hunt, M.P.: The usefulness of virtual reality stress inoculation training for military medical females: A pilot study. In: Widederhold, B.K., Bouchard, S., Riva, G. (eds.) Annual Review of Cyber Therapy and Telemedicine, vol. 4, pp. 51–58. Interactive Media Institute, San Diego (2006)
51. Stetz, M.C., Thomas, M.L., Russo, M.B., Stetz, T.A., Wildzunas, R.M., McDonald, J.J., et al.: Stress, Mental Health, and Cognition: A Brief Review of Relationships and Countermeasures. Aviation Space and Environmental Medecine 78, B252–B260 (2007)

52. Killgore, W.D.S., Stetz, M.C., Castro, C.A., Hoge, C.W.: The Effects of Prior Combat Experience on the Expression of Somatic and Affective Symptoms in Deploying Soldiers. J. Psychosomatic Res. 60, 379–385 (2006)
53. Stetz, M.C., Bouchard, S., Wiederhold, B., Folen, R.: The Receptiveness of Stress Management Techniques by Military Personnel. Poster presented at the annual Cyber Therapy Conference, Verbania (Italy) (June 2009)
54. Stetz, M.C., Strunk, K.K., Reeves, D.L.: The Effectiveness of Immersive Assisted Relaxation Training for Forwards Surgical Teams. Internal Research Report. Contract no. W911NF-07-D-0001 (2009)
55. Sadowski, W., Stanney, K.: Presence in Virtual Environments. In: Stanney, K.M. (ed.) Handbook of Virtual Environments: Design, Implementation, and Applications, pp. 791–806. Lawrence Elbaum Associates, Mahwah (2002)
56. Wiederhold, B.K., Wiederhold, M.D.: Virtual reality therapy for anxiety disorders. APA, Washington (2005)
57. Lombard, M., Ditton, T.: At the Heart of it All: The Concept of Presence. J. Computer-Mediated Comm. 13 (1997), `http://jcmc.indiana.edu/vol3/issue2/lombard.html` (retrieved November, 2009)
58. Slater, M., Usoh, M.: Representations Systems, Perceptual Position, and Presence in Virtual Environments. Presence: Teleoperators and Virtual environments 2, 221–233 (1993)
59. Youngblut, C.: What a Decade of Experiments Reveals about Factors that Influence the Sense of Presence. Institute for Defense Analyses, Virginia (2006)
60. Youngblut, C.: What a Decade of Experiments Reveals about Factors that Influence the Sense of Presence: Latest Findings. Institute for Defense Analyses, Virginia (2007)
61. Heldal, I., Schroeder, R., Steed, A., Axelsson, A.-S., Spante, M., Widerström, J.: Immersiveness and Symmetry in Copresent Scenarios. In: Proceedings of IEEE Virtual Reality 2005, Bonn, Germany, pp. 171–178 (March 2005)
62. Krijn, M., Emmelkamp, P.M.G., Biemond, R., de Wilde de Ligny, C., Schuemie, M.J., van der Mast, C.A.P.G.: Treatment of Acrophobia in Virtual Reality: the Role of Immersion and Presence. Behaviour Research and Therapy 42, 229–239 (2004)
63. Schroeder, R., Steed, A., Axelsson, A.-S., Heldal, I., Abelin, A., Wideström, J., et al.: Collaborating in Networked Immersive Spaces: As Good as Being Together? Comp. & Graph. 25, 781–788 (2001)
64. Herbelin, B., Riquier, F., Vexo, F., Thalmann, D.: Virtual Reality in Cognitive Behavioral Therapy: a Preliminary Study on Social Anxiety Disorder. In: 8th International Conference on Virtual Systems and Multimedia, VSMM 2002 (2002)
65. Bouchard, S., St-Jacques, J., Robillard, G., Renaud, P.: Anxiety Increases the Sense of Presence in Virtual Reality. Presence: Teleoperators and Virtual Environments 4, 376–391 (2008)
66. Michaud, M., Bouchard, S., Dumoulin, S., Zhong, X.-W.: Manipulating Presence and its Impact on Anxiety. In: Paper presented at the Cybertherapy Conference 2004, San Diego (January 2004)
67. Burkhardt, J.-M., Lourdeaux, D., d'Huart, D.M.: La Conception des Environnements Virtuels pour l'Apprentissage. In: Fuchs, P., Moreau, G. (eds.) Le Traité de la Réalité Virtuelle, 2nd edn. Création des Environnements Virtuels et Application École des Mines de Paris, vol. II, pp. 207–296. Les Presses, Paris (2003)

68. Moshell, J.M., Hughes, C.E.: Virtual Environments as a Tool for Academic Learning. In: Stanney, K.M. (ed.) Handbook of Virtual Environments. Design, Implementation, and Applications, pp. 893–910. Lawrence Erlbaum Associates, Mahwah (2002)
69. Cobb, S., Neale, H., Crosier, J., Wilson, J.R.: Development and Evaluation of Virtual Environments for Education. In: Stanney, K.M. (ed.) Handbook of Virtual Environments. Design, Implementation, and Applications, pp. 911–936. Lawrence Erlbaum Associates, Mahwah
70. Youngblut, C., Huie, O.: The Relationship Between Presence and Performance in Virtual Environments: Results of a VERTS Study. In: Proceedings of the IEEE Virtual Reality (2003)
71. Bouchard, S., Côté, S., Richard, D.S.: Virtual Reality Applications of Exposure. In: Richard, D.S., Lauterbach, D. (eds.) Handbook of exposure, ch. 16, pp. 347–388. Academic Press, New York (2006)
72. Holden, M.K.: Virtual Environments for Motor Rehabilitation: Review. Cyberpsychology and Behavior 8, 187–211 (2005)
73. Stetz, M.C., Long, C.P., Schober, W.V., Cardillo, C.G., Wildzunas, R.M.: Stress Assessment and Management While Medics Take Care of the VR Wounded. In: Widederhold, B.K., Bouchard, S., Riva, G. (eds.) Annual Review of Cyber Therapy and Telemedicine, vol. 5, pp. 165–172. Interactive Media Institute, San Diego (2007)
74. Thompson, M.M., McCreary, D.R.: Enhancing mental readiness in military personnel. In: Human dimensions in military operations – military leaders' strategies for addressing stress and psychological support Meeting Proceedings RTO-MP-HFM-134, Paper 4, pp. 4-1–4-12. RTO, Neuilly-sur-Seine (2006b)

Chapter 7

How Can Presence in Psychotherapy Employing VR Be Increased? Chapter for Inclusion in: Systems in Health Care Using Agents and Virtual Reality*

Helene S. Wallach, Marilyn P. Safir, Roy Samana, Idan Almog, and Reut Horef

University of Haifa, Haifa, Israel, 31905
helenwa@yahoo.com, marilyn.safir@gmail.com

Abstract. Virtual Reality (VR) technology has been effectively implemented in psychotherapy as an alternative to exposure. VR has also been employed in treatment of eating disorders, body image disorders etc. As with any other treatment, efficacy varies among clients. One parameter that has been suggested as increasing treatment efficacy is presence. "Presence" is the subjective experience, so that the client/subject feels as if s/he is "in" the situation even though it is not real. Presence is influenced by both personality and technological factors. This chapter presents a comprehensive review of studies examining variables impacting on presence, with the aim of elucidating the optimal VR user profile.

Keywords: Virtual Reality, Presence, Psychotherapy.

1 Introduction

Virtual Reality (VR) has become an effective therapeutic tool as well as a viable alternative to various elements in traditional therapy, such as (but not limited to) exposure (Rothbaum et al., 2006). As this is a relatively new technology, it is still uncertain which elements are necessary or significant to increase VR effectiveness. One of the most probable candidates is presence, especially for VR exposure. For example, for exposure to be effective, therapy must activate the fear structure and modify it. This necessitates a feeling of "being" in the VR exposure environment. Other usages of VR such as for eating disorders, sexual dysfunctions, etc., also require presence. However, little research has been done on presence's effects in treatment of psychological disorders beyond the realm of anxiety disorders.

* We want to thank NetaAmit, and Eran Huber, BA for their help in collecting material for this chapter.

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 129–147.
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2 Presence

Presence is the feeling or experience of "being" in the VR environment. Witmer and Singer (1998) define presence as "the subjective experience of being in one place or environment, even when one is physically situated in another" (pg. 225). Similarly, Nicovich, Boller, and Cornwell (2005) define presence as the subjective feeling of existence in an experienced environment. Sacau, Laarni, & Hartmann, (2008) term this *spatial presence*. They divide presence into two factors: a "physical or perceptual dimension"… "the sense of being physically located in a mediated space" which they term spatial presence and a "social dimension" "the perceived existence of others and the perceived possibility of interaction" which they term *social presence* (pg. 2256). This chapter will deal with spatial presence. Slater (2009) proposes that presence is composed of two orthogonal components: the feeling of "being there" which he calls Place Illusion (PI) and the illusion that what is apparently happening is really occurring which he calls Psi. This is closely related to the plausibility of events and the appearances and properties of objects. Slater proposes that "If you are there (PI) and what appears to be happening is really happening (Psi), then this is happening to you! Hence you are likely to respond as if it were real." (p. 3554). Casati, and Pasquinelli, (2005) agree that the plausibility of events is more important than the exact photo-duplication of reality. "An interesting point here is the difference between a quest for realism and a quest for believability. Photorealism intends to approximate the model, the real world, in a very accurate way…non-photorealism does not attempt to provide a ‘‘one-to-one’’ reproduction of the reality but is after creations that are believable, which include only those details, which are considered relevant or representative of the intention behind the model" (page 429-430).

However, Persky, Kaphingst, McCall, Lachance, Beall, and Blascovich, (2009) were unable to identify presence’s influence on learning within a VE. Price and Anderson (2007) failed to find a relationship between presence and treatment outcome, even though they found that presence contributed to the experience of anxiety in the virtual environment (VE) and was related to the phobic elements in this environment. Furthermore, although Krijn, Emmelkamp, Olafsson and Biemond (2004) reported a significant difference between treatment drop-outs and completers on both presence and anxiety elicited in the VE, they found no treatment effects for those who experienced high presence VE (cave) versus those who experienced low presence VE (head mounted display). One possible conclusion suggested by these studies is that presence levels must be high enough to elicit anxiety, and maintain treatment adherence. However, beyond these minimal levels, further presence enhancement may not be necessary.

Research on the variables necessary to induce presence has been inconclusive. It is both theoretically and practically important to determine the critical elements that contribute to the sense of presence in VR (Banos et al., 2004). This chapter will summarize the existing literature on presence.

3 Variables Which Affect Presence

Possible "candidates" that influence presence may be divided into three categories for ease of reference: technological variables (e.g. vividness of imagery), user variables

Systems in Health Care Using Agents and Virtual Reality 131 (e.g. personality variables), and interaction variables (e.g. control over the environment) (Steuer, 1992).

3.1 Technological Variables

There appears to be some disagreement in the field as to how dissimilar from reality the VR environment may be, and still induce sufficient presence and success in therapy. In fact, "a person may experience a sense of virtual presence similar to the real world even when the virtual environment does not accurately or completely represent the real-world situation" (North, North, & Coble, 1996, pg. 161).

In earlier studies (Wallach, Safir, & Bar-Zvi, 2009a; Wallach, Safir, & Bar-Zvi, 2009b), subjects reported that VR environments containing elements discordant to their actual every day experiences, resulted in difficulties to immerse. Thus, we propose that VRE similarity to the real world is less important, than excluding discordant elements. People appear to be able to "fill in the gaps" in a VR environment, but may be unable to "erase" discordant elements. In a pilot study, Israeli combat soldiers, from different units, viewed the Virtual Iraq environment (Pair, et al., 2006). They tended to focus on discordant elements (difference in uniforms, weapons, vehicles, etc.) and were disturbed by them. Therefore, it is reasonable to hypothesize that presence is influenced by the existence of or lack of discordant elements in the VR environment. This is a novel question which we hope to examine in future research.

Casati, and Pasquinelli, (2005) present a convincing argument as to the importance of taking psychological sensation/perception theories into account. "It is not the fidelity to the real model (the world) that makes the synthetic environment looking and feeling real, but the fidelity to the perceptual conditions involved in the mental construction of perceived objects. This fidelity could be attained by taking into account the specific sensorimotor determinants of visual perception, or some higher level features such as object files. The believability of synthetic objects depends on the adequacy of the reproduction of the relevant aspects of the perceptual mechanism involved, and not on the realism of the reproduction of the stimulus" (page 435). Therefore, if sensory input from the VE is discordant in different sensory modalities, lower presence will be experienced.

Technological variables found to influence presence are vividness of imagery, consistency of sensory inputs, engagement of multiple senses, and obtrusiveness of medium.

Vividness of imagery, consistency of sensory inputs and engaging multiple senses
Vividness is defined as the degree of sensory richness in the Virtual Environment (Schubert, Friedman, &Regenbrecht, 2001). Sensorial breadth and sensorial depth of the stimuli are associated with vividness. These variables affect the involuntary attention the subject/client allocates to the virtual environment (Wirth et al., 2007). Sensorial breadth relates to the number of sensory dimensions that are presented simultaneously. As we have suggested, employing multiple sensory modalities increases presence (Schuemie, Van Der Straaten, Krijn& Van Der Mast, 2001). However, it is important that there is congruence between the different sensory modalities, otherwise using multiple modalities will result in less rather than more

presence (Wirth et al., 2007). Sensorial depth relates to the degree of resolution in each sensory dimension (Wirth et al., 2007). Many factors impact on sensorial depth: detail, continuous versus discontinuous movements, update rate of the program, and stereoscopy. On the other hand, field of view and illumination of the real environment seem not to impact on presence (Schubert et al., 2001; Schuemie, et al., 2001; Steuer, 1992; Wirth et al., 2007). Vividness has been found to influence presence (Biocca, Kim, & Choi, 2001; Schubert, et al., 2001; Steuer, 1992). Sight is the most important in influencing presence of the various senses that are engaged. This may be due to the fact that our visual cortex comprises 70% of our cortex (Park, Cho Hong, Kim, & Han, 2003).

Obtrusiveness of medium

Presence is increased using a VR helmet when compared with viewing images on a flat two-dimension television screen (Wiederhold&Wiederhold, 2005). However, a VR helmet which is cumbersome or uncomfortable reduces presence (Held & Durlach, 1992 in Witmer and Singer, 1998).

Two additional medium related variables that affect presence are transparency and continuity of the interface. Transparency is "the elimination of mediation: the lack of consciousnesses of the medium itself." Continuity is "lack of disruption during interaction. Disruption may occur when the user becomes overly aware of the medium and the physical interface." (Tang, Biocca, & Lim, 2004, pg. 1)

3.2 User Variables

User variables that have been found to influence the experience of presence in Virtual Reality include: personality variables, cognitive abilities, level of anxiety, ethnicity, and gender.

Personality variables

Several personality variables have been examined in relation to the experience of presence. Variables that were found to be unimportant in inducing presence are: neuroticism, reactivity to reward and punishment, sensation seeking (Laarni, Ravaja, Saari, & Hartmann, 2004) and the Big Five personality traits (Sacau, Laarni, Ravaja, & Hartmann, 2005). For example, employing Big Five, Sacau et al. (2005) predicted a correlation between openness to experience, agreeableness, and presence. They assumed that as creativity and a tendency to appreciate art is part of openness to experience, this would lead to an increased visual imaginative ability (which has an effect on presence). In addition, openness to experience is connected to absorption, which also is an important factor in presence. Thus, they assumed that obedience and trust, which are factors in agreeableness will increase presence, perhaps by neutralizing judgment. However, no correlation was found between openness to experience and presence, and the correlation between agreeableness and presence was very weak (O.17). Therefore, they concluded that the Big Five does not significantly impact on presence. Other variables for which the picture is unclear include: introversion and extraversion (LaarniRavaja, Saari, & Hartmann, 2004; Jurnet, Beciu, &Maldondo, 2005), absorption (Sas&O'hare, 2003; Murray, Fox, &Pettifier, 2007) and self forgetfulness (Laarni et al., 2004; Ravaja et al., 2004). For example, Laarni, et al. (2004) found that extroverts experienced significantly more presence than introverts. They explain these results by claiming that extroverts are involved in more simultaneous external events than introverts Thus they assumed that extroverts have greater ability to process many simultaneous stimuli. However, Jurnet et al., (2005) reported an opposite correlation – introversion, and not extroversion, correlated with presence. It is unclear why these two studies produced such contradictory results.

Six personality variables were found to have a clear association with presence. These variables are; empathy, imagination, immersive tendencies, dissociation tendencies, locus of control and cognitive style. Attachment was examined in one study and was found to be associated with presence. Sensory processing is currently under investigation in our lab.

Empathy. Davis (1994) defines empathy as a set of constructs associated with responses of one individual to the experience of another. Empathy involves the ability to engage in the cognitive process of adopting another's psychological point of view, together with the capacity to experience affective reactions observed in others' experience. Nicovich, et al. (2005) assumed that empathy and presence use the same projective "tool set". They suggest that presence, like empathy, is a form of emotional projection. Thus, presence may be understood as an emotional connection to a place, as opposed to the cognitive recognition of being in a space. They propose that the emotional connection strengthens the bond between the subject and his/her virtual environment.

Nicovich, Boller, & Cornwell, (2005) found that as one's empathic ability increases so does the ability to experience presence (R_2=.134). Wickramasekera and Szlyk (2003) found a correlation between empathy and hypnotizability. Sas and O'hare (2003), using the Interpersonal Reactivity Index (Davis, 1980), found a significant correlation (.605) between empathy and presence among 15 subjects. As hypothesized, the Index's fantasy subscale had the highest correlation with presence (.753). In a previous study (Wallach, Safir and Samana, 2009), we found a significant positive correlation between empathy and presence among subjects who were active in the Virtual Environment. Empathy correlated with presence in a simple regression (.40), and was the most important factor in a multiple regression (β=.39). Thus, empathy seems to be an important factor influencing presence, at least among those who are active in the VE.

Imagination. Mental imagery may be defined as an experience that significantly resembles perceptual experience, but which occurs in the absence of appropriate external stimuli for the relevant perception (Thomas, 1999). Sas and O'hare (2003) assumed that the ability to imagine, which was found to be related to hypnotizability (Laidlaw & Large, 1997) was related to ability to experience presence. Sas and O'hare (2003) examined the correlation between imagination and presence using Barber and Wilson's (1979) Creative Imagination Scale (CIS), a measure that assesses the ability to vividly imagine images and situations on demand. They reported a significant positive correlation (.721) between imagination and presence. In a previous study (Wallach, Safir, &Samana, 2009) a significant correlation between imagination and presence was found only among subjects who were inactive in the VE and experienced a sensorial "deprived" VE. Based on Sas and O'hare's findings (2003), we had also predicted a correlation among active subjects who experienced the VE's full impact. However, one possible explanation of difference in outcome between these two studies may have resulted from the fact that the questionnaire they used is actually a measure of hypnotic susceptibility (Yu, 2005) rather than a measure of imaginative ability. Accepting Yu's critique, we chose to employ a measure of imaginative ability (Sheehan, 1967). Therefore, our study is actually the first to examine the correlation between presence and imagination. In addition, Sas and O'Hare employed a relatively primitive virtual environment, whereas we employed an advanced technological environment. Therefore, in our study, imagination was not important for subjects who experienced the full impact of the VE. However, subjects who were inactive, thus experiencing an impoverished VE, resembled the subjects in Sas and O'Hare's (2003) study.

As previously stated in the section on technological variables, vividness has an impact on presence. Thus when the VE is rich, imagination is less significant as the subject does not need to employ imagination to experience the environment as convincing. However, when there are technological limitations, as in Sas and O'Hare's (2003) study, or when, as in our study, subjects limit their utilization of the technological capabilities, sensorial depth of the stimuli is decreased (Steuer, 1992), and it is necessary to employ imagination to fill in what is missing (Jacobson, 2001). This is also in accord with both Wirth et al.'s (2007) claim that "…spatial imagination becomes more relevant if the mediated representation of the space is less intuitive and more fragmented" (p. 502) and Lee's (2004) claim that when an environment is poor in sensorial stimuli, imagination can simulate missing sensorial cues, thus creating a convincing sense of realism. However, it should be noted that these claims have not been experimentally tested in the context of VR.

Immersive tendencies. Immersive tendencies is a theoretical construct that relates to the tendency to behave playfully and to become involved in a continuous stream of stimuli. Unlike presence, this is a trait. Immersive tendencies appear to be related to cognitive and behavioral elements such as concentration, imagination and self-control (Psotka& Davidson cited in Kaber, Draper & Usher, 2002). Individuals who are high on immersive tendencies are able to ignore external distractions and focus on their virtual experiences so that they are not aware of their immediate environment and the passage of time. Such individuals tend to be playful, spontaneous, creative and imaginative (Webster &Martocchio, 1992; Newman, 2005), and to feel as if they are within video games they play (Witmer& Singer, 1998).

Witmer and Singer (1998) reported a significant positive correlation (.24) between immersive tendencies and presence. Johns et al. (2000) also reported a significant positive correlation (.86) between immersive tendencies and presence, but only within an environment that included factors that are thought to facilitate presence (for example: a multitude of sensorial information, adequate isolation from the outside world). Both Laarni, Ravaja, Kallinen, and Saari, (2005) and Laarni et al. (2004) using a different presence questionnaire found that immersive tendencies had a significant main effect in predicting presence. In a previous study (Wallach, Safir, & Samana, 2009), we also found a correlation between immersive tendencies and presence. However, although a correlation was found between immersive tendencies and presence in a simple correlation, immersive tendencies failed to play a major role in the multiple regression analysis. This may have resulted from the strong correlation (r=.67) between empathy and immersive tendencies, rendering immersion unimportant beyond empathy.

Dissociation tendencies. Dissociation may be defined as a disruption of the normally integrated functions of consciousness, memory, identity, or perception of the environment (Banos et al., 1999). Perhaps the ability to dissociate from the surroundings enables the person to "connect" to the virtual environment and thus experience presence. Banos et al., (2004) found a significant positive correlation between the tendency to dissociate and presence. However, this study is problematic as presence was measured by only one item. Murray et al., (2007), using a presence questionnaire that measures three aspects of presence also found a positive correlation (.308).. Murray et al.'s sample (2007) was composed of a non clinical pool of students. However, their average dissociation tendencies scores were high, equal to that of patient groups such as PTSD patients (Somer, Dolgin, &Saadon, 2001). Therefore Murray et al.'s results appear non representative of a normal population. In a previous study (Wallach, Safir, &Samana, 2009), we failed to find such a correlation. Thus, we hypothesize that only when dissociation tendencies levels are very high they correlate with presence.

Locus of control. Locus of control refers to the degree to which subjects feel they control events in their own lives, or that such events are influenced by external forces, chance or luck (Rotter, 1966). Murray et al. (2007) claim that people who feel they lack control over the events in their lives (those with external locus of control), should report a higher sense of presence in the virtual environment. In contrast, Witmer and Singer (1998) claim that one experiences greater presence the more control one has over the virtual environment, or over interaction within it (i.e. internal locus of control). People who feel in control over events in their lives (internal locus of control) focus on elements they are able to control, in contrast with those who feel they lack control (external locus of control) who focus on elements they cannot control (Lefcourt, 1982). Witmer and Singer (1998) argued that "(a sense of) control… is essential for a strong sense of presence" (p. 239). Additionally, Hair, Renaud, and Ramsay (2007) found that a negative correlation exists between external locus of control and the ability to ignore distractions, an ability that is crucial in developing and maintaining presence (Wirth et al., 2007). Furthermore, Taylor, Schepers, and Crous (2006) found that the tendency to experience flow has a positive correlation with internal locus of control, while Jacobson (2002) stated that the feeling of presence can be conceptualized as a "flow experience".

Murray et al., (2007) found a significant positive correlation (.218) between locus of control and presence. Wallach, Safir, &Samana, (2009) failed to find a significant correlation between locus of control and presence. However, locus of control was a significant predictive variable in the multiple regression analysis (β=-.25). In our multiple regression analysis, internal locus of control correlated positively with presence. These conflicting results may be explained by taking into account that our subjects scored significantly higher on the external scale than results reported in previous studies (e.g. Sun, 2005, Valecha&Ostrom, 1974). In addition, Murray et al.

(2007) used a brief presence questionnaire. The SUS includes only six items, none of which examine locus of control.

Cognitive style. The term cognitive style refers to the unique way in which unconscious mental processes are used in approaching and/or accomplishing cognitive tasks (Sas&O'hare, 2003), and in processing and reasoning information (Sacau, et al., 2008). Cognitive style is a combination of mental abilities (Sacau, et al., 2008). Sas and O'hare used Myers-Briggs Type Indicator (Myers &McCaulley, 1998) to assess the effect of cognitive style on presence. Both *Feeling* cognitive style and *Sensitive* cognitive style correlated with presence. Slater, Usoh and Steed (1994) examined the correlation between presence and the dominant representation among visual, auditory and kinesthetic systems. They found that both visual and kinesthetic dominance positively correlated with presence, while auditory dominance negatively correlated with presence.

Field dependency is a cognitive style that relates to the degree that a person is affected by the context of the surrounding perceptual field. In the VE, field-independents selectively attended only to relevant cues and filled in gaps in information with previous knowledge. Thus, they are better at reorganizing and constructing the perceptual (VE) field. This should result in increased presence. Accordingly, Hecht and Reiner (2007) found that field dependency correlates negatively with presence. Perhaps this also is due to the high correlation between field dependency and simulator sickness and visual vertigo (Sacau et al., 2008).

Attachment style. Attachment style is closely linked with reaction to threat (Ainsworth, Blehar, Waters, & Wall, 1978; Mikulincer& Florian, 2000; Wegner & Smart, 1997). Individuals with a secure attachment style show balance between exploration and closeness. They may move from their attachment figure without being anxious or concerned about availability in time of need. They trust their ability to regulate distress and thus permit themselves to be exposed to new and sometimes threatening information (Bowlby, 1973; Mikulincer, 1997; Simpson, Rholes, & Nelligan, 1992). Therefore, they feel free to explore and engage in a novel situation, and would be expected to experience heightened presence in a VRE. In contrast, insecure attachment may lead to overestimation of potentially threatening elements when exploring the environment. These individuals may develop serious doubts about their ability to handle such threats, and serious doubts about the availability of their secure base when exploration becomes threatening, resulting in difficulty in exploring the environment (Mikulincer& Florian, 1998; Mikulincer, Gillath, & Shaver, 2002). Thus, insecure individuals would be less able to explore and to engage in a novel situation, experiencing lower presence in a VRE than secure individuals.

Attachment may be viewed as occurring along two continuous dimensions: anxiety and avoidance. The anxiety dimension reflects the degree of fear of being left without care and support of others, thus experiencing distress or anxiety. The avoidant dimension reflects the degree of lack of trust and emotional distance in interpersonal connections. Insecure attachment may result in high avoidance levels, high anxiety levels, or both. In times of stress, individuals high on avoidance remove themselves from the stressor cognitively or physically. Highly anxious individuals experience arousal of negative thoughts and emotions, and tend to focus on their distress. Those high on both avoidance and anxiety will experience the greatest difficulties as they both approach and distance themselves. Therefore, we propose that securely attached individuals will experience the highest levels of presence, and anxious-ambivalent individuals will experience lower levels of presence than securely attached individuals because of arousal of negative thoughts and emotions. Anxiety, unlike avoidance, may increase presence by increasing alertness to the surroundings. Thatcher, James and Todd (2005) found that anxious people report high levels of immersion. Since dismissingavoidant individuals tend to remove themselves cognitively from new situations, we predicted that dismissing-avoidant individuals would experience lower levels of presence than anxious-ambivalent individuals. Finally, we predicted that fearful-avoidant individuals would experience the lowest levels of presence as they employ the most inadequate coping strategies.

Up to present, we have conducted the only study examining the relationship between presence and attachment (Wallach, Safir, &Almog, 2009). We found a negative correlation between avoidance level and the IC scale (measuring control and involvement) of the presence questionnaire. The higher the individual's score on the avoidance dimension, the less control and involvement he/she feels in the VRE. However, no significant correlation was found between anxiety and presence. When we examined the four attachment categories, we found a significant difference between them. If only the avoidant dimension was relevant, there would have been no difference between the anxious ambivalent and the secure groups or between the dismissive avoidant and the fearful avoidant groups. However, correlations between anxiety and presence were not significant. Perhaps our manipulation, a virtual flight experience, was not relevant or intense enough for significant differences to be found on the anxiety dimension. Also, unlike avoiders, who do not seek personal contact while dealing with discomfort but try to rely on themselves (Shaver &Mikulincer, 2002), anxious people tend to request help and "cling" while distressed. Thus, it may be that the presence of the researcher in the room acted as a mediator for reduced anxiety.

However, we did find that the level of presence was influenced by attachment category. As predicted, "secure" participants reported highest levels of presence, followed by "anxious-ambivalent", then "dismissive-avoidant". "Fearful avoidant" participants reported the lowest levels of presence in the VRE.

Sensory processing. Just as the sensory characteristics of technology affect presence, the individual's sensory processing style affects it as well. Sensory processing relates to the way in which we interpret, organize, regulate and react to sensory stimulus (Royeen& Lane, 1991). Sensory processing has three components: 1. degree of attention we pay to the sensation; 2. regulation of the sensation; and 3. sensory integration, which affects the sensation and the response (Ayres, 1972). Sensory processing enables us to respond in an adaptive manner. Maladaptive processing can lead to difficulties in daily functioning, as well as inadequate interpersonal and cognitive development (Dunn, 1997; Tal-Saban, Yuchman, &Parush, 2002). People differ in the sensitivity of their sensory systems. Some are very sensitive and react to very low levels of stimuli (low threshold), while others need high levels of stimulation to detect stimulus (high threshold) (Knickerbocker, 1980; Wilbarger & Wilbarger, 1991). People react passively, accepting the stimuli they experience (or lack of experience), or actively – avoiding it (if it is too high) or seeking it out (if it is too low). Dunn (1997, 2001) integrated the threshold with behavioral response and created a model with four types: 1. Poor registration – High threshold and passive response. These individuals often do not notice daily sensory events, for example - dirt on their hands. It is difficult to engage their attention. They react slowly to external stimuli, and for them to respond, a strong stimulus is necessary. Therefore, they will experience low levels of presence; 2. Sensory seeking – high threshold and active response. These individuals actively seek out stimuli. They crave intensive sensory experiences, often to the point of endangering themselves (Dunn, 1997; Miller, et al., 2007). Therefore, in a virtual environment that enables them to actively seek stimuli, they will experience high levels of presence, but in an environment that is limited in the level of stimuli, they will experience low levels of presence; 3. Sensory sensitivity – low threshold and passive response. These individuals are very sensitive to sensory stimuli, are easily distracted, and have difficulty concentrating. They are jumpy, nervous, anxious, and have a hard time calming down. They react negatively to sensory stimuli (Brown, et al., 2001; Dunn, 1997, 2001). High anxiety increases presence. Likewise their reactivity to stimuli should increase presence. Therefore, sensory sensitivity should correlate with increased presence; 4. Sensory avoiding – low threshold and active response. These individuals attempt to reduce their sensations by avoiding various activities, or by using daily rituals designed to reduce sensations by providing a familiar set of stimuli (Dunn, 1997, 2001; Miller, et al., 2007). In a virtual environment that enables them to avoid stimuli, they should experience low levels of presence, however, if they cannot avoid the stimuli in the environment, they will experience high levels of presence.

Cognitive abilities. Cognitive abilities, such as performance on a cognitive task, require processing of information. It is probable that these abilities impact on presence. For example, memory and reasoning ability may increase comprehension of the plot of the media stimulus which may increase presence. Or, perhaps, strong spatial and psychomotor abilities render spatial scenes as more fluid thus increasing presence. Unfortunately, these hypotheses have not been empirically tested (Sacau, et al., 2008).

Level of anxiety. Environments that induce an emotional reaction result in higher presence levels than neutral environments. Banos et al. (2004) found that subjects in a sad environment rated presence higher than subjects in a neutral environment. Similarly, we may expect that level of anxiety will increase presence experienced in the VRE. Riva, Mantovani, et. al. (2007) found that the feeling of presence was greater in "anxious" VRE's, than in "neutral" or "relaxing" VRE's, and that the level of anxiety during immersion was influenced by the level of presence. They manipulated the emotional content of the VRE using sound and music, shadows, lights and textures.

Robillard, Bouchard, Fournier, and Renaud (2003) found that phobics reported higher presence ratings for a VRE that contained elements relevant to their phobia, than non phobic subjects. Bouchard, St.-Jacques, and Renaud (2005) found that snake phobics, who were informed that the environment will contain snakes reported higher presence ratings than those reported in a neutral environment. However, Bouchard et al. reported this correlation for verbal ratings of presence (on a one question rating scale), whereas the neutral environment induced higher presence ratings than the "frightening" environment on the full presence questionnaire. This raises questions about the validity of various presence questionnaire ratings. Schubert, Friedman and Regenbrecth (1999), using a VRE to induce fear of heights, found a significant correlation between state anxiety (anxiety experienced during the immersion in the VRE) and presence in non-phobic participants, when they controlled for avoidance and trait anxiety. Similarly, Riva, et al. (2007) reported that the feeling of presence was greater in "anxious" VRE's, than in "neutral" or "relaxing" VRE's, as well as a correlation between level of anxiety during immersion and level of presence. They manipulated the emotional content of the VRE using sound and music, shadows, lights and textures. However, only one study examined the correlation between presence and both anxiety prior to immersion, as well as anxiety during immersion. Employing phobic subjects, Price and Anderson (2007) found that anxiety prior to immersion in the VRE increased presence ratings, which in turn increased the anxiety experienced in the VRE. They also found a significant correlation between the number of phobic elements in the VRE and presence ratings.

These five studies demonstrate that individuals who experience high levels of anxiety (i.e. phobics) experience higher levels of presence than non phobic individuals, and they experience higher levels of presence in a VRE containing elements relevant to their phobia. Higher levels of presence are correlated with higher levels of anxiety in immersion in non-phobic participants as well. In addition, anxiety prior to immersion seems to increase presence ratings, which in turn, increases anxiety experienced during immersion. However, not all studies report these correlations. For example, Krijn, et al. (2004) measured level of anxiety during immersion for spider phobics and found no correlation between presence and anxiety. However, they did find that subjects who dropped out of the study experienced low levels of anxiety and presence. This may have resulted in the lack of statistical significance. An alternative explanation may be that a minimal level of presence is necessary to invoke anxiety, and beyond this, there is no correlation between presence and anxiety. We examined the correlation between attachment and presence and found that although there was a significant negative correlation between the avoidance dimension of attachment, and presence, we failed to find a significant correlation between the anxious dimension of attachment, and presence (Wallach, Safir, &Almog, 2009). However, the anxiety dimension of attachment relates to the degree the individual fears that s/he will not have the support of a significant other at times of discomfort or anxiety, and does not necessarily relate to general anxiety or phobic anxiety.

Ethnicity and gender. Riva, Molinari and Vincelli (2003) suggest that "experiencing presence in a clinical VE (environment *-authors' notation*)…..requires more than reproduction of the physical features of external reality; it requires the creation and sharing of the cultural web that makes meaningful – and therefore visible – both people and objects populating the environment" (p. 97).

Research has demonstrated a unique effect of ethnicity on individuals’ connection to computers or the internet. Three National Telecommunications and Information Administration (NTIA) reports (1995, 1999, 2000), based on Current Population is a significant cultural factor, after controlling for income and education**,** in the digital divide. From extended focus group data, Wilhelm and Thierer (2000) also reported a significant unique ethnicity effect on the level of internet connections. Albarran and Umphrey (1994) and Subervi-Velez et al., (1994) also reported a unique ethnic effect on motivation for media usage. Newhagen (1994) and Children's Partnership (2000) report similar results for media effects. Albarran andUmphrey (1994) also reported the effect of ethnicity on program preferences. Ribisl, Winkleby, Fortmann& Flora (1998) found that ethnicity affects types of information sought through media use. Becker, Kosicki& Jones (1992) found effects on both evaluation of media content as well as on level of understanding of media system operation. Finally, Carroll et al. (1993) found a similar effect on level of active use. In a recent survey among Arabs in Middle-Eastern countries, 46% expressed concern that family and community life may be threatened by the Internet; 58% disagreed that computers are well-accepted in Arab society, a necessary component for the Internet; and 40% disagreed that the Internet would have a positive impact on Arab family and community ties (2003).

VR entails the use of technology similar to internet. From these reports, we may assume that ethnicity may affect motivation to engage in VR, the ability to feel comfortable in VR immersion, and the degree of presence experienced in VR. We conducted a study in which we compared subjects from two different ethnic groups in Israel– Jewish and Arab. As it has been reported that Arabs are not comfortable with internet usage, we anticipated lower levels of presence for Arab when compared with Jewish subjects. Although we did not find a difference on our presence questionnaire, there was a significant difference between Jewish participants and Arab females in their behavior within the VRE. This resulted from the significantly higher percentage of Arab women who avoided viewing the virtual window. Turning one's head and viewing the virtual window may be considered an objective measure of presence in comparison with the self report questionnaire (Almog, Wallach, &Safir, 2009).

3.3 Interaction Variables

Interactivity in the Virtual Environment is defined as the degree to which the environment allows the subject/client to influence the content or the design of the environment (Steuer, 1992). Interaction includes control over the environment and interactivity. Interaction is presumed to influence presence both directly and indirectly by focusing attention and increasing involvement (Van Der Straaten, 2000). Persky, et al. (2009) used VE in a learning task and found when students were able to actively control the environment, they reported higher levels of presence than when they passively experienced the VE. Groenegress, Thomsen, and Slater, (2009) propose that actual body movements performed while immersed in the VE increases the sense of presence. They entitled these movements "body-centered interaction". They found that this control is more important than the realistic depiction of the environment in a series of studies. Subjects, who were able to control an abstract form in the VE by using their voices, gave higher presence ratings than subjects in a conventional VE with limited control and interactivity. They concluded that "there appears to be a quality beyond the conventional "sense of being there" that relates not to the realism of the environment but to whether it responds realistically to a person's own actions" (pg. 430).

Movement in the VE is important over and beyond the control it affords. Riva (2009) states that an important dimension of presence is the perception of feasibility and possibility of motor actions in the VE "In other words, the subject is ‘‘present’’ in a space if he/she can act in it. Moreover, the subject is ‘‘present’’ in space—real or virtual—where he/she can act in it. Interestingly, what we need for presence are both the affordance for action (the possibility of acting) and its enaction (the possibility of successfully acting)." (page 161). Riva goes on to state that action is more important than perceptual aspects of the environment. Moreover, in his opinion, action is closely tied to intention. Therefore, since intention is individually defined, so too presence will vary between individuals in the same VE. A closely related issue is body engagement. Movement in the VE can be performed with a joystick or mouse, or actual body movements. When using body movements, the easiest to implement is "walking in place" as actual walking is difficult due to technological shortcomings such as tracker and hmd cable length. Usoh et al. (1999) found that actual walking induced higher levels of presence than walking in place. The latter was superior to moving a joystick or mouse. The importance of body engagement in inducing presence was replicated by Slater, Steed, McCarthy, &Maringelli, (1998) and by Slater and Steed (2000).

A related issue is the degree of relevance of the VE. The VR environment is "generic" and therefore often lacking in personal links which are necessary to increase belief in the environment. This belief increases the feeling of presence (Wiederhold& Wiederhold, 2005). Riva (2006) stated that the more the environment has intellectual and/or emotional meaning, the more it will induce presence. This is further explicated by Hoffman, Prothero, Wells, &Groen, (1998) and by Kizony, Katz, and Weiss, (2003). Hoffman et al. (1998) found that chess players reported higher presence when the virtual chess pieces were placed in a meaningful way. Kizony, et al. (2003) found that scenes that were functionally relevant to rehabilitation patients (soccer, street crossing) produced higher levels of presence than scenes that were less relevant (snowboarding, birds and balls and shark bait). We propose that an additional method to increase meaning may be to employ guided imagery prior to entering the VR environment. This guided imagery can contain personal references which will make the experience more personal. We are currently investigating this question in a research project.

4 Summary

An important personality variable that has not been discussed or previously addressed is expectations. Expectations have a powerful effect on treatment (Wallach, 2000; Zoellner, Feeny&Bittinger, 2009), so they may be important in inducing presence as well. Casati, and Pasquinelli, (2005) alluded to this when they discussed the motor and sensory expectations naturally evoked in a VE and the effect on presence of discordance between these expectations and the VE. However, we can manipulate expectations, by providing convincing rationales, to ensure that participants expect what they receive (Wallach, 1988). This is an important variable that has yet to be examined in the context of VR.

Although the picture is still not clear, we can start to sketch the optimal VR user profile. In terms of VRE: the environment need not be an accurate depiction of reality, however it should not contain discordant elements, it should be "believable". Using multiple sensory dimensions (which are congruent), detail, continuous movements, high update rate of the program and stereoscopy all add to the experience of presence. AVR HMD is superior to a flat TV screen, but only if the HMD is comfortable. Finally, it is important that the medium be as unobtrusive as possible.

Regarding user variables, empathy, imagination, immersive tendencies, dissociation tendencies, locus of control and cognitive style have all been found to influence presence. Unfortunately, most studies examined these variables independently. When they have been combined in a multi variable design, we discovered that only locus of control and empathy remain influential when the VE is rich. Imagination is important in an impoverished environment. Perhaps, several variables correlate highly with one another, thus adding little to the prediction of presence. The degree of interactivity and movement the VE enables is closely linked to locus of control. Higher levels of control and movement have been found to increase presence. In addition, both attachment and cognitive style seem to influence presence. Sensory processing holds promise as an important additional variable.

Finally, the more relevant the individual experiences the VE, the greater the participant experiences presence. Relevance can be influenced, for example, by employing anxiety relevant VEs for phobic participants, or a VE that is personally meaningful to the participant.

In summary, it is necessary to conduct research that examines a multiplicity of variables jointly, in order to determine their interaction, what remain significant, and what "disappear". In addition, it is unclear how gender and culture influence responsivity to the VE. These important issues are only beginning to be studied. We suggest that as individuals from traditional societies have less technological exposure, and experience, they will be less comfortable in a VE and experience less presence, however this is a hypothesis to be further investigated.

References

Ainsworth, M.D.S., Blehar, M.C., Waters, E., Wall, S.: Patterns of attachment: A psychological study of the strange situation. Erlbaum, Hillsdale (1978)

Albarran, A.B., Umphrey, D.: Marketing cable and pay cable services: impact of ethnicity, viewing motivations, and program types. Journal of Media Economics 7, 47–58 (1994)

Almog, I., Wallach, H.S., Safir, M.P.: Ethnicity and sense of presence in a Virtual Environment: Arab women – a case in point. In: Accepted for Publication in Virtual Rehabilitation 2009 International Conference Proceedings (April 2009)

Ayres, A.J.: Sensory integration and learning disorders. Western Psychological Services, Los Angeles (1972)

Banos, R., Botella, C., Alcaniz, M., Liano, V., Guerrero, B., Rey, B.: Immersion and emotion: The impact on the sense of presence. Cyberpsychology and Behavior 7, 734–741 (2004)

Barber, T.X., Wilson, S.C.: The Barber Suggestibility Scale and the Creative Imagination Scale: experimental and clinical applications. American Journal of Clinical Hypnosis 21, 84–108 (1979)

Becker, L.B., Kosicki, G.M., Jones, F.: Racial-difference in evaluations of the mass media. Journalism Quarterly 69, 124–134 (1992)

Biocca, F., Kim, J., Choi, Y.: Visual touch in virtual environments: An exploratory study of presence, multimodal interfaces, and cross-modal sensory illusions. Presence-Teleoperative Virtualit 10, 247–265 (2001)

Bowlby, J.: Attachment and loss: Separation: Anxiety and anger, vol. 2. Basic Books, New York (1973)

Brown, C., Tollefson, N., Dunn, W., Cromwell, R., Filion, D.: The adult sensory profile: Measuring patterns of sensory processing. The American Journal of Occupational Therapy 55, 5–82 (2001)

Bouchard, S.J., St-Jacques, Renaud, P.: Anxiety Increases the Feeling of Presence in Virtual Reality. Presence 17, 376–391 (2005)

Carroll, R.L., Silbergleid, M.I., Beachum, C.M., Perry, S.D., Pluscht, P.J., Pescatore, M.J.: Meanings of rado to teenagers in a niche-progarmming era. Journal of Broadcasting & Electronic Media 37, 159–176 (1993)

Casati, R., Pasquinelli, E.: Is the subjective feel on ”presence” an uninteresting goal? Journal of Visual Languages and Computing 16, 428–441 (2005)

Children’s Partnership, Online Content for Low-income and Underserved Americans: The Digital Divide’s New Frontier, Children’s Partnership, New York (2000)

Davis, M.H.: Empathy. In: A Social Psychological Approach, Westview Press, Oxford (1994)

Dunn, W.: The impact of sensory processing abilities on the daily lives of young children and their families. Infants and Young Children 9(4), 23–35 (1997)

Dunn, W.: The sensations of everyday life: Empirical, theoretical, and pragmatic considerations, Eleanor Clarke Slagle Lecture. The American Journal of Occupational Therapy 55, 608–620 (2001)

Gerhard, M., Moore, D., Hobbs, D.: Close encounters of the virtual kind: Agents simulating copresence. Applied Artificial Intelligence 19, 393–412 (2005)

Groenegress, C., Thomsen, M.R., Slater, M.: Correlations between vocal input and visual response apparently enhance presence in a virtual environment. CyberPsychology & Behavior 12, 429–431 (2009)

Hair, M., Renaud, K.V., Ramsay, J.: The influence of self-esteem and locus of control on perceived email-related stress. Computers and Human Behavior 23, 2791–2803 (2007)

Hecht, D., Reiner, M.: Field dependency and the sense of object-presence in haptic virtual environments. Cyberpsychology and Behavior 10(2), 243–251 (2007)

Hoffman, H., Prothero, J., Wells, M., Groen, J.: Virtual chess: Meaning enhances users’ sense of presence in virtual environments. International Journal of Human-Computer Interaction 10(3), 251–263 (1998)

Jacobson, D.: Presence revisited: Imagination, competence, and activity in text based virtual worlds. Cyberpsychology and Behavior 4, 653–673 (2001)

Jacobson, D.: On Theorizing Presence. Journal of Virtual Environments 6, 1–11 (2002)

Johns, C.L., Nunez, D., Daya, M., Sellars, D., Casaneuva, J.S., Blake, E.H.: The interaction between individuals’ immersive tendencies and the sensation of presence in a virtual environment. In: Mulder, J.D., van Liere, R. (eds.) Virtual Environments 2000: Proceedings of the Eurographics Workshop, Springer, London (2000)

Jurnet, I.A., Beciu, C., Maldonado, J.: Individual differences in the sense of presence. In: Slater, M. (ed.) Proceedings of the 8th International Workshop on Presence (Presence 2005). University College, London (2005)

Kaber, D.B., Draper, J.V., Usher, J.M.: Influence of individual differences on application design for individual and collaborative immersive virtual environments. In: Stanney, K.M. (ed.) Handbook of Virtual Environments; Design, Implementation, and Applications, pp. 379–402. Lawrence Erlbaum Associates, New Jersey (2002)

Kizony, R., Katz, N., Weiss, P.L.T.: Adapting an immersive virtual reality system for rehabilitation. The Journal of Visualization and Computer Animation 14, 261–268 (2003)
Knickerbocker, B.M.: A Holistic approach to learning disabilities. C.B. Slack, Thorofare, N. J (1980)
Krijn, M., Emmelkamp, P.M.G., Olafsson, R.P., Biemond, R.: Virtual reality, exposure therapy of anxiety disorders: A review. Clinical Psychology Review 24, 259–281 (2004)
Laarni, J., Ravaja, N., Saari, T., Hartmann, T.: Personality-related differences in presence. In: Raya, M.A., Solaz, B.R. (eds.) Proceedings of the Seventh Annual International Workshop PRESENCE 2004, pp. 88–95. Universidad Politecnica de Valencia, Valencia (2004)
Laarni, J., Ravaja, N., Kallinen, K., Saari, T.: Influence of user-related factors on presence. In: Thatcher, A., James, J., Todd, A. (eds.) Proceedings of CybErg 2005, the Fourth International Cyberspace Conference on Ergonomics, Johannesburg International Ergonomics Association Press (2005)
Laidlaw, T.M., Large, R.G.: Harvard Group Scale of Hypnotic Susceptibility and the Creative Imagination Scale: defining two separate but correlated abilities. Contemporary Hypnosis 14, 26–36 (1997)
Lee, K.M.: Presence, Explicated. Communication Theories 14, 27–50 (2004)
Lefcourt, H.M.: Locus of control: Current trends in theory and research. Lawrence Erlbaum Associates, Hillsdale (1982)
Loch, K., Straub, D., Kamel, S.: Diffusing the Internet in the Arab world: The role of social norms and technological culturation. IEEE Transactions on Engineering Management 50, 45–63 (2003)
Mikulincer, M.: Adult Attachment Style and Information Processing: Individual Differences in Curiosity and Cognitive Closure. Journal of Personality and Social Psychology 72, 1217–1230 (1997)
Mikulincer, M.: Adult attachment style and affect regulation: Strategic variations in self-appraisals. Journal of Personality and Social Psychology 75, 420–435 (1998)
Mikulincer, M., Florian, V.: Exploring individual differences in reactions to mortality salience: Does attachment style regulate terror management mechanisms? Journal of Personality and Social Psychology 79, 260–273 (2000)
Mikulincer, M., Gillath, O., Shaver, P.R.: Activation of the Attachment System in Adulthood: Threat-Related Primes Increase the Accessibility of Mental Representations of Attachment Figures. Journal of Personality and Social Psychology 83, 881–895 (2002)
Miller, L.J., Anzalone, M.E., Lane, S.J., Cermak, S.A., Osren, E.T.: Concept Evolution in Sensory Integration: A Proposed Nosology For Diagnosis. The American Journal of Occupational Therapy 61(2), 135–140 (2007)
Murray, C.D., Fox, J., Pettifer, S.: Absorption, dissociation, locus of control and presence in virtual reality. Computer and Human Behavior 23, 1347–1354 (2007)
Myers, I.B., McCaulley, M.H.: Manual: A Guide to the Development and Use of the MBTI. Consulting Psychologist Press, Palo Alto (1998)
Newhagen, J.E.: Media use and political efficacy: the suburbanization of race and class. Journal of American Society for Information Science 45, 386–394 (1994)
Newman, K.: Albert in Africa: online role-playing and lessons from improvisational theatre. Computational Entertainment 3, 4–4 (2005)
Nicovich, S.G., Boller, G.W., Cornwell, T.B.: Experienced presence within computer-mediated communications: Initial explorations on the effects of gender with respect to empathy and immersion. Journal Computer-Mediated Communication 10, 1–17 (2005)
NTIA, Falling through the Net: A Survey of the “have-nots” in Rural and Urban American, Department of Commerce, Washington, DC (1995)

NTIA, Falling through the Net: Defining the Digital Divide, Department of Commerce, Washington, DC (1999)

NTIA, Falling through the Net: Towards Digital Inclusion, Department of Commerce, Washington, DC (2000)

Pair, J., Allen, B., Dautricourt, M., Treskunov, A., Liewer, M., Graap, K., Reger, G., Rizzo, A.: A virtual reality exposure therapy application for Iraq war post traumatic stress disorder. In: IEEE VR Proceedings, pp. 64–71 (2006)

Park, J., Cho, D., Hong, S., Kim, G.J., Han, S.: Relative Contributions of Visual Elements toward Presence. In: Proceedings of IEEE International Conference on Virtual Reality (March 2003)

Persky, S., Kaphingst, K.A., McCall, C., Lachance, C., Beall, A.C., Blascovich, J.: Presence relates to distinct outcomes in two virtual environments employing different learning modialities. CyberPsychology & Behavior 12, 263–268 (2009)

Price, M., Anderson, P.: The role of presence in virtual reality exposure therapy. Journal of Anxiety Disorders 21, 742–751 (2007)

Ravaja, N., Saari, T., Salminen, M., Laarni, J., Holopainen, J., Jarvinen, A.: Emotional response patterns and sense of presence during video games: Potential criterion variables for game design. In: Hyrskykari, A. (ed.) Proceedings of the NordiCHI 2004, pp. 339–347. ACM Press, New York (2004)

Ribisl, K.M., Winkleby, M.A., Fortmann, S.P., Flora, J.A.: The interplay of socioeconomic status and ethnicity on Hispanic and White men's cardiovascular disease risk and health communication patterns. Health Education Research 13, 407–417 (1998)

Riva, G.: Virtual Reality. In: Wiley Encyclopedia of Biomedical Engineering, John Wiley & Sons, Inc., Chichester (2006)

Riva, G.: Is presence a technology issue? Some insights from cognitive sciences. Virtual Reality 13, 159–169 (2009)

Riva, G., Molinari, E., Vincelli, F.: Virtual reality as communicative medium between patient and therapist. In: Riva, G., Davide, F. (eds.) Communications Through Virtual Technology: Identity Community and Technology in the Internet Age, pp. 87–100. IOS Press, Amsterdam (2003)

Riva, G., Mantovani, F., Capideville, C.S., Preziosa, A., Morganti, F., Villani, D., Gaggioli, A., Botella, C., Alcaniz, M.: Affective interactions using Virutal Reality: The link between presence and emotions. CyberPsychology & Behavior 10, 45–56 (2007)

Robillard, G., Bouchard, S., Fournier, T., Renaud, P.: Anxiety and presence during VR immersion: A comparative study of the reactions of phobic and on-phobic participants in therapeutic virtual environments derived from computer games. CyberPsychology and Behavior 6, 467–476 (2003)

Rothbaum, B.O., Anderson, P., Zimand, E., Hodges, L.F., Lang, D., Wilson, J.: Virtual reality exposure therapy and standard (in vivo) exposure therapy in the treatment of fear of flying. Behavior Therapy 37, 80–90 (2006)

Rotter, J.: Generalized expectations for internal versus external control of reinforcement. Psychological Monographs 80, 1–28 (1966)

Royeen, C.B., Lane, S.J.: Tactile processing and sensory defensiveness. In: Fisher, A.G., Murray, E.A., Bundy, A.C. (eds.) Sensory Integration: Theory and Practice, pp. 108–136. F. A. Davis, Philadelphia (1991)

Sacau, A., Laarni, J., Hartmann, T.: Influence of individual factors on presence. Computers in Human Behavior 24, 2255–2273 (2008)

Sacau, A., Laarni, J., Ravaja, N., Hartmann, T.: The impact of personality factors on the experience of spatial presence. In: Slater, M. (ed.) Proceedings of the 8th International Workshop on Presence Presence 2005, pp. 143–152. University College, London (2005)

Sas, C., O'Hare, G.M.P.: Presence equation: An investigation into cognitive factors underlying presence. Presence: Teleoperators and Virtual Environments 12(5), 523–537 (2003)

Schubert, T.W., Friedman, F., Regenbrecht, H.T.: Embodied presence in virtual environments. In: Paton, R., Neilson, I. (eds.) Visual representations and interpretations, pp. 268–278. Springer, London (1999)

Schubert, T., Friedmann, F., Regenbrecht, H.: The experience of presence: Factor analytic insights. Presence-Teleoperative Virtual 10, 266–281 (2001)

Schuemie, M.J., Van Der Straaten, P., Krijn, M., Van Der Mast, C.A.P.G.: Research on Presence in Virtual Reality: A survey. CyberPsychology & Behavior 4, 183–201 (2001)

Shaver, R., Mikulincer, M.: Attachment-Related Psychodynamics. Attachment and Human Development 4, 133–161 (2002)

Simpson, J.A., Rholes, W.S., Nelligan, J.S.: Support seeking and support giving within couples in an anxiety-provoking situation: The role of attachment styles. Journal of Personality and Social Psychology 62, 434–446 (1992)

Slater, M.: Place illusion and plausibility can lead to immersive virtual environments. Philosophical Transactions of the Royal Society of Biological Sciences 364, 3549–3557 (2009)

Slater, M., Steed, A.: A virtual presence counter. Presence-Teleoperators And Virtual Environments 9, 413–434 (2000)

Slater, M., Steed, A., McCarthy, J., Maringelli, F.: The influence of body movement on subjective presence in virtual environments. Human Factors 40, 469–477 (1998)

Slater, M., Usoh, M., Steed, A.: Depth of presence in virtual environments. Presence: Teleoperators and Virtual Environments 3, 130–144 (1994)

Somer, E., Dolgin, M., Saadon, M.: Validation of the Hebrew version of the Dissociative Experiences Scale (H-DES) in Israel. Journal of Trauma Dissociation 2, 53–66 (2001)

Stever, J.: Defining virtual reality: Dimensions determining telepresence. Journal of Communications 42, 73–93 (1992)

Steuer, J.S.: Defining virtual reality: Dimensions determining telepresence. Journal of Communication 42, 73–93 (1992)

Subervi-Velez, F.A., Berg, C.R., Constantakis-Valdes, P., Noriega, C., Rios, D.I., Wilkinson, K.T.: Mass communication and Hispanics. In: Padilla, F. (ed.) Hand book of Hispanic Cultures in the United States: Sociology, pp. 304–357. Arte Publico Press, University of Houston, Houston (1994)

Sun, J.: User readiness to interact with information systems – a human activity perspective. Unpublished doctoral dissertation, University of A&M, Texas (2005)

Tal-Saban, M., Yuchman, A., Parush, S.: Dunn's Sensory Profile questionnaire and it's adaptation to Israeli children. Israeli Journal of Occupational Therapy 11, 33–48 (2002) (in Hebrew)

Tang, A., Biocca, F., Lim, L.: Comparing differences in presence during social interaction in augmented reality versus virtual reality environments: An exploratory study. In: Proceedings of the International Workshop on Presence, Citeseer (2004)

Taylor, C.M., Schepers, J.M., Crous, F.: Locus of control in relation to flow. Journal of Individual Psychology 32, 63–71 (2006)

Thatcher, A., James, J., Todd, A.: Proceedings of CybErg 2005, The Fourth International Cyberspace Conference on Ergonomics. International Ergonomics AssociationPress, Johannesburg (2005)

Thomas, N.J.T.: Are theories of imagery theories of imagination? An active perception approach to conscious mental content. Cognitive Science 23, 207–245 (1999)

Usoh, M., et al.: Walking > walking-in-place > flying, in virtual environments. In: Proceedings of the 26th annual conference on Computer graphics and interactive techniques, pp. 359–364. ACM Press/Addison-Wesley Publishing Co (1999)

Valecha, G.K., Ostrom, T.M.: An abbreviated measure of internal-external Locus of control. Journal of Personality Assessment 38, 369–376 (1974)

Van der Straaten, P.: Interaction affecting the sense of presence in virtual reality. Report written as product of the "research task" component of the informatics curriculum at the Delft Unviersity of Technology, Faculty of Information Technology and System, presented December 13 (2000)

Wallach, H.S.: Dysmenorrhea: Clients' expectations and psychological therapy. University of Western Ontario, London, Ontario, Canada, PhD Thesis under supervision of Prof. Gary Rollman (1988)

Wallach, H.S.: Patient treatment interaction: Where are we and how do we proceed. Israel Journal of Psychiatry 37, 51–63 (2000)

Wallach, H.S., Safir, M.P., Almog, I.: Attachment and sense of presence in a Virtual Environment. Virtual Reality 13, 205–217 (2009)

Wallach, H.S., Safir, M.P., Bar-Zvi, M.: Virtual Reality Cognitive Behavior Therapy for Public Speaking Anxiety: A Randomized Clinical Trial (2009a) (accepted for publication in Behavior Modification October 2008)

Wallach, H.S., Safir, M.P., Bar-Zvi, M.: Exposure versus Cognitive Restructuring therapy in the treatment of Public Speaking Anxiety – a pilot study. Accepted for publication in Israel Journal of Psychiatry (2009b)

Wallach, H.S., Safir, M.P., Samana, R.: Personality variables and presence. Accepted for publication in Virtual Reality (April 2009)

Webster, J., Martocchio, J.J.: Microcomputer playfulness: development of a measure with workplace implications. MIS Quarterly 16, 201–226 (1992)

Wegner, D.M., Smart, L.: Deep cognitive activation: A new approach to the unconscious. Journal of Consulting and Clinical Psychology 65, 984–995 (1997)

Wickramasekera II., I.E., Szlyk, J.P.: Could empathy be a predictor of hypnotic ability? International Journal of Clinical and Experimental Hypnosis 51, 390–399 (2003)

Wiederhold, B.K., Wiederhold, M.D.: Virtual Reality Therapy for Anxiety Disorders: Advances in Evaluation and Treatment. American Psychological Association, Washington (2005)

Wilbarger, P., Wilbarger, J.L.: Sensory defensiveness in children aged 2-12. An intervention guide for parents and other caretakers. Avanti Educational Programs, Santa Barbara (1991)

Wilhelm, A.G., Thierer, A.D.: Symposium: many sectors of society technically disadvantaged. Insight on the News 16(33) (2000)

Wirth, W., Hartmann, T., Bocking, S., Vorderer, P., Klimmt, C., Schramm, H., et al.: A process model of the formation of Spatial Presence experiences. Media Psychology 9, 493–525 (2007)

Witmer, B.G., Singer, M.J.: Measuring presence in virtual environments: A presence questionnaire. Presence 7, 225–240 (1998)

Yehuda, R.: Post-traumatic stress disorder. New England Journal of Medicine 346(2), 108–114 (2002)

Zoellner, L.A., Feeny, N.C., Bittinger, J.N.: What you believe is what you want: Modeling PTSD-related treatment preferences for sertaline or prolonged exposure. Journal of Behavior Therapy and Experimental Psychiatry 40, 455–467 (2009)

Chapter 8
The Healing Potential of Online Virtual Worlds

Jacquelyn Ford Morie

University of Southern California
Institute for Creative Technologies
Marina Del Rey, CA 90292
morie@ict.usc.edu

Abstract. This chapter describes the research being done to create a healing center for veterans of recent conflicts in the online virtual world Second Life. This work, started in 2008 and funded by the US Army's Research Office, is building a dedicated online virtual world space to provide not only social connectivity for widely dispersed veterans, but also to offer stress-reducing health care and activities, especially in the area of Complementary and Alternative Medicine. The social space is populated by several intelligent agent-avatars that serve various functions. For example, there is a knowledgeable guide that can show people the various activities and spaces the site has to offer, find out and store a list of the visitors' interests, and keep a record of what they have seen and done. There are also intelligent agents who can provide guidance for certain activities such as walking a labyrinth, and a story activity called "The Warriors' Journey." Working with experts in Mindfulness-Based Stress Reduction (MBSR), we are implementing MBSR therapy in this Second Life space for veterans. These experts will run the in-world group sessions, inhabiting an avatar for this purpose. Experiments with returning veterans are planned for 2010 that will test the efficacy of such therapies deployed in the virtual world. We expect the use of virtual worlds for both group and individual therapies to increase in the future and this project is a first step in determining their viability.

Keywords: Virtual Worlds, health care, CAM, online therapy, intelligent agents, AI agents.

Disclaimer: The project or effort described here has been sponsored by the U.S. Army Research, Development, and Engineering Command (RDECOM). Statements and opinions expressed do not necessarily reflect the position or the policy of the United States Government.

1 Introduction: Social Networks and Virtual Worlds

The beginning of the 21st Century has fast become the age of web-based social networking. Internet applications such as Facebook, MySpace, Twitter, forums, blogs and simple-to-set-up community websites are used daily by tens of millions of participants across the globe.

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 149–166.
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In addition to the countless social networking applications on the Internet, online virtual worlds (VWs) have also seen a huge rise in popularity. As contrasted to other online offerings, VWs are the most graphic, immersive, and in some ways the most personal, of all applications. Virtual worlds are not new, with text-based examples dating back to the 1970s in the form of MOOs and MUDs. Since the mid-1980s, however, such environments have advanced from early 2D to fully 3D forms, with rich graphical capabilities. Today's virtual worlds have unique properties in addition to being three-dimensional graphical spaces: they have persistence (the world continues to exist and change even when you are not there), they require representation by an avatar (usually of one's choosing or design), and they feature highly immersive and interactive experiences (you can fully explore the 3D space).

In 2003, a small team at Linden Lab in San Francisco built a new virtual world for consumers. This one was a bit different than those that had gone before (e. g. Alpha World, Active World, Lucas Films' Habitat World). The Linden Lab world, called "Second Life," was made in a way that allowed the participants themselves to design, create, and even own elements of the world.

To use the Second Life virtual world, a person must download a software program called a "client" to their computer. Running this client connects the user to a network of server machines run by Linden Lab. Each server in the huge network grid (several thousand at the end of 2009) contains a piece of the virtual world expanse, and communicates to all the other servers to maintain a consistent state across the entirety of the world.

1.1 Creating, Existing and Participating in the Virtual World

Second Life contains in-world tools that allow players to build content, while certain assets such as textures, sounds and animations can be uploaded from other content creation programs, such as PhotoShop, Maya, or 3D StudioMax. This content reflects the ways in which Second Life residents mold the world to their own goals and purposes.

A distinctive characteristic of virtual worlds is that people inhabit them by taking the form of an avatar, a 3D representation of one's "self." Thus, communication in the world is primarily via avatar-to-avatar interactions, which brings a rich social component that goes beyond other web-based social networking programs. A new virtual world "resident," as they are called, can choose an avatar from a default starting set, but customization tools allow for modifying that avatar to a form more compatible with a person's self image. The tools available in Second Life are extremely flexible. Users can change not only clothing, but also the shape of body parts, and can add attachments and animations as they desire. People have created avatars that range from tiny furry creatures to fantastical forms such as dragons, fairies, genies and even a prehistoric mammoth. It is also possible to map an actual photograph of one's face onto a human avatar, thus creating a virtual look-a-like with which to inhabit the world.

With this avatar, a resident can participate in hundreds of activities. In the early days of Second Life, people built houses, cars, tourist destinations and entertainment spots. A popular activity was to dance in a nightclub, with special dance animations controlling one's avatar. Another early pursuit was virtual gambling – playing slot machines by paying them with an in-world currency called Linden Dollars (L$). The odds were with the house, as they would be in a standard casino, but it was a good way to socialize and you could actually win a few L$ once in a while. (In-world gambling has since been disallowed due to legal issues.) Besides the nightclubs and gambling, there was shopping (for virtual goods to wear and use), parties, musical performances, role-playing and casual games, and creating new forms of virtual art.

Residents also formed groups as a means to define their use of the virtual world and find others with shared interests. These groups range in size from a few people to literally thousands of members. Some are for role-playing (Kingdom of Sand and Gorean medieval role-playing groups), some are to bring attention to certain activities (Virtual Artists Alliance, Merchant Theft Protection Group), some just for fun (Star Trek Aliens, SL Pirate Crew), and several are reflections of real world groups (Virtual Nurse Educators, Breast Cancer Awareness, Relay for Life, NASA). In addition, more than 400 universities and colleges have some form of Second Life representation, with interests ranging from doing research to holding classes in-world.

In recent years, groups in this last category have grown as academics began to see the potential of the virtual world. Businesses tried to take advantage of its popularity, as well as entrepreneurs hoping to make some real money from those virtual dollars (L$ can actually be exchanged for real cash). A very few succeeded, but most capitalists found it disappointing. Second Life was a world looking for its purpose, and money-making ventures were not that purpose, for the most part.

In 2007, the USC Annenberg School for Communication's Network Culture Project issued a challenge to residents: What can you do in the virtual world for the public good? [1] The group offered three L$300,000 prizes for development (in Linden Dollars) to the projects deemed to have the best potential for a SL experience to do real world good.

One of the three winners was the Ability Commons group, whose stated purpose is to make:

> A virtual space dedicated to providing support for those living with disabilities. The purpose of the project is to provide a space for educating people about a wide range of disabilities, and to provide a common safe space for discussion and socialization. [2]

The roadmap for the Second Life virtual world was beginning to take a real world positive turn. In 2008 Linden Lab itself initiated the Linden Prize, specifically to award an innovative in-world application that meets the following criteria:

- Work in Second Life that also achieves tangible, compelling results outside of Second Life.
- Distinctive, original work using Second Life that clearly demonstrates high quality, execution, function, aesthetics and technical sophistication.
- Work that has the capacity for inspiring and influencing future development, knowledge, creativity, and collaboration both inside and outside of Second Life. [3]

The first year awardees, chosen from 230 entries, were Studio Wikitecture (a distributed architecture and urban planning team collaborating through SL) and the Virtual Ability group that had previously won the Annenberg prize. [4]

A small team at the USC Institute for Creative Technologies (ICT) had been using the Second Life platform since 2005 as a freely accessible, powerful test bed to demonstrate possibilities for sensor-driven feedback in a simulation environment. This was possible because Second Life provides a custom scripting language that permits a range of expansions to the SL software client. We at the ICT have built a simple Iraqi Village as a background environment for players to walk through. If the participant's arousal threshold, as measured by heart rate and skin conductance sensors, fell below a certain level indicating inattentiveness or boredom, some action would be triggered in the virtual world. This could be a car explosion, or other arousal event. A reverse connection was also possible: being too aroused could set off other consequences.

1.2 An Idea to Support a Need

This project engendered a great deal of discussion within the team about other functional designs that could be implemented in the virtual world, for example: making people relax, or helping them deal with stress, or giving them access to activities that they might not be able to do in real life.

We talked about which population might be best served by these ideas. ICT has received funding from the US Army and has developed many training simulations for them. Therefore, we thought military personnel would be a group that could benefit greatly, especially soldiers returning from deployment. We decided that we could harness the virtual world to create a place for veterans to get together and also access activities that would be beneficial to them. This project was proposed to our Army sponsors as the Transitional Online Post-deployment Soldier Support in Virtual Worlds (TOPSS-VW), but is more colloquially known as *Coming Home*. As the project proposal began to take shape over the summer of 2008, there was increasing media coverage and research about the needs of returning soldiers and the issues involved with obtaining that help.

A 2008 study by the Rand organization called *Invisible Wounds of War* [5] found that there were approximately 300,000 soldiers who had either psychological issues or some form of Traumatic Brain Injury (TBI) as a direct result of their military service. The Rand study noted that several gaps existed in the effort to get returning veterans health care for deployment-related psychological or brain injuries. These include a lack of accessibility, shortages of therapists trained to understand the military mindset, and the sometimes difficult process of getting the priority needed to qualify for care through the Veterans' Administration services. Rand's recommendations included expanding treatment options beyond the VA system through private insurers and the government TRICARE system [6] while noting that the availability of mental health specialists varies considerably by region.

In addition, recent studies by the Walter Reed Army Medical Center and the Army Research Institute (ARI) using the Post-Deployment Health Assessment and Reassessment instruments (PDHA and PDHRA, respectively) found that soldiers often take six months or more after they return home to self-report mental health concerns. This signals that even if soldiers do not think they need help they may come to require treatment at a later stage. From a long-term longitudinal study published in the Journal of the American Medical Association:

> Soldiers indicated more mental health distress on the PDHRA than on the PDHA and were referred at higher rates […] mental health concerns also increased substantially, including PTSD (active, 11.8% to 16.7%; reserve, 12.7% to 24.5%), depression (active, 4.7% to 10.3%; reserve, 3.8% to 13.0%), and overall mental health risk (active, 17.0% to 27.1%; reserve, 17.5% to 35.5%). [7]

Perhaps the most challenging obstacles to minimize are the "considerable" military cultural barriers that stigmatize admitting one needs such help. For many in the military, stigma is the single biggest deterrent to getting necessary treatment. Soldiers are inculcated with the need to be strong as an essential component of the warrior's ethos. The 2008 Rand study notes that mental health disorders are often looked upon as a sign of weakness, not only throughout the military but in the civilian world as well. Admitting the need for help is often perceived as failure, and it may also cause considerable damage to one's military career.

1.3 Benefits of the Virtual World

We realized that key aspects of the virtual world could be very beneficial to address some of these issues, such as stigma, difficulty in getting to or sticking with treatments, and finding others with similar interests despite being in remote or rural regions of the country.

Accessibility. Today's returning soldiers are most likely geographically dispersed, which may make it difficult to get to centers where medical help is typically aggregated. In addition, a social support structure may be lacking, leaving veterans unable to socialize with comrades in person on a regular basis. Psychological, physical or social factors can also prevent soldiers from attending live meetings, subsequently missing beneficial interactions with others. Online shared virtual worlds, however, are easily accessed from any personal computer, and can support the formation of social networks, facilitate access to care, and provide social activities between soldiers where geography is no barrier. It should be noted that soldiers are of the generation that is quite comfortable playing video games and using social networks, and they are therefore likely and willing to join online communities.

Awareness. We believe that a social space where soldiers can access treatment information, resources, activities, and socialize with other post-deployment soldiers, may create an awareness of symptoms that are typical of stress and encourage them to access appropriate traditional therapies. Specific resource areas can be made available within the virtual space dedicated to self-assessment and information about potential therapies soldiers can obtain. Such information might encourage them to seek out real-world treatment if and when they determine they need it.

Stigma. Another powerful aspect of virtual worlds is that they can provide anonymity, safekeeping one's real identity. When a player creates an account with their avatar in Second Life, the system is set up so that they choose a fictitious name for that character. While Linden Lab allows freedom in choosing the first name, the last name is selected from a provided list of sometimes colorful choices (e.g. Cupcake, Puddlegum, Calamity). This system encourages a "new" name for the person while they inhabit the virtual world. No one can know your real name unless you disclose it because the full details of account ownership are known only to Linden Lab.

Groups. Another feature of SL is the ability to form groups themed around a particular idea, cause, or interest. As the Coming Home Project idea was taking shape, the team did a search on SL groups to determine if there was anyone already providing care to veterans in the world. We did not find any at that time, with most keywords turning up military-like role-playing groups. We did discover one existing social group – the U. S. Military Veterans in Second Life. This group comprises veterans from all conflicts and branches of the service, and was started by two real life veterans named (in Second Life) Cowboy Wayne and Gwill Brickworks. This group had 300 members in the summer of 2008 and grew rapidly to more than 1000 members by late 2009.

The group serves a strong social function, uniting veterans so they can feel confident that the people they are connecting to in the virtual world share the same worldview, and understand the types of experiences they have encountered in their military service. It also screens those who want to join the group to be sure they are veterans by having fellow members from their specific branch of the service interview them.

2 Virtual Solutions to Health Care

There has been increasing focus on innovative uses of technology to assist with treatment methods, with many specifically targeted at military personnel. For example, Virtual Reality Environments [1] that recreate the area of conflict with real time computer graphics are being used to aid in imaginal therapy approaches. This Virtual Reality Exposure Therapy (VRET) has been shown to be more effective than the standard approach of simply asking the patient to try to imagine the situation (something that their coping mechanisms tend to fight against). VRET ensures a graduated therapeutic approach by giving the therapist control over the timing and intensity of distressing triggers. [8, 9, 10, 11, 12]

2.1 Designing the Veterans' Healing Center

The Coming Home Project was funded by the Army's Research, Development, and Engineering Command (RDECOM) in the Fall of 2008. Considering the myriad social affordances of SL, such as nightclubs and public gathering spots, we decided instead to create a calm, quiet, welcoming place for the veterans to gather. We used

[1] Virtual Reality Environments (VREs) differ from Virtual Worlds (VWs) in several ways. VREs are usually built for single purpose use and are not designed for social interaction. They are also not persistent, but do allow events and other arousal triggers to be consistently controlled by the therapist utilizing them in a clinical setting. VWs, by contrast, are more open-ended, persistent and notably social in nature.

the vacation destination of a Western lodge as inspiration for the design of the main building, and called it "Chicoma Lodge" after a mountain in the Southwestern United States known as a place of spiritual centering to the native populations. Within the Lodge, a central "great hall" was built in a circular shape with comfortable seating around several fireplaces where avatars could sit while users converse or simply enjoy the space. Two wings of the lodge were filled with interactive games such as pool, darts, arm wrestling and air hockey. There is also music provided by a jukebox that streams radio stations, and a grand piano where one can sit and play music like a well-trained music lover.

Fig. 1. The great hall of Chicoma Lodge, built as the social hub of the veterans healing center in Second Life.

The Chicoma Lodge is but one part of a complex of offerings in our space. A primary focus for our veterans' center is to make information available about disorders and their associated symptoms, and ways to try various types of therapies. Rather than recreate the entire range of possibilities for therapy, we chose to include ones that were part of the Complementary and Alternative Medical (CAM) arena that focus on a holistic mind-body approach. We chose this route for several reasons. First of all, the military is open to CAM approaches in the real world, and have been offering activities such Yoga Nidra (a practice that leads to deep relaxation and better sleep) at Walter Reed Army Hospital, and other military medical facilities. [15] Secondly, these approaches may be easier for the veterans to try, as they do not involve medications, or revealing information to a doctor. And finally, CAM activities are often considered pleasant and relaxing to those who participate in them. [2]

[2] It should be noted that the efficacy of any therapies presented within a virtual world space, whether traditional or CAM-based, have yet to be studied and verified. Because of this we chose to start with CAM techniques that have a body of real world evidence-based research supporting them.

2.2 Focus Therapies

What exactly are CAM therapies and how can they be implemented in Second Life? These techniques are designed to promote an integrated approach to treating illness. They focus on providing intervention strategies that promote a person's health through various relaxation techniques, self-reflection, and cognitive behavioral therapy, as well as through body movement and alternative medical practices such as acupuncture.

The National Institutes of Health (NIH) sponsors the National Center for Complementary and Alternative Medicine Research (NCCAM) to research the effectiveness of CAM treatments through evidence-based studies. The main categories of CAM include whole body approaches, mind-body medicine, biologically based substances such as herbs and vitamins, body work such as massage, and energy therapies such as eastern movement activities. [14] The aim of CAM treatments is not to replace traditional clinical treatments, but instead to provide positive adjustments in a person's life that may work in addition to any clinical intervention. The use of CAM techniques has been recognized by the Department of Defense (DoD), which through the Defense Center of Excellence (DCoE) for Psychological Health (PH) and Traumatic Brain Injury (TBI) is currently studying the use of CAM in helping soldiers recover from the war. [15]

The Second Life Coming Home center provides basic information about many CAM therapies and encourages soldiers to try them out, focusing on the mind-body and movement areas of CAM. The first therapy we are implementing is Mindfulness-Based Stress Reduction (MBSR). This therapy was pioneered by John Kabat-Zinn and is a form of cognitive therapy that trains the mind to eschew judgmental thoughts and to accept each moment "as is". [16] It has been proven effective in stress reduction, chronic pain alleviation, and even remission of some physical diseases. [17, 18, 19, 20, 21]

Working with experts Dr. Steve Hickman and his colleague Rochelle Voth from the San Diego Mindfulness Center, we have begun to adapt this CAM technique to the virtual world. We first held a real world workshop to bring all members of the team up to speed on the methodology of the technique. Initial in-world sessions for veterans are planned for the near future that will be run by Drs. Hickman and Voth, each using an avatar through which they will lead the virtual world sessions, with veterans also represented by avatars.

A typical MBSR routine involves an eight-week commitment. The group meets once a week with the facilitators in person, and participants are then required to do MBSR exercises at home during the rest of the week. In our case, the participants will be given space in the Second Life Coming Home center to both meet and to do their exercises. Data logs will be collected from these group and individual sessions for several purposes. They will be initially used to track how much time a veteran spends on the "homework" for the class. The long-term goal is to use the data logs as the basis for a virtual human who can eventually run these homework sessions more interactively than the standard CD that is provided for this purpose.

Once the initial sessions have been run in SL with a pilot group of veterans, we will run controlled evaluation studies to determine the level of efficacy this therapy provides.

These studies are being developed with Dr. Valerie Rice Chief, ARL-HRED AMEDD Field Office with the Wounded Warriors Program at Ft. Sam Houston, Texas.

Any CAM activity implemented in the virtual world must be evaluated to assess its effectiveness in a controlled study. Until this is done, we cannot be sure whether or not the activities are beneficial when delivered within the virtual world. However, as noted, Mindfulness-Based Stress Reduction has a large body of evidence-based research to show its effectiveness. As it has been shown to be a valuable real world therapy, we can then judge its effectiveness in the virtual world with some degree of confidence.

As we are able to show the effectiveness of the MBSR stress reduction techniques in the virtual world, we will explore other therapies that seem especially suited to this platform. One promising technique is behavioral activation, which focuses on reducing avoidance-behavior activities by reinforcing activities the veteran finds pleasurable or rewarding. [22, 23] Others include movement-based activities such as Tai Chi and Yoga.

2.3 Supporting Research for Virtual World Effectiveness

One might question whether having an avatar perform the actions rather than a person doing them physically in real life would have any benefit whatsoever. Yet there is a growing body of evidence that strongly indicates there is a beneficial effect in even simply watching one's avatar do the required movements. Several of these studies have been done in Stanford University's Virtual Humans Interaction Lab headed by Jeremy Bailenson. Early work by Bailenson and colleague Nick Yee defined what is termed "The Proteus Effect" whereby the appearance of one's avatar actually influences the behaviors a person feels that avatar must exhibit in the world. In their study, tall avatars perceived themselves to be more confident in the virtual world, and surprisingly, some of that confidence carried over into their real world demeanor. [24]

A later study by Jessie Fox and Bailenson examined the real world effect incurred by simply watching one's avatar exercise in the virtual world, a form of vicarious reinforcement. [25] Participants were divided into three groups. One group watched an avatar that looked very much like their real self (accomplished by presenting an avatar with a video scan of each participant's face) exercise vigorously in the virtual world. The second group watched a generic avatar (a virtual "other") perform the same exercise. The third group watched their look-a-like avatar do no exercise. The researchers found that those in the first group were actually stimulated to exercise more in the real world over the next 24 hours (walking, climbing stairs, bicycling, aerobic exercise or sports). Simply seeing a virtual "other" do the exercise was not sufficient to incur this effect. The connection of the viewer to their avatar was key in this experiment. Considering that avatars in Second Life are designed or customized by participants and used over a long period of time, a strong connection is often formed, and therefore a similar effect can be expected from vicarious activities in the Second Life environment even if the physical resemblance is not as pronounced.

2.4 Other Activities and Intelligent Agents

In addition to the CAM offerings in the Coming Home Center, we are populating the Second Life veterans' space with a variety of interactions to make it an engaging and interesting place to visit and hang out. These include musical performances and other gatherings such as themed parties and contests. We have several enrichment activities that might promote relaxation, though they are not backed up by evidence-based research in the same way that MBSR is. An example of this is a labyrinth that can be walked in the Second Life space. We have designed this to be accompanied by an agent (a conversational avatar that is controlled by an Artificial Intelligence or AI program) who can be summoned to explain how people have traditionally utilized the labyrinth. Unlike a real world labyrinth, a person walking the virtual labyrinth hears a tone at each turn taken and upon reaching the center is rewarded with a shower of golden particles.

Fig. 2. A visitor encounters the storytelling agent in the Warriors' Journey of the Cheyenne Dog Warrior.

Storytelling. We have also built a Storytelling Tower that features classical Warriors' Journeys from throughout history. The individual warrior's story is presented in several illustrative panels adorning the interior walls of the tower. The visitor also hears ambient sounds and music and a voice-over narrating the story. At the top of the tower the visitor meets an AI storytelling agent (a fully costumed 3D avatar), who finishes narrating the story, after which the visitor is informed that the storyteller may be asked any questions about his journey. This is done via the in-world chat function, so questions are typed, and the responses come back as text messages from the storyteller agent. In this way the story of the warrior can become more relevant for the participant.

Psychologists and other heath care professionals often use the power of narrative to aid in dealing with troubling situations or psychological issues. [26] Judith Norman states: "The benefit of telling and retelling stories of trauma reflects the constructivist literature indicating that the human mind makes every effort to establish personal meanings regarding circumstances and events." [27: 308]

While the Warriors' Journey activity is not a formal narrative therapy, it may serve to reinforce a positive self–image in the veteran who experiences it. A current real world project, called "Real Warriors" [28], is working with veterans to find positive growth in their combat experiences, and to share that growth with family, friends and colleagues.

In year two of the Coming Home project, we plan to take the storytelling activity to a more personal level by encouraging the veterans to author their own Warriors' Journey stories. A second intelligent and more advanced story-agent will be created to work with the veterans, helping them to compose narratives from their real life experiences, based on the story-related work of Dr. Andrew Gordon at the ICT. [29] This agent will listen for language of strength, survivorship, and resilience in a way similar to that of a social worker. McMillen (1999) noted that through storytelling some patients have been able to identify "positive by-products" of traumatic experiences by identifying personal strengths in themselves and others around them. Among these he includes: "increased self-efficacy, increased compassion through a sense of vulnerability, increased optimism or faith due to interpersonal support, stress inoculation or a sense of feeling stronger than others adding a perceived heightened ability to handle future stress or trauma, and finding meaning such as increased or new-found spirituality or settling on a new cause which often focuses on helping others." [30]

The Running Path. The virtual world does not have to be totally divorced from the real world. People immersed in Second Life still utilize inputs like the keyboard and mouse for navigation and interaction. Other inputs are also available, such as game controllers and more esoteric devices. Using alternative inputs to the virtual world is challenging unless these devices are widely available. For our activities, we decided to use real world inputs that could be easily accessed by most computer users, to maximize the coverage.

In discussions with a military social work expert, we were informed that many soldiers really longed for their daily Physical Training, especially running, and were asked if we could implement this activity in Second Life. Rather than simply create a path one could make their avatar run on by clicking the "up" arrow button (i.e. move forward), we chose to implement a new and potentially more helpful method to make one's avatar run. The connection in this case is a standard microphone and a little known function of the Linden scripting language that can recognize three levels of breath. To activate the jogging activity, a veteran need only breathe into a microphone in a regular, rhythmic pattern, matching their breath to a pulsing visual graphic on screen.[3] This breathing is akin to that performed by yogic practice, which can produce very relaxed and meditative states. As long as the person can maintain this type of breathing, their avatar jogs around the perimeter of the Second Life Island. This technique of requiring real world physical input to control an action in the virtual world (beyond keyboard/mouse control) is one that may provide positive physical benefits and is an area we will continue to explore.

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[3] To be clear, this breath is not meant to mimic the fast breathing of a runner who has been exerting himself, as this could lead to hyperventilation or dizziness if practiced by someone who is not physically exercising.

Fig. 3. and 4. An avatar "jogging" in SL, showing the red and green bars that indicate proper breathing rhythms, and a person using a microphone to accomplish this running.

Helper Agents. In addition to the agents connected to specific enrichment activities, there is an overall guide for the veterans' island. This guide greets each person when they arrive on the island. If it is the visitor's first time, he will offer to give them a walking tour of the space. He can also ask a visitor about specific interests and answer any questions the person may have about the center and its offerings. He can teleport the person to a specific region or activity. The guide remembers people he meets, and can store information about their questions and interests. Additionally, this guide can offer to connect veterans with others from their units without revealing the real life identity of the Second Life resident (who is known in-world only by a pseudonym), based on information the veteran shares with the guide. We plan to expand this guide to recognize trigger words that might indicate that a veteran is in a potentially dangerous psychological state, and alert a real world therapist.

For the Mindfulness Based Stress Reduction sessions, we plan to record all the activities of the group leader over several such sessions and use that information to create an intelligent agent that can perform some of the facilitator's functions. This will not take the place of the expert session leader, but will serve much the same function as the practice CDs usually given out for MBSR "homework," with the advantage of providing an interactive experience rather than being simple recitation. The agent can also allow the therapist to track users' at-home participation. This will be done for any CAM activities we implement under the idea that an agent can not only serve as a homework aid, but can also gently remind someone to engage in the activity on their own.

2.5 Expected Results

The Coming Home veterans healing center project is currently starting its second year of funding and exploration. Pilot studies are now in process for studying the efficacy and usability of both the Running Path and the Storytelling Tower containing the Warriors' Journey activities. In addition we plan to roll out the Mindfulness Based Stress Reduction group sessions in the virtual world in the second quarter of 2010.

The results of these studies will confirm or disprove our hypothesis that activities in the virtual world can produce real world benefits including both psychological and physiological improvements (regardless of the parallel real world analog). We look forward to reporting on the results of our experiments and expect that they will present the virtual world of Second Life as a powerful, easily accessible tool that can be part of the health routine of soldiers and civilians alike. It is our goal to have the Veterans Administration include such virtual therapies as an additional possibility for healing for those with psychological injuries from their military service.

2.6 Other Health Examples from the Virtual World

To date there are only a few notable examples of therapeutic practice in virtual worlds such as Second Life. Richard Dillon, Senior Vice President of Planning and Development at Preferred Family Healthcare in Missouri (Coughran Mayo in Second Life), has been running a program to help teens combat addictions by using an open source ("OpenSim") version of Second Life for several years now. This program provides each patient with a $500 laptop and instructions on how to use the software. The laptops are equipped with a camera. The kids do their "home assignments" in the virtual world and know that they can be watched so they are not tempted to let someone else stand in for them.

Dillon reports: "The retention/participation rates are astounding. Our retention rate is around 90.4% with 20 clients, compared to a 10.9% retention rate for the control group. "Other measures, such as client/family satisfaction, behavior change etc. also seem to be at or above what we are experiencing with the control group." [31, 32, 33] In the coming year Dillon's group plans to admit new clients, train those who have gone through the program to be mentors, and increase role playing scenarios within the virtual world.

Another group aimed at doing real world good in Second Life is the Virtual Abilities group, founded by Alice Krueger (Gentle Heron in SL) and previously mentioned as the recipient of several prizes in the Second Life community. This group provides experiences for people in Second Life that they might not be able to perform in the physical world. In November 2009 they received funding from the Telemedicine and Advanced Technology Research Center (TATRC), part of the US Army Medical Research and Materiel Command's (USAMRMC) to provide research into best practices for virtual world support that can benefit veterans who have experienced amputations due to their service. The Amputee Virtual Environment Support Space (AVESS) looks to not only affordances of the virtual world that can provide quality of life experiences for the veterans, but also the role of peer support in these environments. [34]

Peer support cannot be underestimated as a driving force in the virtual world domain. Above all, VWs are social spaces, and the ability to reach out to a fellow veteran in the world appeals, even if subconsciously, to those who often find themselves isolated or surrounded by people who have not shared combat experiences.

3 Issues and Concerns

Even though these worlds are primarily social in nature and offer great potential, there are still many challenges to successfully deploying assistive health regimens in the virtual world.

It is not clear what sorts of activities are most beneficial for the social group cohesion that keeps a virtual worlds-based group active and effective to its members. Many of the dances, musical performances, and other activities are often poorly attended. Even when wildly popular, a region in Second Life is only capable of accommodating about 40 avatars before the simulators that run the world begin to lag unacceptably. A workaround for this is to have a meeting place at the junction of four regions, such that each section can have 40 avatars, allowing for 160 total. Yet, attracting them is still more of an art than a predictable process. Most invitations are delivered via an in-world note card. If a person belongs to several groups (in SL the maximum is 25) then it is possible to get so many group invitations that they become mere noise or even an annoyance. It is up to the group managers to find the optimum balance of information to value. Especially with a group of over a thousand, information sent in this way may not be relevant to all, but subgroups are not yet supported by Linden Lab.

Kollock (1998) has examined the general features that lead to successful online communities, including 3D graphic virtual worlds. He explains, "There is no algorithm for community ... what makes for a successful online community is often poorly understood." He goes on to note, "the tendency of those involved in building graphical virtual worlds is to create visually compelling worlds that look good, but do a poor job of fostering social interaction." [35, 36] Simply believing that "if you build it, they will come" does not hold for the virtual world. It takes a concerted and ongoing effort to bring people to your part of the virtual world. There are thousands of things to do and people make choices based on decisions that may have nothing to do with being able to get help. In fact, the myriad activities available in a virtual world may actually distract from exploring needed health options. Techniques still need to be developed and codified to ensure that the correct population is being served and their needs are met.

Secondly, the very thing that makes such worlds attractive – the anonymity that can mitigate stigma – may also lead to a lack of accountability for those who are in the VW. There are no real world negative consequences for interrupting or not finishing a treatment. There may also be potential ethical concerns for the relationship between a therapist and a patient operating in virtual space. Does the therapist have knowledge of the person's true identity? If not, what are the limits on their responsibility to that patient?[4] In addition, if in-world therapy is offered and utilized, what will it take for insurance companies, or institutions such as the Veterans Administration, to cover costs associated with such health care?

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[4] In a story related to the author by veterans in the Second Life veterans group, a fellow vet had one particularly rough night when he announced in SL that he was going to commit suicide. His colleagues did not know his real name or whereabouts. The Linden Lab company, which does require this information when a person signs up for an account, was contacted. The in-world group members asked the company to alert emergency personnel near the veteran's home address (that they had on file) without revealing any of that information to those requesting this action. Linden Lab refused, citing their policy that such information was never given out under any circumstance. To date, though, there have been no court cases that seek to clarify the responsibilities of either individuals or health care providers when it concerns life or death situations in a virtual world.

Data in the virtual world is not secure, so there is potential for anyone who tries hard enough to get hold of it for purposes other than that for which it was intended. New firewall technology has been made available in late 2009 by Linden Lab that might be able to make this less of an issue, but running behind a firewall means that the vast (unsecured) areas of the world are not available. This is another challenge, among many, for widespread use of virtual worlds for health purposes.

4 Conclusion

We see the Coming Home project for veterans, and others like it, as the beginning of validation for the virtual world as a potentially powerful mechansim for therapeutic work and behavioral change. We look forward to studies that can confirm what we hypothesize will be true: In a virtual world, we have an amazing tool that can be harnessed for good and that can provide positive results in therapies applied within its domain.

Our work with actual veterans will be a pioneering step in this validation process. We can only hope it is the start of an exceptionally pertinent approach to therapy for the Internet savvy, socially connected generation of both military personnel and civilians who find themselves in need of a helping hand.

Acknowledgements

A project of this scope requires an interdisciplinary team. The author would like to acknowledge the work of past and present team members including Eric Chance (SL building and scripting, avatar design, video), Dinesh Purohit (programming, agent implementation), Kip Haynes (programming, agent design, display research), Sean Bouchard (sensory inputs, programming, game design), Jamie Antonisse (game design, story development), the Natural Language team at the ICT, headed up by Dr. David Traum and including Anton Leuski, Dusan Jan, Antonio Roque, Jillian Gerten, Ron Artstein, Kenji Sagae and many other who contribute to the creation of virtual human technology at ICT others. We especially appreciate the advice of the many experts from the military and the CAM communities that have contributed to this work, especially Dr. Richard Satava, a pioneer in Virtual Reality medical uses. And finally, I owe a special thank you to the following people at the ICT: Dr. Skip Rizzo, Associate Director for Medical Virtual Reality, Dr. Bill Swartout, Technology Director, and ICT's Executive Director, Dr. Randall Hill. This work would not have been possible without them.

References

1. Ondrejka, C.: A Challenge for the Public Good. Blog post from The MacArthur Foundation's Spotlight on Digital Media and Learning blog (Posted May 14, 2008), http://spotlight.macfound.org/blog/entry/cory_ondrejka_challenge_public_good/ (retrieved October 20, 2009)

2. USC Annenberg Network Culture Project Press Release, USC's Network Culture Project Awards More Than $1 Million Lindens for Second Life and the Public Good Community Challenge (Posted July 1, 2008), http://networkculture.usc.edu/insidencp/newsroom/8-news/63-uscs-network-culture-project-awards-more-than-1-million-lindens-for-second-life-and-the-public-good-community-challenge.html (retrieved July 20, 2008)
3. Linden Lab, Announcement of criteria (2009), http://lindenlab.com/lindenprize (accessed July 30, 2009)
4. Second Life Blogs (2009), Announcement of winners from: https://blogs.secondlife.com/community/features/blog/2009/04/30/the-linden-prize-goes-to-studio-wikitecture-and-virtual-ability
5. Rand Corporation (Rand Health Division and Rand National Security Research Division). In: Tanielian, T., Jaycox, L.H. (eds.) Invisible Wounds of War: Psychological and Cognitive Injuries, Their Consequences, and Services to Assist Recovery, http://www.rand.org/multi/military/veterans(retrieved June 12, 2008)
6. Rand, Invisible Wounds of War: p. 302 (2008)
7. Milliken, C.S., Auchterlonie, J.L., Hoge, C.W.: Longitudinal Assessment of Mental Health Problems Among Active and Reserve Component Soldiers Returning From the Iraq War. Journal of American Medical Association 298, 2141–2148 (2007)
8. Gerardi, M., Rothbaum, B.O., Ressler, K., Heekin, M., Rizzo, A.A.: Virtual Reality Exposure Therapy Using a Virtual Iraq: Case Report. Journal of Traumatic Stress 21(2), 209–213 (2008)
9. Rizzo, A.A., Rothbaum, B.O., Graap, K.: Virtual reality applications for combat-related posttraumatic stress disorder. In: Figley, C.R., Nash, W.P. (eds.) Combat Stress Injury: Theory, Research and Management, pp. 183–204. Routledge, New York (2007)
10. Rizzo, A., Pair, J., Graap, K., Manson, B., McNerney, P.J., Wiederhold, B., Wiederhold, M., Spira, J.: A Virtual Reality Exposure Therapy Application for Iraq War Military Personnel with Post Traumatic Stress Disorder: From Training to Toy to Treatment. In: Roy, M. (ed.) NATO Advanced Research Workshop on Novel Approaches to the Diagnosis and Treatment of Posttraumatic Stress Disorder, pp. 235–250. IOS Press, Washington (2006)
11. Rothbaum, B.O., Hodges, L., Alarcon, R., Ready, D., Shahar, F., Graap, K., et al.: Virtual reality exposure therapy for PTSD Vietnam Veterans: A case study. Journal of Traumatic Stress 12, 263–271 (1999)
12. Van Etten, M.L., Taylor, S.: Comparative efficacy of treatments of post-traumatic stress disorder: An empirical review. Journal of the American Medical Association 268, 633–638 (1998)
13. Shachtman, N.: Walter Reed Using Yoga to Fight PTSD. Wired Magazine (May 6, 2008); Article about Yoga Nidra at Walter Reed
14. National Center for Complementary and Alternative Medicine. Cambasics (retrieved June 12, 2008), http://nccam.nih.gov
15. Defense Center of Excellence for Psychological Health and Traumatic Brain Injury. Military Psychological Health Research – Complementary and Alternative Strategies. (retrieved June 12, 2008), http://www.health.mil/content/docs/pdfs/DCoE/DCoE%20BAA.pdf
16. Bishop, S.R., Lau, M., Shapiro, S., Carlson, L., Anderson, N.D., Carmody, J., Segal, Z.V., Abby, S., Speca, M., Velting, D., Devins, G.: Mindfulness: A Proposed Operational Definition. Clinical Psychology and Scientific Practice 11, 230–241 (2004)

17. Kabat-Zinn, J., Lipworth, L., Burney, R., Sellers, W.: Four year follow-up of a meditation-based program for the self-regulation of chronic pain: Treatment outcomes and compliance. Clinical Journal of Pain 2, 159–173 (1986)
18. Kabat-Zinn, J., Massion, A.O., Kristeller, J., Peterson, L.G., Fletcher, K., Pbert, L., et al.: Effectiveness of a meditation-based stress reduction program in the treatment of anxiety disorders. American Journal of Psychiatry 149, 936–943 (1992)
19. Kabat-Zinn, J., Wheeler, E., Light, T., Skillings, A., Scharf, M., Cropley, T.G., et al.: Influence of a mindfulness-based stress reduction intervention on rates of skin clearing in patients with moderate to severe psoriasis undergoing photo- therapy (UVB) and photochemotherapy (PUVA). Psychosomatic Medicine 60, 625–632 (1998)
20. Richard, J., Davidson, R.J., Kabat-Zinn, J., Schumacher, J., Rosenkranz, M., Muller, D., Santorelli, S.F., Urbanowski, F., Harrington, A., Katherine Bonus, K., Sheridan, J.F.: Alterations in Brain and Immune Function Produced by Mindfulness Meditation. Psychosomatic Medicine 65, 564–570 (2003)
21. Grossman, P., Niemann, L., Schmidt, S., Walach, H.: Mindfulness-based stress reduction and health benefits: A meta-analysis. Journal of Psychosomatic Research 57(1), 35–43 (2004)
22. Jakupcak, M., Roberts, L.J., Martell, C., Mulick, P., Michael, S., Reed, R., et al.: A pilot study of behavioral activation for veterans with posttraumatic stress disorder. Journal of Traumatic Stress 19, 387–391 (2006)
23. Tull, M.: Behavioral Activation for PTSD. At About.com (2008), http://ptsd.about.com/od/treatment/a/behavioralact.htm (accessed January 10, 2009)
24. Yee, N., Bailenson, J.: The Proteus Effect: The Effect of Transformed Self-Representation on Behavior. Human Communication Research 33(3), 271–290 (2007)
25. Fox, J.A., Bailenson, J.N.: Virtual self-modeling: The effects of vicarious reinforcement and identification on exercise behaviors. Media Psychology 12, 1–25 (2009)
26. Greene, L., Lee, M.: The Social construction of empowerment. In: O'Melia, M., Miley, K. (eds.) Readings in Contextual Social Work Practice, pp. 175–201. Allyn and Bacon, Boston (2002)
27. Norman, J.: Constructive Narrative in Arresting The Impact of Post-Traumatic Stress Disorder. Clinical Social Work Journal 28(3), 303–319 (2000)
28. See more about this group at, http://www.realwarriors.net
29. Gordon, A.: Story Based Learning Environments. In: The PSI Handbook of Virtual Environments for Training and Education: Developments for the Military and Beyond, pp. 382–383. Praeger Security International, Westport (2008)
30. McMillen, J.C.: Better for It: How People Benefit from Adversity. Social Work 44(5), 455–468 (1999)
31. Conversation with Coughran Mayo (Richard Dillon), (November 20, 2009) (in world)
32. The Robert Wood Johnson Foundation Pioneer Portfolio. Exploring the Potential of the Web-based Virtual World of Second Life to Improve Substance Abuse Treatment Outcomes (2008), http://www.rwjf.org/files/research/3485.34428.pdf (accessed November 22, 2009)
33. Enos, G.A.: Are Services in the virtual world near? Addiction Professional (2008), http://www.addictionpro.com/ME2/dirmod.asp?sid=&nm=&type=Publishing&mod=Publications:Article&mid=&tier=4&id=4EAEBA9918D64DF1941DE22DDE37190F (accessed October 12, 2009)

34. Virtual Ability, The Amputee Virtual Environment Support Space. Press Release (2009), `http://www.virtualabilities.org` (accessed December 10, 2009)
35. Kollock, P.: Design principles for online communities. PC Update 15(5), 58–60 (1998)
36. Kollock, P., Smith, M.: Introduction: Communities in Cyberspace. In: Smith, M., Kollock, P. (eds.) Communities in Cyberspace, pp. 3–25. Routledge, London (1999)

Author biography

Dr. Jacquelyn Ford Morie – has worked in immersive technology since 1990, focusing on affective and meaningful applications of virtual environments and online virtual worlds. Since 2000, she has been a Senior Research Scientist at USC's Inst. for Creative Technologies, working on multi-sensory immersive environments, and most recently on emplacing intelligent agents into Second Life for social and healing applications. She is a frequent speaker on immersive applications and has published widely, including a recent chapter in the 2007 book *Computer Games and Team and Individual Learning*.

Part 2: Virtual Reality and Rehabilitation

Chapter 9
Virtual Reality and Serious Games in Healthcare

Minhua Ma[1] and Huiru Zheng[2]

[1] Digital Design Studio, The Glasgow School of Art, The Hub, Pacific Quay, Glasgow, G51 1EA, United Kingdom
m.ma@gsa.ac.uk
[2] Computer Science Research Institute, School of Computing and Mathematics, University of Ulster, Co. Antrim, BT37 0QB, United Kingdom
h.zheng@ulster.ac.uk

Abstract. This chapter discusses the applications and solutions of emerging Virtual Reality (VR) and video games technologies in the healthcare sector, e.g. physical therapy for motor rehabilitation, exposure therapy for psychological phobias, and pain relief. Section 2 reviews state-of-the-art interactive devices used in current VR systems and high-end games such as sensor-based and camera-based tracking devices, data gloves, and haptic force feedback devices. Section 3 investigates recent advances and key concepts in games technology, including dynamic simulation, flow theory, adaptive games, and their possible implementation in serious games for healthcare. Various serious games are described in this section: some were designed and developed for specific healthcare purposes, e.g. BreakAway (2009)'s Free Dive, HopeLab (2006)'s Re-Mission, and Ma et al. (2007)'s VR game series, others were utilising off-the-shelf games such as Nintendo Wii sports for physiotherapy. A couple of experiments of using VR systems and games for stroke rehabilitation are highlighted in section 4 as examples to showcase the benefits and impacts of these technologies to conventional clinic practice. Finally, section 5 points some future directions of applying emerging games technologies in healthcare, such as augmented reality, Wii-mote motion control system, and even full body motion capture and controller free games technology demonstrated recently on E3 2009 which have great potentials to treat motor disorders, combat obesity, and other healthcare applications.

Keywords: Virtual Reality, video games technology, serious games in healthcare, adaptive games, flow experience, games-based therapy, dynamic simulation, motor rehabilitation.

1 Introduction

Virtual reality (VR) or virtual environment (VE) can be defined as a computing technology that generates simulated or artificially three dimensional (3D) environment, which imitates reality (Sisto, Forrest & Glendinning, 2002c). VR presents a convincing

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 169–192.
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interface that allows the user to engage with the computer-generated environment in a naturalistic way (Schutheis & Rizzo, 2001). Through 3D computer graphics via advanced input and output devices, users believe they actually perceive sensory information that is similar to that of the real world. In very simple terms, virtual reality can be defined as a synthetic or virtual environment which gives a person a sense of reality. It comprises a range of computer technologies that present information in a form that people perceive as similar to real world.

VR system can be classified into three categories: immersive, semi-immersive and non-immersive. Immersive VR systems are properly the most widely known VR systems where the user either wears a Head-Mounted Display (HMD), or a Head-Coupled Display (HCD), or uses some form of head display unit. Visual, auditory and tactile sensory aspects of the VE are delivered to the individual through visual display units and speakers within a HMD unit, data gloves or body suits. Additional movement may be obtained using joystick, space ball, 3D mouse, other hand-held sensors, or cameras.

In non-immersive VR, the user is placed in a 3D environment that can be directly manipulated with a conventional graphics workstation using a monitor, a keyboard and a mouse.

A semi-immersive VR system comprises of a relatively high performance graphics computing system coupled with either a large screen monitor, or a large screen projector, or multiple television projection systems. Using a wide field of view, semi-immersive VR system provides a better feeling of immersion or presence than the non-immersive system. Readers are referred to Kalawsky (1996) for detail comparison of the three types of VR system.

Two principal features of VR are (1) the user can control the viewpoint in the VE with six degree of freedom; and (2) the user can interact with objects within the VE (Wilson, 1997). When the user interacts with the VE through mouse, joystick, glove, or other input devices, the force or pressure, i.e. haptic feedback, will also be fed back to the user, hence the user can experience a sense of touching, including the weight, surface texture of the object (e.g. smooth, rough, soft, hard, sticky), and the force from the simulated environment, such as the gravity. These features have been very attractive to the digital entertainment, video games and the media industry. More recently, VR technology has been applied to medicine and healthcare to improve patient treatment and care. For instance, Rose *et al* (1996) reviewed four areas in neurological rehabilitation that VR could be applied to, i.e. assessment, training, interaction and enablement. In stroke rehabilitation, VR has been used as a rehabilitation intervention for both upper limb and lower limb. Rose *et al* (1998) evaluated the effectiveness of active participation versus passive observation of VEs in memory retaining after brain injury and the results showed significant improvement in spatial recognition tests in participants using VR. Readers are referred to Crosbie *et al* (Crosbie 2007) for a review on applications of VR in stroke rehabilitation. VR applications have also been developed to improve the lives of children with disabilities. VR systems could help to minimise the effects of a disability, improve patients' quality of life, enhance social participation, and improve their life skills, mobility and cognitive abilities, while providing a motivating and interesting experience for children with disabilities (McMomas 1998). Sun & Zheng (2004) applied non-immersive VR in using a virtual intravascular endoscopy to assess the effect of suprarenal stent struts on the renal artery with ostial calcification. VR has also been applied in medical training, such as laparoscopic surgery training. Cates (2007) suggested that VR simulation should be used in medical training to allow inexperienced physicians to acquire meaningful new procedural skills without jeopardizing patient safety in the process.

In VR application for healthcare, VR technologies are aliased with other technologies. For instance, Jaffe et al. (2004) used an immersive VR system (HMD and a video camera) in conjunction with treadmill training, Crosbie et al. (1997) applied a non-immersive PC based VR system with a motion tracking system in the stroke rehabilitation interventions.

In this chapter, we will first introduce VR devices in section 2. Section 3 will discuss the combination of VR and video games technologies and its applications in healthcare, focusing on dynamic simulation and using adaptive game play to keep players (patients) in the *flow*. Next, some experimental research and results are discussed in section 4, followed by the conclusions and the future directions of applying VR and video games technologies in healthcare, such as Augmented Reality (AR), full body motion capture and controller free games technology which have great potentials to treat motor skill disorders, combat obesity, and other healthcare applications.

2 VR Devices

An implementation of a VR application consists of a set of devices, such as computers, gloves, haptics feedback devices, motion tracking devices and display devices (HMD, projectors, VR goggles or screens for examples). This section will describe some of state-of-the-art VR devices.

2.1 Haptic Force Feedback Devices

In VR, the user is able to interact with the objects in VE. The term haptic refers to sensing and manipulation through touch (Srinivasan & Basdogan, 1997). Haptic feedback is the use of sense of touch in a VR system to provide 'real feeling' to the user. Using haptic feedback, the user could sense the pressure or force when carrying out rehabilitation exercises or training tasks, such as moving a ball in a virtual room, the ball will stop moving when colliding with a virtual wall or the virtual roof; when the user moves the ball on different type of surface, the user can feel the difference between a smooth surface and a rough surface from haptic feedback. The first type of feedback is an example of force feedback and the second one is an example of tactile feedback.

Haptic feedback has been incorporated in the development of haptic devices to improve the user's interaction with the VE (Laycock & Day, 2003). Fig. 1 illustrates the processes associated with haptic rendering when the user manipulates a haptic device. The following section reviews some of the haptic devices used in healthcare rehabilitation.

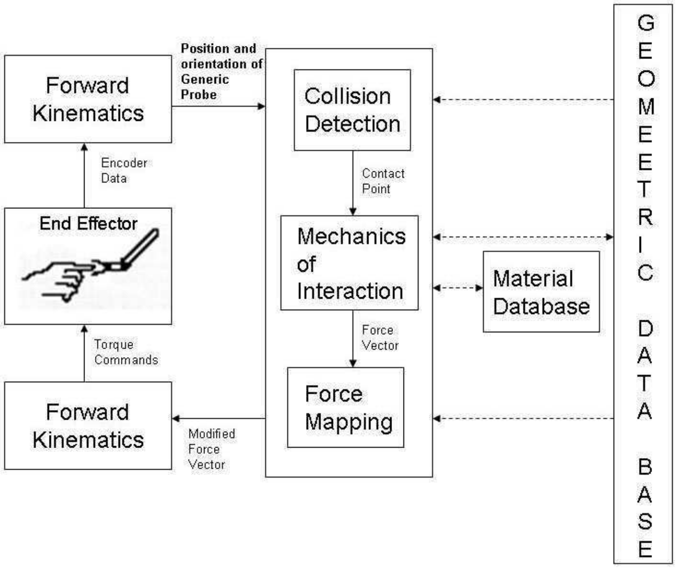

Fig. 1. The processes associated in haptic rendering with a force display. The solid and dashed lines represent the process flow and information exchange respectively (reproduced from Srinivasan & Basdogan, 1997)

One of the most popular haptic devices is PHANTOM (Personal Haptic Interface Mechanism) force feedback devices from Sensable Technologies. The PHAMTOM series have been widely used in VR applications, e.g. Steinberg et al. (2007) developed a haptic 3D dental training simulator and practitioners found its tactile sensation was realistic for teeth though not satisfactory for gingiva. PHANTOM Desktop or Omni devices offer affordable desktop solutions while the Premium models provide larger workspaces and higher forces. Fig. 2 illustrates the PHANTOM Desktop haptic feedback device. It consists of a kinematic framework with three rotational degrees of freedom, and a 3D force feedback workspace of 160Wx120Hx12D mm. The user interacts with the device by gripping a stylus attached to the distal point of the framework. The range of motion aligns with the hand movement pivoting at wrist. It provided three dimensional position sensing, three dimensional force feedback and three dimensional stiffness feedback. PHANTOM Premium devices provide a workspace up to 838Wx584mmx406Dmm (Premium 3.0), 6 degrees of position sensing, and the range of movement can be full since movements are pivoting at shoulder (Premium 3.0). The device is nominally passive (i.e. it does not resist the motion of the user), but motors located on each of the joints can be selectively activated to convey the illusion of contact with a rigid surface.

Fig. 2. PHANTOM Haptic Devices, from http://www.sensable.com

CyberGrasp system is another force feedback haptic option from Immersion's CyberGlove device (www.immersion.com). It provides force feedback to both hand and fingers for the user to naturally interact with complex 3D VE, and to control end-effectors in telerobotic applications that requiring a high level of dexterity. The CyberGrasp system (Fig. 3) includes three main components: CyberGlove (www.cyberglovesystems.com), position tracker and exoskeleton. The CyberGlove is the core of the system. It is used to measure the joint angles of the fingers, hand and wrist. The CyberGlove data is used to render a graphic hand on the screen or to control a telerobotic manipulator. The exoskeleton is in charge of providing force feedback to the user by restricting the finger movements.

2.2 Tracking Devices

Glove-Based Tracking Devices

Since the late 1970s people have studied glove-based devices for analysis of hand gesture. Gove-based devices adopt sensors attached to a glove that transduces finger flexion and abduction into eletrical signals for determining the hand pose (Zhou, 2004).

The Dataglove (originally developed by VPL Research, the pioneer of virtual reality technology and networked 3D graphics) is a neoprene fabric glove with two fiber optic loops on each finger. Each loop is dedicated to one knuckle and at one end of each loop is an LED and at the other end is a photosensor. The fiber optic cable has small cuts along its length. When the user bends a finger, light escapes from the fiber optic cable through these cuts. The amount of light reaching the photosensor is measured and converted into a measure of how much the finger is bent. The Dataglove requires recalibration for each user (Hsu, 1993). One potential problem is that if a user has extra large or small hands, the loops will not correspond very well to the actual knuckle position and the user will not be able to produce very accurate gestures (Aukstakalnis and Blatner 1992).

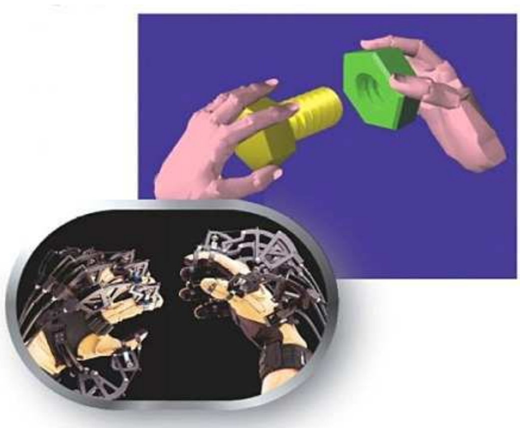

Fig. 3. The CyberGrasp system

The CyberGlove system includes one CyberGlove (www.cyberglovesystems.com), its instrumentation unit, a serial cable to connect to a host computer, and an executable version of the VirtualHand graphic hand model display and calibration software. To accomplish the measurement of the position and orientation of the forearm in the 3D space, the position tracker, which can be Polhemus Trackers (www.polhemus.com) or Ascension Trackers (www.ascension-tech.com) for example, measures the position and the rotation of the hand in the 3D space, is, mounted on the glove wristband. The CyberGlove has a software programmable switch and LED on the wristband to permit the system software developer to provide the CyberGlove wearer with additional input/output capability. The instrumentation unit provided a variety of convenient functions and features including time-stamp, CyberGlove status, external sampling synchronization and analog sensor outputs.

Based on design of DataGlove, PowerGlove was developed by Abrams-Gentile Entertainment (AGE Inc.) (http://www.ageinc.com/tech/index.html) for Mattel through a licensing agreement with VPL Research. PowerGlove consists of a sturdy Lycra glove with flat plastic strain gauge fibers coated with conductive ink running up each finger; measures change in resistance during bending to measure the degree of flex for the finger as a whole. It employs ultrasonic system (back of glove) to track roll of hand (reported in one of twelve possible roll positions), ultrasonic transmitters must be oriented toward the microphones to get accurate reading; pitching or yawing hand changes orientation of transmitters and signal would be lost by the microphones; poor tracking mechanism. Whereas the Dataglove can detect yaw, pitch and roll, the PowerGlove can only detect roll, and provides 4D information, i.e. x, y, z and roll.

Initial Sensors

All body movements will have concurring accelerations and decelerations, which can be applied for movement tracking or detection. Micromachined inertial sensors, including accelerometers and gyroscopes, are silicon-based sensors. They are small in size and can be worn on the body. The working principle of these sensors is based on the measurement of inertia, and can be applied anywhere without a reference. Due to these advantages, an extensive amount of research has been carried out to evaluate their use for tracking human movement.

Accelerometers are instruments that measure the applied acceleration acting along a sensitive axis. Conceptually, a single axis accelerometer consists of a mass, suspended by a spring in housing. The mass is allowed to move in one direction and the displacement of the mass is a measure of the difference of acceleration and gravity along the sensitive axis given by the unit vector. To track human motion one is needed for each of the three planes of motion. A triaxial accelerometer (TA) can be constructed by mounting three such single axis accelerometers together or by using a single mass with three translational degrees of freedom.

Measurement of human movement can be summarised into three types: inclination (angle to the vertical), orientation (relative angle of limbs or body) and ambulatory measurement (for example, monitoring activity, training of motor skills during daily life), the latter requires both measurement of inclination and orientation. Accelerometers measure the gravity vector and the acceleration, and can not provide information about the rotation around the vertical and therefore do not give a complete description of orientation. Gyroscopes measure angular velocity and can be combined with accelerometers to estimate orientation. A combination of accelerometers and gyroscopes will then be an approach to obtain both inclination and orientation information.

Typically, angular orientation of a body segment is determined by integrating the output from the angular rate sensors strapped onto the segment. A relatively small offset error on the gyroscope signal will introduce large integration errors. The magnetometer is an instrument for measuring the direction and/or intensity of magnetic fields. It is sensitive to the earth's magnetic field. It gives information about the heading direction in order to correct drift of the gyroscope about the vertical axis.

One example of the initial sensor is the Xsens MTx (Xsens Dynamics Technologies, Netherlands). It is a digital measurement unit that measures 3D rate-of-turn, acceleration and earth-magnetic field. It provides real-time 3-D orientation data in the form of Euler angles and Quaternions, at frequencies up to 512 Hz and with an accuracy better than 1 degree RMS. An MTx miniature inertial orientation sensor, with 2g acceleration range and 900 deg/sec rate-of-turn range. Readers are referred to Zheng et al, 2005 for a detail review on inertial sensor technologies.

Motion Tracking

Human motion tracking systems generate real-time data that represent human movement (Mulder, 1994). Sensors or markers are placed on the body to measure the distance to, or orientation or position of an external source. Alternatively, sensors or markers can be attached to anatomical landmarks on the body and used to calculate their relative positions in space.

Motion tracking systems can be classified according to the position of the sensors and sources (Kalawsky et al. 1993), or according to the motion tracking techniques, such as electromagnetic position and orientation trackers, acoustic position and orientation trackers, mechanical position and orientation trackers, electrostatic position and orientation trackers, and video and electro-optical tracking systems for example. Zhou et al (2004) suggested the following classifications: non-vision based system, vision-based tracking systems with markers and vision-based tracking systems without markers, and robotic-guided tracking systems . Examples of non-vision based systems include MTx, MotionStar (http://www.vrealities.com/motionstar.html), InterSense (www.intersense.com/), Polhemus and Glove-based devices. Systems such as Qualisys (http://www.qualisys.com/), VICON (http://www.vicon.com/), and CODA (www.codamotion.com/), are vision-based tracking systems with markers.

All of the above commercial available systems require specialist setting, dedicated space and expensive equipments. They also restrict body movement to some degree. For example, robotic-guided tracking systems are limited in the range of human motion and, in particular walking or other transitional motion, Glove-based systems are disadvantaged by wires attached to each sensor. 3D optical tracking systems, such as Vicon or CODA, are being used for rehabilitation in clinical environments. They comprise one or more video cameras or sensor arrays, interface with PC and active or passive markers. The CODA system is pre-calibrated and uses active (light emitting) sensors (markers) that can be set up at a new location without recalibration. It can use up to six sensors units altogether and can track 360 degree movements. The VICON system uses multiple video cameras with passive markers and must be calibrated each time it is relocated. Both systems calculate the 3-D coordinates of each of the markers in real time. However, operation of the systems, mounting of markers and interpretation of the kinematic data requires bioengineering expertise and they are limited to a laboratory environment and are not suitable for use at domestic home (Zheng et al, 2005).

3 VR Games for Healthcare

Games beyond entertainment have been explored in various application domains such as education and training for decades. Typical applications of VR and games technologies in health care include therapy, pain relief (Sharar et al. 2008), surgical procedures (e.g. pre-operative planning, intra- and post-operative applications, augmented surgery, and remote surgery), patient education, medical training, skill enhancement and rehabilitation (Ma and Bechkoum, 2008), etc. To date, such applications have improved the quality of healthcare, the quality of life of patient, accessibility to healthcare, and reduce the cost of healthcare.

3.1 Dynamic Simulation

Dynamic simulation, a.k.a. physically-based simulation, is an important feature in VR. It creates realistic motions of virtual objects based on the laws of Newton's laws of motion. The behaviour of virtual objects and their responses to external force and torque are simulated in a physically realistic manner. Physics simulation models objects with physical properties, such as mass, inertia, barycentre, joint constrains, restitution and surface friction — it can make objects in virtual worlds not only *look real* but *act real*. Typical dynamic simulation includes collision detection (and response) and the simulation of gravity, friction force, and kinematics in motor actions. Physics can be applied to rigid bodies or deformable bodies such as human tissues. Rigid body dynamics plays an important role in motor rehabilitation and is especially needed when dexterous manipulation of virtual objects is concerned.

Originated in engineering simulation and high-end video games, it has been recently introduced to VR systems in healthcare. For instance, the advantage of using VR in clinical settings of motor rehabilitation is that by virtue of its programmability, environments and the type and difficulty of tasks can be modified according to the user's capacities and therapeutic goals. Dynamic simulation provides more flexibility on experiment configuration in which not only object positions, orientations, and size can be modified but also gravity, restitution, force and torque damper, and joint constrains can be reliably modified, thereby creating a very individualised set of rehabilitation tasks which would be impossible to achieve with the user's residual motor control in the physical world. These tasks can then be reliably recreated over a period of several weeks or months and participant's outcome can be assessed. The addition of dynamic simulation to the VR therapy can increase patients' experience of immersion in virtual environments, which may in turn increase engagement and activity enjoyment and thereby improve clinical outcome.

The quality of dynamic simulation that is required in a VR system is application specific. In the cognitive and affective domains of learning where the focus of training is more on attitudes such as using VR therapy for treating phobia, high physical fidelity is not always required. However, in medical simulation such as surgical procedures, high quality physical fidelity, such as using haptic feedback to provide accurate feeling of tissue characteristics, is so important that without it the skills acquired in the virtual world may not transfer to the real one or the operation may fail. In the motor rehabilitation domain, previous research suggests that physics fidelity may be important for motor rehabilitation. Viau et al. (2004)) compared movement kinematics of identical tasks of reaching, grasping, transporting, placing and releasing a ball in a real and a virtual environment. Their results showed that there is a slight change in motor patterns when grasping and placing a ball in the two reality conditions for both healthy subjects and hemiparesis patients with motor deficits, which was mainly due to lack of collision handling in the virtual environment. The results suggest that dynamic simulation in VR rehabilitation may reduce the difference of movement strategies in the virtual and real world, which may be an important factor in the transferability of virtual skills to the real world.

Dynamic simulation in serious games for healthcare can be implemented using state-of-the-art game engines, either commercial engines like Havok Physics and Emergent Game Technologies' Gamebryo or open source engines such as OGRE and ODE. Notably, many commercial game engines, e.g. Ageia PhysX, Epic's Unreal Engine and Unity Technologies' Unity engine, provide free licenses for educational, non-commercial applications, or for independent developers (i.e. Indie games). These tools have been prosperously adopted in indie games industry recently, and they provide great low-cost solutions for serious game developers as well.

3.2 Serious Games for Healthcare

The recent emergence of serious games as a branch of the digital games field has introduced the concept of games designed for a serious purpose other than pure entertainment. Health care is a major application domain for serious games. To date the application of serious games to health care, such as PlayStation 2's EyeToy, GestureTek's Irex system, and Nintendo Wii, has primarily been used as a tool that gives players a novel way to interact with games in order to promote physical activities. Many studies have identified the benefits of using serious games in rehabilitation and therapy. Since games technology is inexpensive, widely available, fun and entertaining people of all ages, if combine with conventional healthcare it could provide a powerful means of encouraging patients more effectively.

It has been suggested that playing games can improve neuromotor coordination, and VR-based games have been designed to engage patients' active participation in motor learning and to treat sensori-motor deficits (Huang et al. 2006). For instance, Ma and Bechkoum (2008) described a series of VR games for bilateral upper limb training for stroke patients: catch-the-orange game, shield-ball game, fishing game, and whack-a-mouse game. Fig. 4 shows a screenshot of the fishing game and a photo of a user playing the game. In this game, the player is in a under water world using his/her hands catch fish which are swimming randomly in the water. The player can see the virtual representation of his/her hands on the screen or through a HMD. The

Fig. 4. The fishing game screenshot and interface (Ma and Bechkoum, 2008)

hand movement is captured through a sensor attached on each hand. When both hands collide with a fish, the fish does a little struggling, i.e. wagging its tail drastically on the spot which is implemented by speeding up the speed of swim animation whereas not changing position, and regarded as caught. It then disappears and the number of fish caught is incremented on the Head-Up-Display (HUD). If only one hand collides with a fish, it swims away and escapes. All fish swim in a random manner. If two fish collide with each other, one of them will swim away and the other continue its movement. There are simple Artificial Intelligence (AI) built in the fish object.

The gravity in this under-water virtual environment is also set to zero to free the fish. The size of target area in the 3D space, the size of the fish and their swimming speed, and the size of the virtual hands can all be adjusted to suit individual participant's needs or his/her in-game performance.

VR games have also been explored recently as a non-pharmacologic pain relief techniques for treating treating burn patients (Sharar et al. 2008) due to the intense cognitive distraction they provide. The experiments suggest that immersive VR games are logistically feasible, safe and effective in ameliorating the pain and anxiety experienced in various settings of pain.

In addition, the technique is applicable to a wide age range of patients and is particularly well-adapted for use in children (Gershon et al. 2004). BreakAway's *Free Dive* (Emergent, 2009) is one in the growing wave of video games designed for pediatric pain management. It is a VR undersea exploration adventure game that invites players to swim with sea turtles and tropical fish as they hunt for hidden treasure. HopeLab's *Re-Mission* (HopeLab, 2006)—a third-person shooter that stars a cell-blasting nanomachine and features a voyage-like plot—was designed for educating young cancer patients. The game cleverly provides information about various kinds of cancer and the medicine used to fight it. Studies have proven its efficacy in educating the youngsters who play. The game was tested via a randomised trial on 375 patients, both male and female aged between 13 and 29 (Kato, 2008). The results showed a significant increase in quality of life, self efficiency cancer related knowledge for adolescents and young adults with cancer. Patients in the intervention group showed lighter serum levels of chemotherapy and higher rate of utilisation of antibiotics, suggesting an increased adherence to cancer chemotherapy regimens. The participants in the game intevention group also went through their treatment with a better knowledge and understanding of cancer and related therapies.

Off-the-shelf console games such as Nintendo Wii sports (boxing, tennis, bowling, and golf etc.) have being used for rehabilitation of patients with cerebral palsy (Deutsch, 2008) and hemiplegia to to aid their recovery and regaining strength and ability through repetitive physical exercises. Wii's intuitive control design allows for control through natural movements without restriction of sensors and cables. Wii sports and Wii Fit are currently being used in rehabilitation therapy for patients undergoing treatment following stroke, traumatic brain injury, spinal injury, and combat injury. The Hines Veterans affairs hospital in Chicago even installed a Wii game station in their spiral injury unit to assist physical rehabilitation following various surgical procedures. Previous research on the console (Kerrigan et al. 2008) has demonstrated that Wii’s active gameplay is an effective tool for physical exercise, and that Wii games are more useful in limb extension exercises and in burning calories.

Emotional and psychological impact of game play can be immense. VR games have also been used to support the social-emotional development of teenagers with autism spectrum disorders (Khandaker, 2009) and to treat different types of psychological phobias, e.g. spider phobia, social phobia/public speaking anxiety, fear of driving/flying, agoraphobia, and other mental health problems (Gregg and Tarrier, 2007).

3.3 Flow and Its Application to Serious Games

Understanding how people engage in video games has implications for the development of effective serious games. *Flow* is a term that has been coined (Csikszentmihalyi and Csikszentmihalyi, 1988) to define the experience of becoming engaged in activities in which challenges and skills are progressively balanced. When challenges and skills are out of balance, people feel overwhelmed—the challenges exceed the individual's skills—which results in anxiety and stress; and when the challenges do not engage an individual's skills he feels underwhelmed and becomes bored.

With increasingly realistic graphics and intrigue story lines, the flow theory has been applied to video games (Charles et al., 2005 and Gregory, 2008) and game designers have been implementing flow in games to reach a larger demographics. Gregory (2008) summarised that the flow experience in gaming can be achieved through well-designed game mechanics and interactivity:

- Clear goals—the player is aware of what he or she wants to do. At any moment of the game play, the player should have a clear goal which might be short-term or long-term.
- Immediate feedback—the player knows how well he or she is doing at any moment. Cause and effect are reasonable and obvious. Every action the player performs has immediate feedback, preferably multimodal feedback.
- Challenges match skills—the skill level of a player is in balance with the tasks
- Deep concentration—the player focuses all attention on the task at hand and is able to dismiss irrelevant stimuli that may interfere with concentration.
- Control is possible—a feeling of mastery is gained
- Self-consciousness disappears—the player feels able to transcend the limits of the ego
- The sense of time is altered—the gamer either loses track of time or time seems to pass with rapidity
- The activity is intrinsically rewarding—the experience is worth engaging for its own sake

Among these, challenge-match-skill is especially critical for games for healthcare and rehabilitation purposes. Ideally, rehabilitation should be targeted to the individual needs of patients. Patients have a wide range of abilities and tasks which are impossible for some can be trivial for others. It is usual to tailor a rehabilitation session to individual patients according to the type of injury, their capabilities, and therapeutic goals. Typically this is done by assessing the patient in a number of standardised tests prior to the rehabilitation session. The therapist can then create a suitably challenging set of exercises for the patient. A key principle in rehabilitation is matching therapeutic tasks to the patients' abilities in order to enable them to improve residual capabilities without causing fatigue and frustration. This is a time-consuming part of the physiotherapist's duties, as constant monitoring is required to ensure the tasks remain adequately challenging throughout the sessions, which typically last for several weeks.

The key issue to implement challenge-match-skill and to achieve the *flow* experience of gameplay is adaptivity. This is also another advantage of games for healthcare, no matter it is a VR game or 2D flash game. Taking motor rehabilitation as an example, the VE and training tasks are easily customized and the system can assess the motor function recovery of users and adjust level of difficulty to users' performance.

Adaptation is one technique that VR therapy systems and games can exploit to benefit a group of users with a wide range of abilities. In order to maintain patient motivation, rehabilitation tasks should be set at an appropriate level of challenge. Also, for the patient to stay engaged in the process, he or she should experience a feeling of immersion in the virtual environment. Charles et al. (2005) applied the flow theory to adaptive game design, and they suggested that the game should find a balance between the annoyance of an activity that is perceived as trivial and the frustration of one that is perceived as too difficult. This is even more important in the context of VR rehabilitation due to the repetitive nature of the exercises and the limitations of the players (patients).

In post-stroke rehabilitation, a physiotherapist will typically design motor therapy exercises for a stroke patient based on a number of factors, such as the patient's age, gender, culture background, usual handedness, and his or her medical condition (e.g., time since stroke, left or right hemiplegia and cognitive, sensory, and motor abilities based on standardised tests like the Line Cancellation Test). Not only the difficulty level of the exercises but also the body parts activated during the task may be adapted to individual patient's needs. For example, tasks may be developed to train a specific movement such as wrist extension in order to increase range of motion or endurance of the wrist joint. This data, taken together, forms an individual patient profile which can then be used to initially configure the system to present a suitably challenging, individualised rehabilitation session. Various elements of the simulation can be customised according to the user profile. These include the number and type of objects, their sizes, speed, mass, distance from the patient, distance of object transportation etc.

Additionally, data collected during the game session can be used to further improve the patient experience. Such in-session data (e.g., the time taken to perform a task or achieve a goal in a game, the accuracy rate or stimuli-response time) can be used to evaluate the initial configuration of the system. If tasks are not being successfully completed then the objects or game elements in the simulation should be reconfigured to make them easier. Objects can be made larger (easier to grasp), for example, or moved closer to the patient (easier to reach). Alternatively, if activities are being completed much too quickly it may be that the activity is too easy for the patient, and corresponding changes can be made to make the task more challenging.

The ability to dynamically adjust the difficulty of the simulation is a key benefit since in addition to offering a tailored solution which suits the patient's individual needs it also decreases the dependence on human therapists to monitor and provide similar solutions.

3.4 Train a User by Modeling Him—User Profiling

User profiling, initiated from online commerce (such as cookies and user profiles in tracking technology) to build records over time and to assess user preferences, has also been used in serious games and VR rehabilitation systems. Depends on the purpose of a system, the parameters in a user profile vary. Many of them require assessing the users.

In our motor rehabiliation VR system (Ma et al. 2007), we have constructed a patient model using traditional symbolic classifiers based on patients' age, time since stroke, left or right hemiplegia, impairment and functional measurement, and hemispatial neglect. Table 1 below shows the profile of three patients participating in the case study. For each patient, three Motricity Index (MI) [9] and Action Research Arm Test (ARAT) [10] scores are given, representing their status before training, post training, and 6 weeks after training. Patients 1 and 3 have no hemispatial neglect, while patient 2 has a mild deficit.

In the Catch-the-orange game we had developed, the player holds a basket with either one hand (for unilateral upper limb training) or two hands (for bilateral training) to catch falling oranges which fall from random positions on trees onto a target area (Fig. 5A). The position and orientation of the virtual basket are controlled by a sensor attached on a real basket, which the user holds with one hand or both hands (Fig. 5B). If the patient tilts the basket, he or she may not able to catch the oranges and the ones already in the basket may fall to the ground. The target area on the x-z plane, the falling speed of oranges (controlled by simulating gravity in the virtual environment), the time between oranges falling and the size of oranges and the basket can all be adjusted to suit individual patient's skills. All sensor data is recorded to disk, allowing post-therapy visualisation of the trajectories and analysis of joint angles, velocity, acceleration and range of movement.

Table 1. Examples of patient profiling: Motricity Index [9] is for impairment measurement, and Action Research Arm Test (ARAT) [10] is for functional measurement

	Patient #1	*Patient #2*	*Patient #3*
Age	76	62	42
Gender	M	F	M
Years since stroke	4	4	1
Usual handedness	R	R	R
Left/Right hemiplegia	L	L	L
Motricity Index	77,77,81	62,73,77	77,79,77
ARAT	3,6,11	4,11,19	54,53,54
Hemispatial neglect	None	Left-sided	None

A. a screenshot of the game

B. A user playing the game

Fig. 5. The *Catch-the-orange* game

In the Catch-the-orange game, the sense of depth is enhanced through the use of depth cues such as shadows, perspective, relative motion, occlusion, and most effective of all, a transparent vertical stripe of each orange which is still in the air (Fig. 5A). An experiment showed that using the depth cue of transparent vertical stripe improved the sense of depth perception in the user.

The game provides immediate feedback via a Head-Up-Display (HUD) at the upper right corner of the screen, showing information such as player's name, number of caught oranges, number of miss, success rate and a time bar. A statistics window (Fig. 6) also shows score etc. when the game ends.

Fig. 6. The Game over statistics window

Fig. 7 shows another serious game for bilateral training. In this game the player holds a virtual shield with either one hand or two (for bilateral upper limb training) to fend off iron balls which are shot from the opposite castle with a random initial positions originating from an x-y plane and with an initial +z force (towards the player) which influences the speed of the ball movement. The position/orientation of the virtual shield is controlled by a sensor attached on a real object (we used a tray in our lab), which the user holds with one hand or both hands (Fig. 7B). This game requires less depth cues than the Catch-the-orange game since the player's movements are expected to be in the x-y plane. We adjust the alpha blend of the shield's texture map to make the player to be able to see-through the virtual shield and hence to see the iron balls occluded by the shield. The gravity in this game is set to zero to avoid the balls reach the ground before they reach the player. The target area on the x-y plane, the size of the iron balls and their speed (controlled by the initial thrust on +z direction), the time between two shoots and the size of the virtual shield can all be adjusted to suit individual patient's skills or in-game performance.

The above VR games have two levels of difficulty. The first level is non-adaptive. All game parameters are set by the operator, or loaded from a previous session, or set by a computer program based on the patient profile. The configuration dialogue is shown in Fig. 8. Level two is adaptive. The game adapts its difficulty depending on the player's in-game performance, for example, in the fishing game if the average time (seconds) for a player to catch one fish is less than a threshold, which means the game is too easy for him/her, the fish will become smaller and swim faster, and the virtual hands may become smaller too.

A. a screenshot of the game

B. a user playing the game

Fig. 7. The shield-ball game

4 Experiments and Results of Using VR in Stroke Rehabilitation

In the UK, stroke is the most significant cause of adult disability. Reports (DoH, 2000) showed that six months after stroke, 49% of patients need help with bathing, 31% of patients need help with dressing and 33% of patients need help with feeding. Research suggests that intensive and repetitive training may be necessary to modify neural organization (Miltner et al. 1999, Rossini et al. 2003). Stroke rehabilitation is one of the most prosperous research areas in healthcare where VR and games technologies have been applied to create new tools for intervention and influenced our current practice in post-stroke physiotherapy.

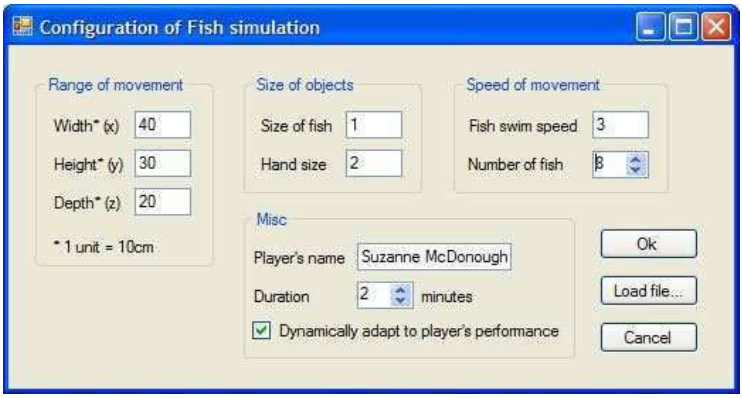

Fig. 8. The configuration dialogue of the fishing game

4.1 SMART Rehabilitation

Being the third biggest killer and the leading cause of severe disability in the UK, there is an increasing demand of providing stroke rehabilitation to improve the conditions and quality of life for stroke survivors. Repeat interventions are important to maintain and regain limb functions for people after stroke. However, inpatient rehabilitation length of stay for patients with stroke is decreasing in the UK, with limited outpatient rehabilitation. Therefore, there is a need to develop a low-cost, accessible, home-based rehabilitation system for post stroke users.

The SMART (www.thesmartconsortium.org) project, entitled ‘SMART rehabilitation: technological applications for use in the home with stroke patients’, was funded under the EQUAL (extend quality of life) initiative of the UK Engineering and Physical Sciences Research Council (EPSRC). The project aims to examine the scope, effectiveness and appropriateness of systems to support home-based rehabilitation for older people and their carers.

The SMART rehabilitation system consists of three components, namely (i) motion tracking unit, (ii) base station unit and (iii) web-server unit. The motion tracking unit consists of two MTx inertial sensors which are attached to the patient’s arm to track the movement during activities such as drinking or reaching. The MTxs record the movement information (positions and angles) of three joints, i.e. wrist, elbow and shoulder and then send wirelessly to the base station (PC) via a waist worn digital data box, “XBus”, for further processing by the decision support platform. The measurement of the 3D position and rotation of the user’s arm by the motion tracking unit is rendered to generate the movement of a avatar’s rehabilitation exercises in a 3D environment. The 3D rendering is applied to a virtual head and arm. In order to provide a reference for patients, stored target movement templates (3D renderings) are available which can be overlaid or mirrored on the screen to help the patient replicate the best movement. Fig. 9 shows two types of methods used in presenting the 3D information, one displays exercise movement and the target template movement in two separate windows; and the other displays them in the same window with the template movement as a ghost layer. Through preference settings, users are able to choose either mode. When the user carries out the rehabilitation interventions, such as drinking, reaching, the arm movement will be rendered in the 3D environment and compared to a virtual 'model' movement. Readers are referred to Zheng et al (2006, 2007) for detail description of the SMART rehabilitation system.

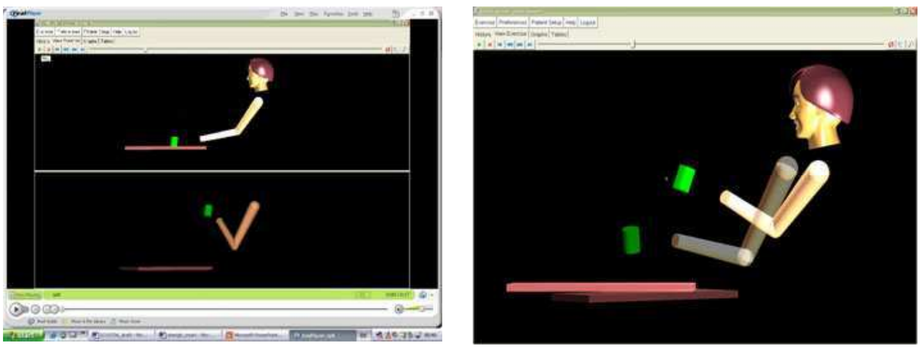

Fig. 9. 3D repesentation of a user avatar and target movement template in the Smart rehabilitation system (Zheng et al 2006)

4.2 VR Game Intervention for Movement Therapy

Ma et al. (2007) carried out an experiment on the VR game intervention described in section 3. Eight participants who suffer from post-stroke upper limb motor disorders participated the study (Table 2). A patient model was constructed for each participant, using traditional symbolic classifiers based on their age, time since stroke, left/right hemiplegia, impairment and functional measurement. They were 4 men and 4 women, mean age in years = 56.4±4.3 (standard deviation). All participants had a first hemispheric stroke, and all were right-handed. The mean time since stroke until beginning of the VR intervention was 10.7 months. 4 participants suffer from right hemiplegia and 4 from left hemiplegia.

The participants were divided into two groups. Participants S, J, F, R (group A) received both functional training (i.e. the users were asked to perform functional tasks such as reaching and grasping) and serious games intervention (i.e. the users were asked to play the VR games described in section 3), whereas participants P, B, E, C (group B) received functional training only.

Each participant attended ten supervised sessions. Three clinical assessments were performed for each participant before training, post training, and 6 weeks after training using Motricity Index (MI) and Action Research Arm Test (ARAT) scores.

Table 2. User profiles of the participants

Paticipants	Age	Gender	Mths since stroke	Usual handedness	L/R hemiplegia	MI	ARAT
S	49	Male	6	Right	Right	92,100,100	54,54,57
J	49	Female	6	Right	Right	73,77,73	45,54,50
F	66	Female	12	Right	Left	71,77,71	32,35,35
R	74	Male	8	Right	Left	100,100,100	57,57,57
P	45	Female	23	Right	Right	77,77,77	57,57,57
B	75	Male	12	Right	Right	77,85,100	54,55,57
E	69	Female	11	Right	Left	84,84,84	57,57,57
C	43	Male	10	Right	Left	77,79,77	54,53,54

Most participants showed improvement in short term, i.e. comparing post training scores to pre-training scores: MI(2)-MI(1) and ARAT(2)-ARAT(1)[1]. However, for some the intervention hasn't shown long-term clinical benefits, i.e. comparing scores at 6-week after intervention to pre-intervention scores: MI(3)-MI(1) and ARAT(3)-ARAT(1).

Since the sample sizes were small, a paired t-Test on each group and all participants was conducted to compare the effect of games intervention (Group A) with that of functional training (Group B). Three paired t_Test values (of group A, group B, and all participants) between MI(1) and MI(2) values were calculated, indicating the probability associated with participants' MI(1) and MI(2) scores with a one-tailed distribution, if the null hypothesis is true.

The results show that the probability of observing the improvement between MI(2) and MI(1) in Group A is 0.038997, in Group B is 0.13916, and for all participants is 0.012807. Therefore, the data support that all participants had significant improvement immediately after intervention (because 0.012807 is a very small probability and the null hypothesis is refuted), and that the intervention on Group A was more effective than the intervention on Group B (because 0.038997 is much smaller than 0.13916). Similar results were observed with the paired t-Test on each group associated with participants' ARAT(1) and ARAT(2) scores. Hence, the serious games intervention did have an impact on the recovery of movement.

Data analysis on tracking individual patient's in-game performance in the games also support the findings. Take participant J and F as examples, look at their improvements on ARAT and MI scores and game performance in the adaptive whack-amouse game. Both participants' game performance improves significantly over the sessions in terms of their reaction speed, i.e. how many seconds it took them to hit a mouse and how many seconds a mouse stays still.

Having plotted their speed and interval on charts, we see exponential trend of their speed and intervals during the sessions, with the square of correlation coefficient around 0.8. Both parents show a significant improvement on speed of movement and response time. Correlating their game performance and their improvement in the real world in term of MI and ARAT scores, we find that the VR-based motor therapy

[1] MI(1) indicates the MI score before training, MI(2) indicates the MI score after training, MI(3) indicates the MI score 6 weeks after training. Same for ARAT scores.

using both functional training and serious games was more effective than using functional training solely, in terms of improving motor functions shortly after completion of the intervention and it may bring long term benefits as well. For the experiment details and data analysis of this study, please see Ma and Bechkoum (2008).

Serious games therefore appear to have potential to become a useful tool for movement therapy, as well as virtual reality technology.

5 Conclusions and Future Work

This chapter has shown how VR and video games technologies can contribute to healthcare by providing motivating, realistic, and adaptive simulations. The integration of VR simulation with serious games adds richness to the virtual environment which has been proved to be motivational and beneficial in healthcare. Previous results of user trials and experiments, for instance, in physiotherapy, are very positive, showing VR and games intervention had an impact on the recovery of movement both in the real world impairment and functional measurements and in-game performance, with patients reporting that they enjoy playing the games.

Although the current state-of-the-art of VR and serious games in healthcare is a decade behind the digital entertainment industry, i.e. video games and 3D movies, the technological developments in today's games industry show some of the future directions of applying these technologies in medicine and healthcare, such as augmented reality, Wii-mote motion control, and even full body motion capture and controller free games technology demonstrated recently on E3 2009 which have great potentials to treat motor skill disorders, combat obesity, and other healthcare applications.

References

1. Aukstakalnis, S., Blatner, D.: Silicon Mirage - The Art and Science of Virtual Reality. Peachpit Press, Berkeley (1992)
2. Bruce, K.B., Cardelli, L., Pierce, B.C.: Comparing Object Encodings. In: Abadi, M., Ito, T. (eds.) TACS 1997. LNCS, vol. 1281, pp. 415–438. Springer, Heidelberg (1997)
3. Cates, C.: Virtual Reality Simulation in Carotid Stenting: a New Paradigm for Procedural Training. Nature Clinical Practice Cardiovasculaer Medine 4(4) (2007)
4. Charles, D., McNeill, M., McAlister, M., Black, M., Moore, A., Stringer, K., Kücklich, J., Kerr, A.: Player-centred game design: player modelling and adaptive digital games. In: Proceedings of the Second International Digital Games Research Conference, DIGRA 2005, Vancouver, Canada, June 2005, pp. 285–298 (2005)
5. Crossbie, J.H., Lennon, S., Baldonado, M., Chang, C.-C.K., Gravano, L., Paepcke, A.: The Stanford Digital Library Metadata Architecture. Int. J. Digit. Libr. 1, 108–121 (1997)
6. Crosbie, J.H., Lennon, S., Basford, J.R.: Virtual reality in stroke rehabilitation: still more virtual than real. Disability and Rehabilitation 29, 1139–1146 (2007)
7. Csikszentmihalyi, M., Csikszentmihalyi, I.S. (eds.): Optimal experience: Psychological studies of flow in consciousness. Cambridge University Press, New York (1988)
8. CyberGlove devices: `http://www.immersion.com` (site visited on January 6, 2010)

9. Deutsch, J.E., Borbely, M., Filler, J., Huhn, K., Guarrera-Bowlby, P.: Use of a Low-Cost, Commercially Available Gaming Console (Wii) for Rehabilitation of an Adolescent With Cerebral Palsy. Physical Therapy 88(10), 1196–1207 (2008), doi:10.2522/ptj.20080062
10. Emergent Game Technologies: Free Dive—Pediatric Pain Management (2009), http://www.emergent.net/en/Clients-Titles/Visual-Simulation-and-Serious-Games/Free-Dive/ (site visited on January 7, 2010)
11. Gershon, J., Zimand, E., Pickering, M., Rothbaum, B.O., Hodges, L.: A pilot and feasibility study of virtual reality as a distraction for children with cancer. Journal of Amer Academy of Child & Adolescent Psychiatry 43(10), 1243–1249 (2004)
12. Gregg, L., Tarrier, N.: Virtual reality in mental health: A review of the literature. Social Psychiatry and Psychiatric Epidemiology 42(5), 343–354 (2007)
13. Gregory, E.: Understanding Video Gaming's Engagement: Flow and Its Application to Interactive Media. Media Psychology Review 1(1) (2008), http://mprcenter.org/mpr/index.php?option=com_content&view=article&id=207&Itemid=161 (site visited on January 9, 2010)
14. HopeLab: Re-Mission (2006), http://www.re-mission.net/ (site visited on January 7, 2010)
15. Hsu, J.: Active Interaction. Encyclopedia of Virtual Environments (1993), http://www.hitl.washington.edu/scivw/EVE/I.D.1.a.ActiveInteraction.html
16. Huang, H., Wolf, S.L., He, J.: Recent developments in biofeedback for neuromotor rehabilitation. Journal of Neuro Engineering and Rehabilitation 3, 11 (2006), doi:10.1186/1743-0003-3-11
17. Jain, L.C.: Soft Computing Techniques in Knowledge-based Intelligent Systems. Springer, New York (1997)
18. Kato, P.M., Cole, S.W., Bradlyn, A.S., Pollock, B.H.: A Video Game Improves Behavioral Outcomes in Adolescents and Young Adults With Cancer: A Randomized Trial. In: PEDIATRICS, vol. 122(2), pp. 305–317 (August 2008), doi:10.1542/peds.2007-3134
19. Kerrigan, D.J., Chen, H., Wiederhold, M.D., Gamberini, L., Wiederhold, B.K.: Evaluation of the Nintendo Wii for Physical Exercise and Rehabilitation. Cyber Therapy 13 (June 23-25, 2008)
20. Khandaker, M.: Designing affective video games to support the social-emotional development of teenagers with autism spectrum disorders. Studies in Health Technology and Informatics 144, 37–39 (2009)
21. Kilanowski, C.K., Consalvi, A.R., Epstein, L.H.: Validation of an electronic pedometer for measurement of physical activity in children. Pediatric Exercise Science 11(1), 63–68 (1999)
22. Laycock, S.D., Day, A.M.: Recent Developments and Applications of Haptic devices. Computer Graphics Forum 22(2), 117–132 (2003)
23. Minhua, M., Bechkoum, K.: Serious Games for Movement Therapy after Stroke. In: Yeung, D.S., Poo, A.N., Ang Jr, M.H. (eds.) IEEE International Conference on Systems, Man and Cybernetics (IEEE SMC 2008), Singapore, October 12-15, pp. 1872–1877 (2008)
24. Ma, M., McNeill, M., Charles, D., McDonough, S., Crosbie, J., Oliver, L., McGoldrick, C.: Adaptive Virtual Reality Games for Rehabilitation of Motor Disorders. In: Stephanidis, C. (ed.) UAHCI 2007 (Part II). LNCS, vol. 4555, pp. 681–690. Springer, Heidelberg (2007)
25. Mulder, A.G.E.: Human movement tracking technology, Technical Report 94-1, Simon Fraser University (1994)

26. Rose, F.D., Johnson, D.A., Attree, E.A., Leadbetter, A.G., Andrews, T.K.: Virtual reality in neurological rehabilitation. Br. J. Ther. Rehab. 3, 223–228 (1996)
27. Rose, F.D., Attree, E.A., Brooks, B.M., Johnson, D.A.: Virtual Environments in Brain Damage Rehabilitation: A Rationale from Basic Neuroscience. In: Riva, G., Wiederhold, B.K., Molinari, E. (eds.) Virtual Environments in Clinical Psychology and Neuroscience: Methods and Techniques in Advanced Patient-Therapist Interaction. Technology and Informatics, vol. 58, IOS Press, Amsterdam (1998)
28. Sharar, S.R., Miller, W., Teeley, A., Soltani, M., Hoffman, H.G., Jensen, M.P., Patterson, D.R.: Applications of virtual reality for pain management in burn-injured patients. Expert Rev. Neurother 8(11), 1667–1674 (2008), doi:10.1586/14737175.8.11.1667.
29. Smart Consortium (2007), `http://www.shu.ac.uk/research/hsc/smart` (site visited on January 10, 2010)
30. Srinivasan, M.A., Basdogan, C.: Haptics in Virtual Environments: Taxonomy, Research Status, and Challenges. Computers and Graphics 21(4), 393–404 (1997)
31. Steinberg, A.D., Bashook, P.G., Drummond, J., Ashrafi, S., Zefran, M.: Assessment of Faculty Perception of Content Validity of PerioSim©, a Haptic-3D Virtual Reality Dental Training Simulator. Journal of Dent Education 71(12), 1574–1582 (2007)
32. Sun, Z., Zheng, H.: Effect of Suprarenal Stent Struts on the Renal Artery with Ostial Calcification Observed on CT Virtual Intravascular Endoscopy. Eur. J. Vasc. Endovasc. Surg. 28, 534–542 (2004)
33. van Leeuwen, J. (ed.): Computer Science Today. Recent Trends and Developments. LNCS, vol. 1000. Springer, Heidelberg (1995)
34. Viau, A., Feldman, A., McFadyen, B., Levin, M.: Reaching in Reality and Virtual Reality: a Comparison of Movement Kinematics in Healthy Subjects and in Adults with Hemiparesis. Journal of NeuroEngineering and Rehabilitation 1(11) (2004)
35. Wilson, P.N., Foreman, N., Tlauka, M.: Transfer of sptial information from a virtual to real enviroment. Human factors 39, 526–531 (1997)
36. Zheng, H., Black, N.D., Harris, N.: Position-sensing technologies for movement analysis in stroke rehabilitation. Med. Biol. Eng. Comput. 43, 413–420 (2005)
37. Zheng, H., Davies, R., Zhou, H., Hammerton, J., Mawson, S.J., Ware, P.M., Black, N.D., Eccleston, C., Hu, H., Stone, T., Mountain, G.A., Harris, N.D.: SMART project: Application of emerging information and communication technology to home-based rehabilitation for stroke patients. International Journal on Disability and Human Development Special. Issue on Advances in Virtual Reality Therapy and Rehabilitation 5(3), 271–276 (2006)
38. Zheng, H., Davies, R.J., Stone, T., Wilson, S., et al.: SMART Rehabilitation: Implementation of ICT Platform to Support Home-Based Stroke Rehabilitation. HCI (5), 831–840 (2007)
39. Zhou, H., Hu, H.: A survey - human movement tracking and a research proposal, Technical Report (2004)

Authors' Short Bio

Dr. Minhua Ma is the Head of Academic Programmes at Digital Design Studio, The Glasgow School of Art. Before joining GSA, she was Reader in Visualisation & Virtual Reality and Programme Leader for MSc Computer Games Production at the School of Computing and Mathematics, University of Derby. She completed her Doctorate from the University of Ulster in 2005 and MSc in Computing Science from the University of Newcastle upon Tyne in 2001. Her research areas include Virtual Reality, 3D visualisation, and serious games. Her principal lines of work have been published in over 40 peer-reviewed books, journals as well as conference proceedings. She has received grants from EU and East Midlands Development Agency for her work on computer games intervention with mucus clearing devices for cystic fibrosis; the Northern Ireland Chest, Heart and Stroke Association for her work on Virtual Reality in stroke rehabilitation, and a number of other grants for her research in visualisation and games.

Dr Huiru Zheng is a Lecturer in Computer Science at the University of Ulster. Since 1989, she has been an active researcher in the broad area of biomedical informatics, especially in medical system design, decision support, pattern discovery and recognition, assistive living technology, and tele-healthcare. She has published over 80 scientific papers within this area. She was the main researcher in the Application of Virtual Reality in Medicine project, funded by Health & Personal Social Services, and the SMART Rehabilitation project funded by EPSRC, UK. She is a co-investigator of the SMART:Self Management supported by Assistive, Rehabilitation and Telecare Technologies project funded by EPSRC, UK; and the NOCTURNAL, Night Optimised Care Technology for UseRs Needing Assisted Lifestyles project funded by TSB-ALIP/EPSRC, UK.

Chapter 10

Development and Evaluation of a Mixed Reality System for Stroke Rehabilitation

Dave Hilton[1,2], Sue Cobb[2], Tony Pridmore[3], John Gladman[4], and Judi Edmans[4]

[1] School of Nursing, Midwifery and Physiotherapy
dave.hilton@nottingham.ac.uk
[2] Virtual Reality Applications Research Team (VIRART)
[3] School of Computer Science
[4] Department of Rehabilitation and Ageing,
University of Nottingham, UK

Abstract. Computer simulations are gaining interest from researchers and therapists involved in stroke rehabilitation because they offer a means to monitor user activity and replicate tasks within safe and controlled environments. We developed a virtual environment (VE) to simulate the potentially hazardous task of making a hot drink. A three dimensional representation of a kitchen, including objects and utensils, was displayed on a computer screen and controlled through a touch screen interface. We also developed a user interface that employed real, physical kitchen objects, adapted in order to provide the computer with spatial and orientation data through a combination of motion sensors and a computer vision system. This tactile interface technology is known as a tangible user interface (TUI) and together with a VE comprises a mixed reality (MR) system. The MR system described here enabled users to perform naturalistic upper limb movements in order to interact with the task simulation. In this chapter we explain how the VE and MR systems were developed through a user-centred design process that involved the participation of consultants, clinicians and stroke survivors. Case examples of feasibility and evaluation studies using both the VE and MR systems are presented and discussed. Recommendations for the design and development of MR systems specifically for stroke rehabilitation are included.

Keywords: Stroke rehabilitation, virtual environment, mixed reality.

1 Introduction

A stroke is a debilitating disease that is characterised by a sudden disruption to normal blood supply in the brain. The focal destruction of brain cells leads to impairment of cognitive processes. Under these circumstances performing activities of everyday living such as preparing a hot drink or a meal can be challenging and potentially dangerous. Sequential tasks can be demanding for people with short term memory impairments and handling vessels that contain hot liquids or using kitchen appliances

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 193–228.
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present obvious hazards [1]. In the hospital setting simulated tasks may be used as a means for the stroke survivor to practise everyday skills but the opportunity to do this is restricted by the availability of human and physical resources. Computer supported simulations are becoming of increasing interest in this scenario because they can monitor task performance and provide the user with constructive feedback. The problems of encouraging naturalistic upper limb movement and offering realistic physical force feedback are not addressed by computer software simulations alone [2]. This led us to consider designing a novel tactile user interface to address these issues.

This chapter is about the design and development of a computer simulation that was designed to enable stroke survivors to practise a potentially hazardous activity in a safe and controlled environment. The unique aspect of this project was the user interface, which was designed to provide tactile sensation and to promote naturalistic upper limb movement. By using a combination of motion sensors and a computer vision system, real kitchen objects were digitally connected to a laptop computer so that the user's actions were constantly monitored and assessed. User errors were detected by software algorithms that calculated the most suitable actions for a given situation. In such instances the user's input was automatically paused while the correct action was explained and demonstrated using a computer generated three dimensional simulation of the kitchen. The interface described above is referred to as a tangible user interface (TUI). The virtual environment (VE) and the TUI together form a mixed reality system (MR).

The first part of this chapter is an introduction to stroke and this includes a stroke rehabilitation model that was employed in the design of our mixed reality system. We review the literature with respect to the emerging field of virtual reality applied to rehabilitation and present a case for the involvement of users in the design of these systems. The subsequent sections of this chapter present the design, development and evaluation of the virtual environment and the complete mixed reality system. We explain how the tangible user interface was constructed and tested, and we present a study in which stroke survivors used the mixed reality system in a hospital stroke unit. These studies have enabled us to propose recommendations and guidance for the future development of mixed reality systems specifically applied to post-stroke rehabilitation. These are presented in the discussion.

1.1 Stroke

The major causes of stroke are cerebral thrombosis, cerebral embolus or cerebral haemorrhage [3]. The effects of stroke are observed as an interruption to a combination of normal cognitive and physical processes, for example short term memory loss. Stroke can affect any person of any age however the World Health Organisation's Multinational Monitoring of Trends and Determinants in Cardiovascular Disease (MONICA) project found that the incidence of stroke increases sharply with age [4]. Although stroke is now amongst the top three causes of death globally, along with cancer and coronary heart disease, the survival rate is improving. Kwan [5] reports that 130,000 people suffer a stroke each year in the UK, of which approximately two thirds will survive to the end of the first year. Of the survivors, 40% will be disabled in some way. For those individuals with a predicted outcome of recovery, early rehabilitation is generally accepted as good practice [6].

The role of stroke rehabilitation is to improve the quality of life of the stroke survivor by increasing ability to participate in useful activities. Two contrasting approaches to enabling participation are referred to as ‘adaptive’ rehabilitation and ‘restorative’ rehabilitation [7]. Adaptive rehabilitation is the modification of the environment around the patient, using adjustments to existing equipment and facilities to assist the patient in their activities. It is considered appropriate for a progressive illness (for example dementia) in which recovery is unlikely [7],[8]. Restorative rehabilitation aims to improve quality of life and participation in activities by improving the patient’s function. It is appropriate for strokes where restoration of function is a realistic outcome [7].

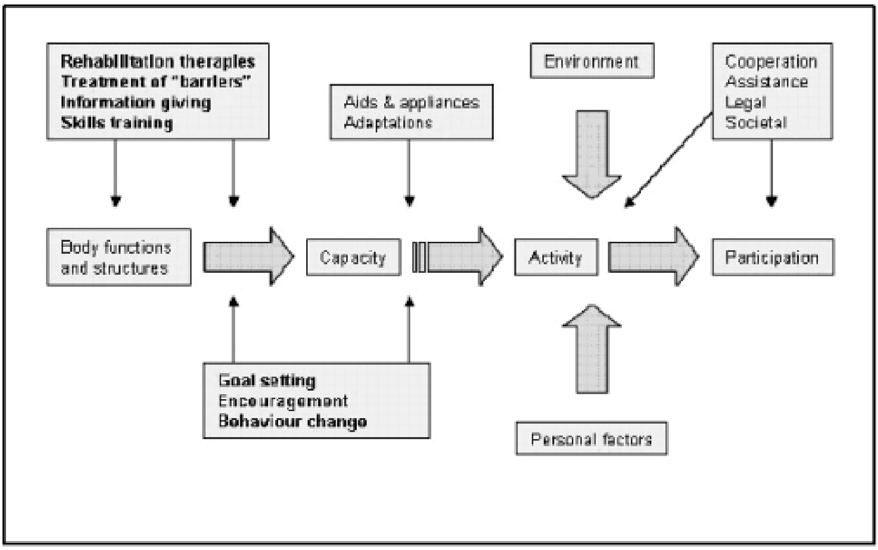

Fig. 1. A model of restorative rehabilitation

A study by Tromby and Hui-ing Ma [9] found that participation by patients in activities of daily living (ADLs) improved significantly for those patients who received training compared to subjects in a control group. They conclude that “task specific practise on activities [that] clients identify as important to them may be accepted cautiously as best practise”.

Executive function is the mental process involved in planning and organising actions and behaviours. Many every day activities such as cooking and shopping require the application of executive function. Edmans et al. [10] propose that it is deficits in executive function more than any other cognitive processes that determine the extent of social and vocational recovery.

Instrumental Activities of Daily Living (IADLs) are ADL activities that are involved in maintaining independence and include using a telephone, shopping, food preparation and housekeeping [11]. Performance in IADLs is commonly used an indicator of ability to live independently in the community [12].

Carr and Shepherd [13] recommend that rehabilitation therapy should be aimed at familiar and useful task specific activity. Therapy aimed at specific muscles rather than useful tasks may improve muscular strength where this has been reduced due to inactivity, but the movements that have been relearned in this manner may not be particularly useful to everyday living because they may not be relevant in the context of a useful task.

1.2 Applications of Virtual Reality for Rehabilitation and Therapy

Virtual reality has been shown to have potential application for treating a variety of conditions including autism, phobias and physical disability. People who have difficulty making a decision or coping with a social situation in the real world are being given the opportunity to practise these skills in a simulated interactive environment. Virtual environments for use by children with autism have been the focus of works by Trepagnier et al. [14] and Andersson et al. [15]. Adults with social anxiety disorder used a virtual reality system developed by Grillon et al., [16] in order to gain confidence. Virtual reality has also been used to treat agoraphobia and arachnophobia [17], [18]. Virtual reality has been used to facilitate restoration of upper limb motor function following a stroke [19], [20], [21].

Home based rehabilitation is an emerging application of VR technology which is beginning to show promise. Advances in interaction and remote sensing have enabled researchers to study the way in which people interact with technologies that can be installed in the home setting. This has the potential to enable people in rehabilitation to continue their treatment at home under remote observation and supervision [22],[23], [24].

Devices have recently emerged into mainstream technology that are changing the way we interact with virtual environments. The Nintendo Wii™ is an example of a household product that has recently shifted the boundaries of the gaming console interface from the common user input methods (joystick, keyboard, tethered handset) to a wireless interface in which physical movements made by the user are used to control the gaming program [25],[26]. The Sony EyeToy™ has been used in rehabilitation as a means of capturing the user's image in real-time and merging it with virtual objects in an interactive virtual environment as a form of augmented virtuality [27],[28].

Virtual reality has also been used to support the rehabilitation of people with traumatic brain injury by enabling them to practise activities of everyday living. Preparing a meal or a hot drink in a computer simulation of a kitchen has been the focus of studies conducted by Zhang et al. [29], Christiansen et al. [30], and Edmans et al. [31]. Comparison of patient assessment scores between real and simulated tasks has established that assessment in the virtual environment can show adequate validity and reliability. Thus virtual reality offers the prospect of simulating tasks that can be used to support stroke rehabilitation in safe and controlled environments. Rizzo and Buckwalter summarise the potential benefits of virtual reality for stroke rehabilitation (see table1).

Table 1. Benefits of virtual reality for stroke rehabilitation. Adapted from Rizzo and Buckwalter [32]

Tasks can be administered within an ecologically valid setting.
The learner can make mistakes in safety.
Structured and timely support and feedback can be provided.
The environment can be controlled.
Varied levels of stimulus and feedback are possible.
Learning can take place in stages.
Errorless learning can be facilitated through cueing.
Tasks can be repeated.
The interface and presentation can be modified to suit the users impairments.

Although it could be argued that many of the above can be applied to different forms of computer mediated learning without the need for three dimensional simulations, virtual reality has the unique advantage of being able to present safe and controllable computer models of realistic environments that function in a similar way to their real world counterparts.

Despite these theoretical benefits, virtual reality as a learning medium for stroke survivors also presents potential disadvantages. Stroke survivors would be required to interact with a computer simulation and they may not be experienced, proficient or willing computer users. Thus the usability of computer interfaces is of utmost importance in the design of computer applications for elderly and disabled people.

2 The Design and Development Process

We have seen in the previous section that a body of literature recommends that tasks used as part of a programme of stroke rehabilitation should enable stroke survivors to achieve outcomes that are purposeful and useful to everyday living. In order to begin the process of selecting a task for our simulation a consulation with stakeholders was undertaken. The stakeholders in stroke rehabilitation were indentified as therapists, consultants and the service users, i.e stroke survivors. Following the consultation phase a list of minimum design requirements was drawn up and an analysis of the task was written prior to development of the simulation. Section two follows the process described above, beginning with an overview of the user-centred design (UCD) process.

2.1 User Centred Design

It would be naïve of a designer to develop a product for use by people with impairments and special needs without taking these needs into account. User-centred design (UCD) is a broad term that refers to product development in which the users and their representatives contribute to the design of a product to ensure that the final product is both useful and usable [33]. User-centred design is an established design methodology and the International Standards Organisation (ISO) has published benchmarks for the application of UCD in the form of ISO 13407 [34]. The design principles of ISO13407 identify active involvement of users, appropriate allocation of function, iteration of design solutions and a multidisciplinary design team as fundamental to the UCD process. We have adhered to these principles in the design of our virtual environment and tangible user interface.

UCD covers a range of activities in which users are involved in the design of a product. Various approaches to UCD have evolved to address different styles of working with clients. The context of use and the extent of user involvement in design are key drivers to choice of approach. These methods include contextual design, participatory design, empathic design and cooperative design. Participatory Design (PD) involves users of technology as partners or collaborators in the design process. PD embraces the philosophy that users are the best people to decide what they want from a product [35],[36]. The PD approach actively involves users in different stages of the design process, drawing on their experiences as well as acknowledging their capabilities and limitations. Collaboration with users in the implementation of a technology also enables designers to understand how the technology will be used in the context of the participants working environment [37].

2.2 Consultation Phase

Occupational Therapists. The first of three studies in the consultation phase involved occupational therapists. Twenty-two people attended an event organised by the authors during which several virtual environments were demonstrated and data gathering in the form of questionnaires and a focus group took place. Members of the development team gave a short presentation during which terminology and concepts relating to virtual reality were introduced and explained. Following the presentation four different VEs were made available on four computer workstations placed around a large room at the first author's place of work. Participants were divided into four groups and members of each group were given the opportunity to experience each VE in turn. Participants were allocated a ten minute period to review the environments at each workstation.

The Virtual Factory was a simulation of an industrial manufacturing environment that was designed specifically for the assessment of health and safety issues. The factory contained hazards that the user had to locate and identify by navigating the factory layout [38]. The Virtual City was a collection of simulated daily activities. These included acquiring items on a shopping list, using a bus and navigating around streets. It was a dynamic city with moving traffic and people walking along the streets. It included shops and road crossings, and was designed for people with a learning disability to experience everyday activities in safety [39]. Virtual Lego™ was a kit of simulated construction blocks that when assembled in the correct order produce a three-dimensional model of an off-road vehicle. It was demonstrated to show how spatial manipulation and sequential processing can be practised and assessed in a VE [40]. A tangible user interface (TUI) was also demonstrated at this workshop. The TUI was a coffee making simulation in the form of a tactile device that was mounted above a standard computer keyboard. It employed real objects connected to actuators that operated a key-press when the objects were used. A coffee making simulation with three dimensional objects was displayed on the screen. Interacting with a physical object caused activation of the corresponding virtual object in the VE. For example unscrewing the coffee jar lid caused the lid in the VE to unscrew. Interactions with physical objects in the real world were reflected as animations in the VE [41]. Tangible user interfaces are described in more depth later.

Participants at the study were asked to specify their role in stroke patient care, and work location (community or hospital). They were asked about their experiences of using VR and asked about their perspectives of VR for stroke rehabilitation. A focus group was organised during which three key questions were posed to the participants. The aim of the focus group was to gather information about the participants priorities and experiences [42]. The three questions posed to the group were:

- What should influence the design of VR systems for stroke assessment and rehabilitation?
- At what stage in the rehabilitation process would VR best be applied?
- What are the barriers to this (VR) technology being used routinely in stroke assessment and rehabilitation?

A suggestion that VEs might incorporate assessment strategies within the activities was made by the group. Benefits of VR technology were also discussed. The emphasis was placed upon the development of realistic environments in which meaningful activities can take place in safety. Therapists were in a position to report on the pragmatic issues of introducing VR technology to the ward. Concerns were raised that in order for VR to be used routinely in a climate of evidence-based practice, trials of VR based tools would have to show a demonstrable improvement over current procedures. Accountability was also discussed. Occupational therapists would not be expected to introduce new strategies without the consent of a consultant in authority.

Consultants. In the first study, occupational therapists explained that decisions to implement new treatment strategies were not theirs to make but that these were authorised by stroke consultants in line with best practice and current research. The University of Nottingham has an active stroke research community and the logical way forward was to involve consultants in discussions about the design of VR for stroke care. A seminar was organised by the first three authors. This was attended by four medical consultants working in stroke rehabilitation. Two of these consultants were also qualified occupational therapists.

The four virtual environments described in the previous study were demonstrated to the consultants. There was an opportunity to discuss each of these in turn. The same three focus questions that were put to the therapist group were posed to the consultants.

The consultant group suggested that a role for virtual reality would be to embed treatment strategies within realistic simulations of real world environments. The individual needs of the patients were considered to be important factors in the design of virtual environments. The consultants with a qualification in occupational therapy identified patient safety as important and reiterated the ability of VR to facilitate training in a safe and controllable environment.

There was a recommendation from the group that initial research in this area should take a case-based approach, working closely with a small number of patients rather than immediately attempting to identify generic techniques and solutions through randomised controlled trials.

Discussions with the consultants reinforced the idea that VR could be useful for simulating environments for training that are safe for the user to practise in. The recommendation was not to use virtual environments to replace current assessment strategies but instead to use the VEs to assess cognitive and motor abilities that are not currently tested by assessment batteries. Consultants explained that although simple pen and paper tests do not quantify the extent of impairment, they have been shown to be reliable at assessing the presence of impairment. Replicating these on a computer monitor makes little sense and does not make use of the richness offered by a VE.

Stroke Survivors. In the third study we wanted to gain the perspectives of people who had experienced stroke rehabilitation as service users. Of particular interest at this stage were those stroke survivors who have returned to the community after a period of in-hospital rehabilitation because this would enable them to report retrospectively on their personal experiences of rehabilitation in the hospital setting.

A meeting was organised with a community-based stroke club. The virtual environments described previously were presented to the group and a discussion was held based around the three focus questions listed above.

Members present (stroke survivors) suggested that they could see the purpose of VR in rehabilitation. They added that having already returned to the community, this form of activity would be too late for them and the opportunity to practise tasks in the hospital setting was seen as a better place for VR.

The transition from hospital to community caused concern amongst participants. Concern was also expressed that despite attempts by shops and services to improve disabled access, the perception was that environments were not adapted to their needs. Concern was also expressed that computer technology could be too difficult for elderly people to learn and simplicity of operation was considered to be important.

A second meeting was arranged with the stroke club. Those present described the assessments and treatment that had been administered by the OTs in hospital. Proficiency in these was seen as a means to returning home but comments were made about the limited opportunity to practise. Three members of the group (all male) identified making a hot drink as an activity that had been used as a component of their assessment of independence. The group discussed the most appropriate timing and method of using VR technology in their rehabilitation. The opportunity to practise practical household skills was commented upon as something that would be well received.

Of importance in the consideration of designing VR technology was ease of use. Members of the group were mostly elderly and of those attending the second meeting only one person claimed to have any prior experience of using a computer. Ease of operation was therefore an important attribute of any new VR system as the users did not want to learn how to use a computer in addition to the task being practised.

2.3 Virtual Environment Development Phase

Following the consultation phase presented above, a coffee making task was chosen as the focus of the system. The rationale for the choice of task was that making coffee is a useful everyday activity but there are hazards because the task involves boiling water and the use of kitchen appliances.

A multidiciplinary development team was assembled comprising consultants working in stroke rehabilitation, an OT, and virtual reality researchers. The initial activity of the group was to specify the design requirements, describe the task to be modelled and construct a prototype virtual environment.

Design Requirements. The initial activity of the team was to draw up a list of requirements for the VE based upon the findings of the previous consultation phase and from expertise of team members. A list of design requirements was drafted (see table 2).

The OT recommended that task performance should be measurable. The OT was considered by the team to be a suitable candidate for the design of a scoring system because of her previous experience of developing and evaluating a stroke assessment index [43]. For the VE to be useful, a comprehensive record of user activity was requested by the team in addition to a summary score. The team identified the following data as necessary for the purposes of assessing the patient: the objects selected by the patient, whether the patient performs a task independently or requires assistance, whether the action taken was correct or incorrect, and the timing of each action.

Keeping track of performance and enabling freedom of choice in the task sequence (where appropriate) was seen as key to the design. Conveying the status of the task in the form of visible and audible feedback that was meaningful to the patient was also considered to be important by the team. These design requirements and recommendations were summarized in the initial design specification.

Table 2. The desirable and essential attributes of the virtual environment. At this stage it was not highly specific as the design was subject to change, but it provides a broad list of features to be included in the virtual environment

Initial design specification for virtual environment
The task simulated in the VE must resemble a real coffee making task. The objects in the VE must resemble real objects. The objects must be freely mobile so that the therapist can place these as required. The workspace will also resemble the workspace used in a kitchen assessment. There will be no distracting or superfluous equipment.
The order or sequence in which the activities are performed is to be flexible. The constraint on sequence is that any sequences of events that are inappropriate or dangerous (if a real task) are not permitted.
Scores of performance are to be recorded. To be included are user identity, timing of activity, sequence of user input. A scoring system is to be devised and implemented, to score useful measures of task performance on a scale to be devised.
The system will intervene as necessary. The system will not instruct or direct the user unless there is failure to complete an action or an inappropriate action has been performed. The system will offer prompts, warnings and demonstrate correct actions as necessary.
Delivery of the VE for the Stroke Association project is to be portable as equipment is to be recovered and locked away after every trial. For the MR system portability is to be considered. Storage on ward to be investigated as an alternative.

Task Analysis. A task analysis is a design method that investigates how an activity is carried out in existing circumstances [44]. The result of the exercise is data that provides information about the task in a format that is appropriate for the purposes for which it was gathered. Kirwan and Ainsworth [45] have categorized the different task analysis techniques into five categories:

- task data collection methods
- task description methods
- task simulation methods
- task behaviour assessment methods
- task requirements evaluation methods

Task data collection methods are techniques for gathering user performance data about an existing or proposed task. Task description methods represent the task in the form of flowcharts or diagrams that describe the component actions that are involved in the task and the relationships between these actions. Task simulation methods investigate the way people perform during an activity by using simulations of the activity and by expert walkthroughs. Task behaviour assessment methods are used to identify safety problems that may arise in a system. Task requirements evaluation methods are used to determine whether the equipment supports the user adequately in task performance [44].

Of these, a task description was required. Hierarchical Task Analysis (HTA) was selected as a suitable task description method because the result of a task analysis is a representation of the individual actions and the relationship between these actions. It deconstructs a learning activity into its key learning objectives and structures these components to allow the developer to identify strategic stages in the activity where assessment can take place. In the context of this project the HTA was used to identify the components of the coffee making task and identify actions that are individually able to be assessed (see fig. 2).

The OT explained that in the stroke rehabilitation setting, if patients are unable to walk to a tap to fetch water, they would be given a pre-filled jug of cold water. The actions required to fill the kettle were adapted to comply with the procedure that would be followed on the stroke ward. This involved pouring water from a pre-filled jug into an electrical kettle.

Certain top level tasks are not constrained to a fixed sequence, for example coffee can be put in the mug after boiled water has been added to the mug. The only mandatory and commonsense sequence was to fill the kettle prior to boiling and then to boil the water prior to pouring it into the mug. The danger of damaging a real kettle exists if it is switched on when empty.

HTA allows each of the subtasks to be broken down as far as required in order to describe specific actions. For the purposes of designing our VE the level of description shown above was adequate. Each subtask represents a discrete user action and this was considered to be at the appropriate level.

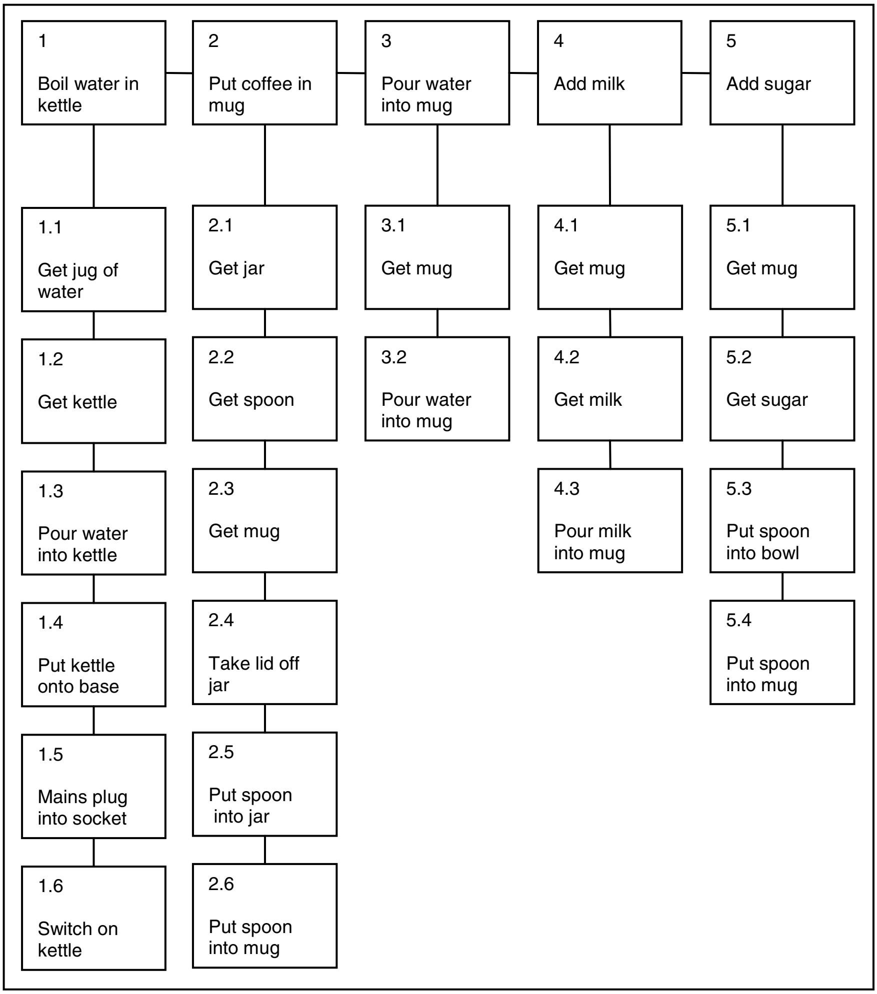

Fig. 2. The task was defined as making a mug of instant coffee. Three requisite tasks were specified (1 to 3). Two optional components were added (4 and 5)

Iterative Design. The design specification was used as basis for the development of the new VE. It broadly defined the major components of the VE, for example the task, the objects, flexibility in layout, and data to be recorded. Data gathered from stroke survivors in the community provided an overview of the general features of computer programs that they considered to be of importance, for example ease of use and relevance. It also provided us with information about the kinds of tasks that they were assessed on in hospital, for example everyday living skills. Service users' opinions and experiences were considered to be critical in the design of the new VE and an iterative user-centred design approach was adopted as explained above.

Stroke patients were recruited to participate in studies in which measures of performance in the hot drink making task were recorded. Studies were also conducted by the OT to investigate the errors made in the VE compared with those in the real world task.

Recruitment of Patients. The design work for the VE commenced following approval by our hospital ethics committee and the process of recruiting patients to participate in the design and testing of the VE began. Patients on a stroke unit were assessed by the OT for suitability to participate. Inclusion criteria were: diagnosis of stroke, goal of going home, ability to sit in chair for 30 minutes, Vocational Near Vision Test <48 and ability to recognise kitchen objects.

Participants were excluded if they presented with or had a recorded history of dementia, susceptibility to screen triggered epilepsy, psychiatric illness, inability to speak English, hearing impairment, no upper limb function or were enrolled on another study. Following the screening process in which 167 patients were invited to participate, a total of 50 patients were successfully recruited by the OT to take part in the study.

Equipment. The equipment used for the VE development studies was a Toshiba Satellite Pro A10 notebook computer with the VE developed by the design team running under Virtools™. Virtools™ is a virtual reality development package. To make the VE system portable and easy to use the OT chose to use a touch-screen interface and to reduce the risk of damage to the screen a rubber tipped wand was employed.

Patient activity was videotaped using a Sony miniDV camcorder mounted on a tripod. Patient interaction with the VE was recorded on a log-file generated by the VE software. The log-file recorded the user's participant code (names were not stored in the log-file), the sequence and timing of detected events. The VE also produced a score sheet which included the user's performance score for each action and a summary score calculated as a percentage of the maximum score possible.

In addition, real kitchen equipment was used by patients under supervision of either the OT or a research assistant recruited to the project, in order to compare performance between real environments and VEs. Patients recruited to the study were expected to undertake both real and virtual tasks.

Method. The location of the studies was a stroke ward at the Queens's Medical Centre (QMC), Nottingham, U.K. Patients who were recruited successfully underwent a series of standardised assessments of cognitive and motor function before being assessed in the real world hot drink task (see Edmans et al. [46]).

Participants proceeded through the real task and their hand movements were recorded using the miniDV camcorder. An assessment protocol comprising 27 stages was used as a measure of performance, this being devised and scored by the OT. Twelve stages were compulsory to the task, the remaining 15 were optional. Video recordings were analysed by a competent trained assessor and from this assessment scores were generated.

Following the real task, participants were then invited to perform the hot drink task in the simulated environment. Prior to performing the hot drink making task in the VE, patients were trained to use the touch-screen by practising a simple on-screen activity in which they were required to pick up a letter, place it in an envelope, pick up a postage stamp and place it on the envelope. Participants were required to hold a pencil-shaped wand with a rubber tip and tap it on the touch-screen against the virtual objects. To move one object to another they tapped the object to be moved then tapped the target object.

Once participants had mastered the technique of using the wand and touch-screen they were then given the hot drink task to attempt, once with the OT giving assistance and then attempting the activity with the computer alone providing assistance and feedback. As with the real task the same assessment protocol was used. Video recordings were made of hand movements and scored independently by an assessor. User data was recorded as a measure of performance. The VE automatically recorded the timing of actions, objects selected, errors of repetition or wrong choice, prompts given and performance scores. This was used to identify discrepancies between observed and recorded activity.

The OT compiled reports in the form of tables of errors and problems that patients experienced during tests. Video recordings that were made by the OT were then used in conjunction with the error reports to troubleshoot technical problems and to observe how users made errors. The videotape recordings were inspected by members of the design team. Errors and technical problems were discussed and these were used to guide the subsequent iteration of software. Of the fifty video recordings made a sample of twenty video recordings for both real and virtual tasks were analysed for user error analysis by the OT and a research assistant. The OT identified and categorized the errors made by patients in both environments and the errors that were made in the real environment only and in the virtual environment only. The numbers of errors made were compared between real, virtual and both environments.

Eight modifications were made to the initial design. Improvements included creating hotspots around small objects such as the kettle switch to make selection easier, providing a pause facility which temporarily disabled user input, making the colour of the liquid in the mug change according to the contents, and providing a help facility in the form of a large red button. A stage was reached when the design team decided that subsequent changes would be of little value. The result was a 3D simulation comprising a worktop upon which nine objects were placed. The starting position was in line towards the back of the worktop. The positioning was consistent with the layout of a real practical kitchen task assessment.

At the centre of the scene was a single power socket. The bench surface was not given any texture pattern in order to reduce possible distraction or confusion. Objects were: a water jug, a spoon, a jar, a teapot, a sugar bowl, a mug, a milk bottle a kettle base and an electric kettle. The addition of the teapot was the result of participants requesting the option of making a cup of tea instead of coffee. The group supported this and extra stages were added to the task to facilitate this, although the focus of the mixed reality system described below remains that of making a mug of coffee.

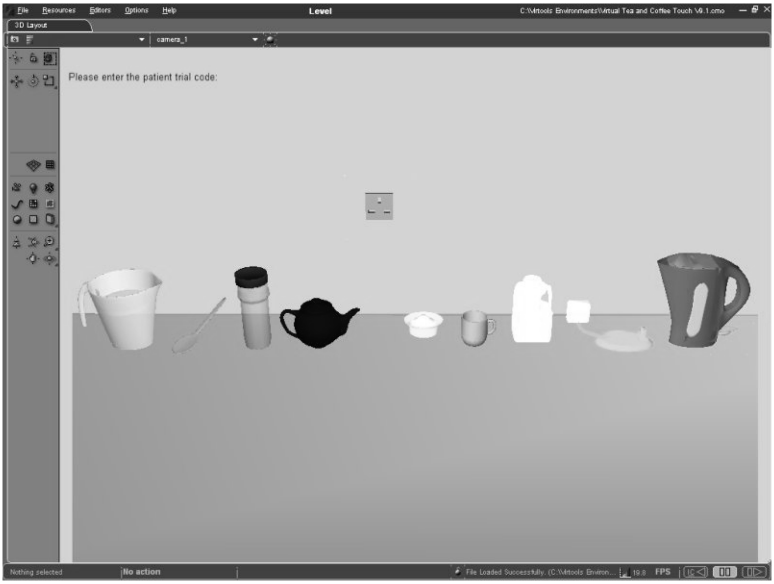

Fig. 3. The final version of the virtual environment for making a hot drink.

In the final version objects were selected by tapping them using the wand. To perform an action involving two objects, both were selected in the correct order. This triggered an animation in which the first object moved to the second and performed the appropriate action. Whilst animations were underway input was disabled to avoid confusion with the position of objects. Support was provided by a verbal prompt followed by a demonstration of the correct action in the VE. Assistance was gained by inactivity for a period of twenty seconds or by pressing the help button. The system recorded every action and intervention by both user and computer. Scores were calculated and displayed when the user had completed the task but not during the task. An electronic version of the OT assessment sheet was automatically completed by the software.

Results. Figure 4 shows a comparison of participants scores when carrying out the hot drink making task in the real worlds compared to their scores in the virtual environment. Real world scores of 100% were not uncommon however fewer patients scored 100% in the VE. Spearman's Rho was calculated ($\rho=0.3$, $p<0.05$). Real and VE scores were not strongly correlated. Errors made in both real and VE tasks are presented below. These tables are based upon a sample of twenty patients from the fifty stroke patients recruited.

Table 3 shows that errors were made in both real environments and VEs. The error pattern was not as expected. Errors were made by subjects in both environments, but errors were more common in the VE. A Wilcoxon Signed Rank Test performed on errors scored $z = 2.14$ ($p<0.05$) showing significant difference between error types in virtual and real environments. This suggests that the two tasks are different and although the VE may enable users to proceed through the task, it does not fully represent the real world task.

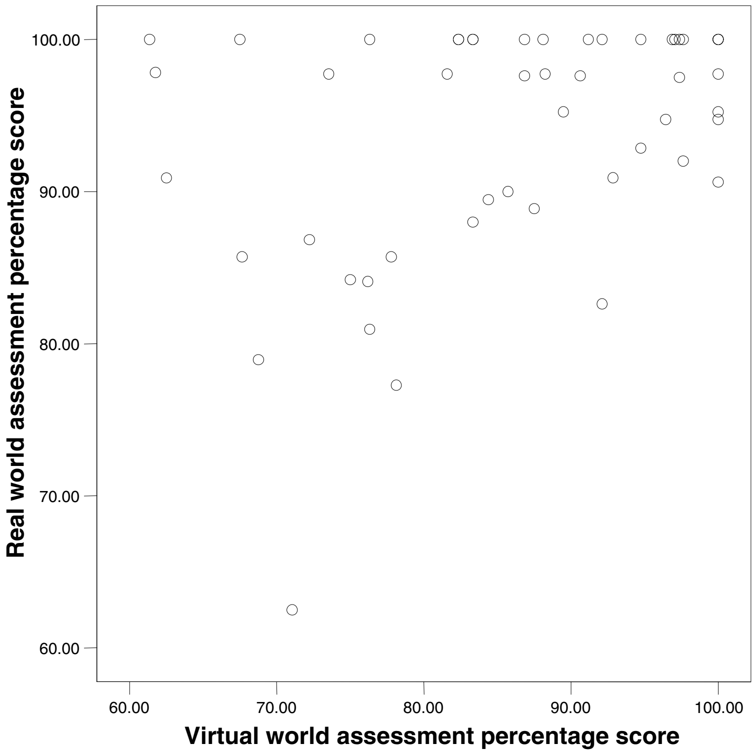

Fig. 4. A comparison of real and VE assessment scores (%)

Table 3. Comparison of errors made by subjects (n=20)

Error type	Error in both real-world assessment and virtual environment	Error in real-world assessment only	Error in virtual environment only
Initiation	3	0	8
Attention	0	3	2
Neglect	0	1	1
Addition	0	1	0
Sequence omission	5	0	9
Perseveration	0	1	1
Selection	0	1	9
Object use	0	0	0
Problem solving	2	0	6
Dexterity	2	0	8
Quantity	0	6	0
Spatial	0	1	0

Discussion. Following an iterative design process involving stroke patients as participants in the design of a virtual environment for making a hot drink, a final version was constructed that enabled the users to proceed through the task. The system was portable and practical, being easily carried to the patient's bedside if required, and easy for the OT to set-up and run.

The VE presented the hot drink making task as a safe and controlled simulation, recording user performance scores and user activity as well as identifying selection and sequencing errors. The evaluation of the completed VE showed that the VE did not completely represent the real world task, however. Two factors that showed high error rate in the VE compared to the real world were dexterity and selection. Initiation, problem solving and selection errors are also more common in the VE [46].

The VE task was more difficult than the real world task and although errors were made in both types of activity, these varied between the two environments. Patients showed greater proficiency in dexterity, selection and problem solving in the real task compared with the VE. The VE presents different problems that are not present when using real objects.

Selecting an object in the VE was achieved by pressing gently against a touch screen using a wand that resembles a pencil, clearly different to the real world action of holding and grasping objects. Some patients who were able to perform the task in the real world showed dexterity errors in the VE.

Although the research in this section was carried out by the OT in consultation with the design team it does show that the VE presents new problems. The fact that the VE scores and real world scores were not strongly correlated suggests that the skills required to make a hot drink in the VE do not equate exactly with those required to make a hot drink in the real world.

2.4 The Design of a Mixed Reality System

The touch-screen did not encourage naturalistic movement of the hand or upper limb to complete the task, the only physical component of the task required was the ability to point a pencil shaped wand. A more realistic and naturalistic user interface was developed as the method of controlling the simulation, the rationale being that activities of everyday living comprise a mixture of cognitive and physical processes, and the stroke rehabilitation literature proposed that it is beneficial to the patient if these processes are trained together in the context of a useful task.

Mixed reality refers to technologies that blend virtual and real components. A spectrum of MR technologies proposed by Milgram and Kishino [47] illustrates the way different applications place a different emphasis on the mix of real and virtual environments.

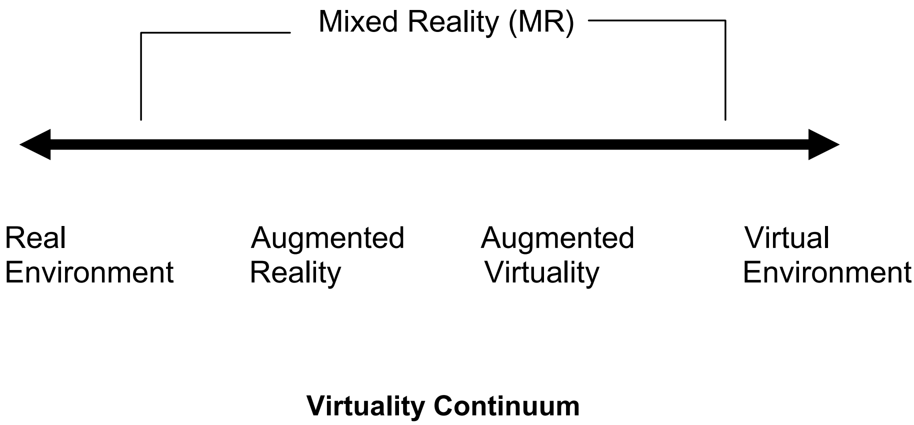

Fig. 5. The mixed reality spectrum

The ‘virtuality continuum’ is the range of experiences and technologies that span the gulf between the virtual and the real environment. Every day experience (the real environment) is situated at the far left side of the spectrum. Progressing to the right there is continually increased emphasis on technologies that use computer generated information to enhance or augment the user’s experience. VEs that do not incorporate the real environment in any way, for example immersive VR systems, are situated at the far right of the spectrum.

Design specification. A tangible user interface (TUI) was proposed to exploit the physical and designed properties of real objects in order to enhance the realism of the experience. The tangible user interface and virtual environment together comprise a mixed reality (MR) system. TUIs control a computer through manipulation of real graspable objects. The definition of TUIs attributed to Ullmer and Ishii [48] are that “they give physical form to digital information, employing physical artefacts as representations and controls of computational data”. The input is of the form of digital data relating to one or more properties of the object(s), such as position, orientation and proximity to other objects. This is achieved using different methods, for example by placing sensors in objects that are coupled to a host computer. Employing real objects immediately removes the complexity of programming appropriate affordances and constraints into the VE. Furthermore it requires the user to interact with the object in a realistic way.

By referring to the task analysis the actions to be monitored by the mixed reality system were identified. A mechanism for detecting user input was required. In addition to detecting correct actions, the facility to detect and identify incorrect actions was also required in order to provide useful feedback to the user and to record errors in user performance. Characteristics of the proposed input device were defined. Broadly, the requirements of the system were that it must:

- Detect and identify an object that is being used
- Detect when two objects are within proximity of each other
- Detect when an action has been performed by or on an object

Mechanisms were required to detect when the activity was taking place. By examining the descriptions, the types of technology required to detect the activity could be considered. These were discussed at team meetings and it was evident that the TUI would require a hybrid of several different kinds of sensing mechanism. For detecting the spatial location of objects a computer vision system was proposed. For detecting when vessels were being poured a tilt switch was suggested and for detecting when an object was in contact with another a pressure sensing mechanism was suggested.

Entity relationship diagrams were used as means of representing the objects and the actions being performed. Entity relationship diagrams show the objects (entities) in boxes and these are connected by lines representing actions, labelled to show the relationship between the entities [49]. Here the entities were real kitchen objects and the relationships were the actions performed on the objects.

Entity relationship diagrams were adapted by the authors by adding a third box to each relationship, which included the proposed mechanisms for detecting the actions. These adapted entity relationships are shown in figure 6. The various sensing mechanisms are explained in more depth in the following sections.

Tracking Objects. Tracking technology was employed to identify and locate objects in the physical workspace. Tracking technologies can be categorized as either 'active' or 'passive'. Active tracking requires a source signal emitted by the object (for example infra red, ultrasound) that is located by remote sensors. The position of the signal source and hence the location of the associated device is triangulated by comparing the timings of received signals at different receivers [50]. Unlike active tracking, passive tracking does not require the object to emit a source signal. Passive sensing mechanisms are used to locate and identify objects. Digital cameras are commonly used. The object to be tracked is placed in the field of view of the digital camera. The digital image generated by the camera is processed by software that identifies any objects located in the workspace by matching a physical property of the image (colour is frequently used) with a stored model of the object.

In the TUI proposed for this project, multiple objects coexist in the workspace. A technology was required with the capability to differentiate between several objects simultaneously. Active tracking of multiple objects poses problems of signal interference, confusing the triangulation and location of an individual object. Infra-red and ultrasound tracking require an unbroken line of sight between the source and receivers.

A passive tracking system was chosen because it is not subject to the constraints of active systems described above. Computer vision technology was available at the School of Computer Science at the University of Nottingham. This used colour matching and had demonstrated adequate performance in distinguishing between multiple objects in the field of vision of a digital camera [51].

Computer Vision. The computer vision system used in this project employed a Logitech™ web-cam positioned to point vertically downwards onto a workspace using a Kodak tripod. The workspace was constructed from a matt-black (i.e. non-reflective) plywood board 100cm X 60cm. The web-cam was connected to a Toshiba Satellite Pro notebook computer running the vision system software coded in C++ by colleagues at the School of Computer Science at the University of Nottingham.

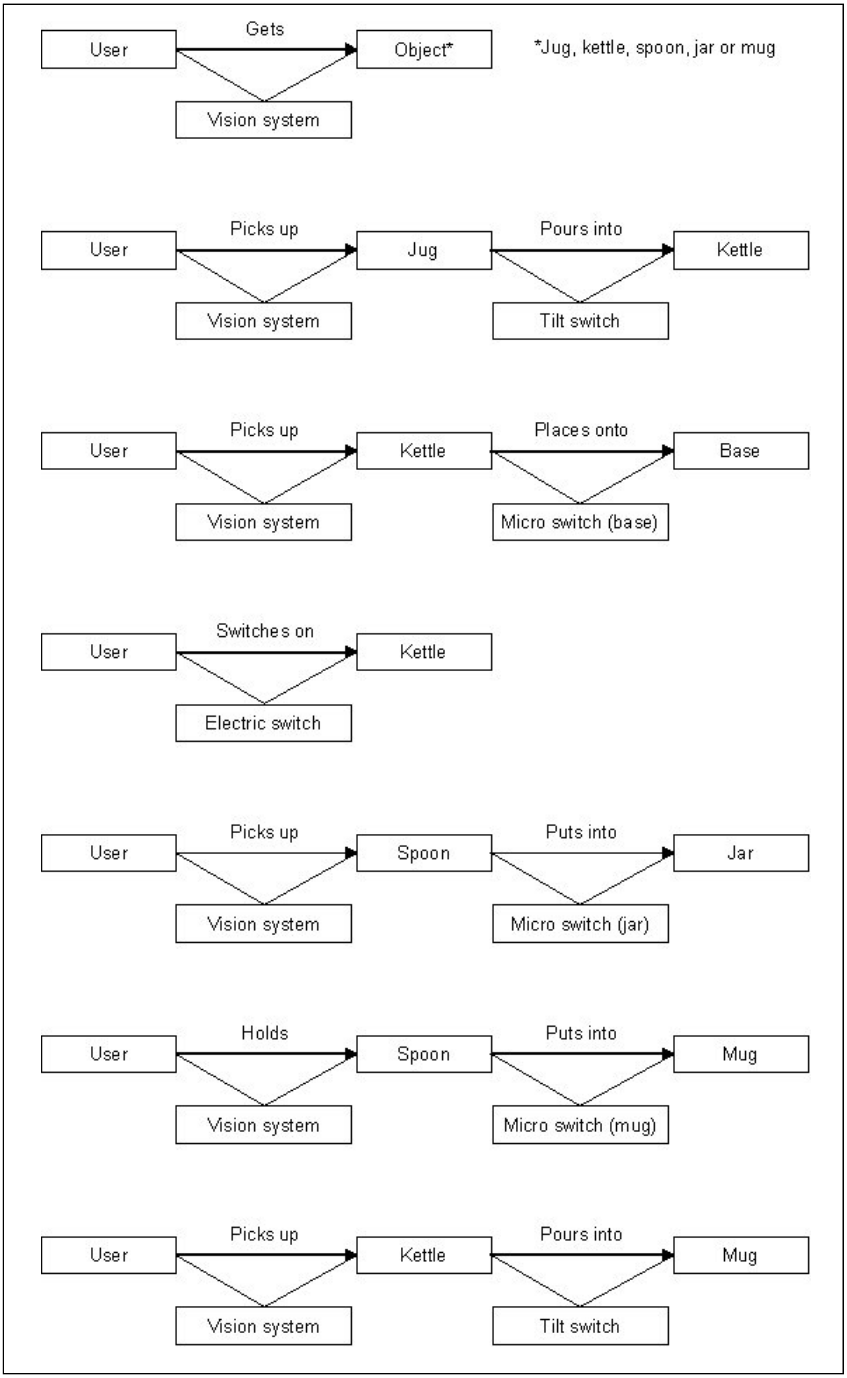

Fig. 6. Entity relationship diagram for coffee making activity with proposed mechanisms for sensing each of the activities remotely

A robust technique for visual recognition of coloured objects and spatial location within the field of view of a video camera has been developed by Swain and Ballard [52]. Their technique compares red, green and blue (RGB) attributes of objects placed within the field of view of a digital camera with the colour histograms of previously trained objects or models. In their technique, the RGB components of an image captured by the camera are compared with those of the model and the resulting match is calculated as a confidence value. Red, green and blue colour (RGB) component segmentation is susceptible to light intensity. Inconsistent or low level lighting produces unreliable results. Instead of using RGB components the Hue, Saturation and Light (HSL) components were measured. The light intensity component (L) was ignored so that the system was not susceptible to light intensity variations. The saturation component of colour (S) refers to the amount of white light or noise that is included in the colour. High saturation gives purer colour and has a low noise component. The saturation was therefore set to the maximum level for optimum colour. The hue (H) component was the remaining variable and this was used to identify objects in the field of view.

A model of each object was generated. Each object was placed in the field of view of the camera in turn and a frame was grabbed. The frame was a snapshot of the entire field of view and the part of the image that would become the model was extracted from the background. The model was separated from the background using Paintshop Pro™ and the resulting image was saved as a portable network graphics (PNG) file. This was repeated until a model was stored for every object. To measure the confidence of a match between a captured image of an object and its model, objects were placed in the field of view of the camera and the images were compared with pre-recorded models of all the objects. The confidence of a match between image and model was calculated by the vision system software in the following way.

When an object was moved into the field of vision of the camera, an 8*8*8 bin hue histogram of the captured image was compared with the hue histograms of every model that was stored as PNG files. Hue values were compared.

If $N_I(i)$ is defined as the value calculated for the i^{th} bin of image I (1)

Then $N_M(i)$ is the value calculated for the i^{th} bin of model M (2)

The difference between (1) and (2) is calculated for all bins and the minimum of the result and zero is registered for each operation. This is repeated for all 8*8*8 colour bins. The summation of each operation results in a value between $-N_M$ and 0, A negative value represents low correspondence of colour matching, a score of zero representing a positive colour match.

The confidence that a model matches an image is defined as C(M,I) (3)

Pridmore et al. [53] present an expression to calculate C(M,I) based upon the work of Swain and Ballard [52] as:

$$C(M,I)=\left[1+\frac{\sum_{i=1}^{i=511}\min\left(N_I(i)-N_M(i),0\right)}{N_M}\right]$$

Low intersection between a model and the image will result in a summation approaching $-N_M$ thus:

$$C(M,I) \text{ will be approaching } 1 + (-N_M/N_M) = 0 \tag{4}$$

High intersection between the model and the image will result in a summation approaching 0, thus:

$$C(M,I) \text{ will be approaching } 1 + (-0/N_M) = 1 \tag{5}$$

A threshold value is predefined within the configuration file prior to sampling. Values computed in excess of this minimal value are considered to indicate a positive match between image and model.

The spatial location of the object is calculated in two stages. First the average location of pixels in a given bin is calculated. The proportion of pixels in a given bin that match the model is calculated. This is used as a weighting in which high values correspond to a confident match. Using these weightings the coordinates that correspond to a good match are aggregated, the result being x and y coordinates that approximate to the centre of the matched object.

A technique was developed for passing object identity and coordinate data from the vision system to the virtual environment. When operational, the vision system constantly updates a data file that contains the object identity and its spatial coordinates relative to the camera origin. The identity and coordinates of a positive matched object were then used to control a simulation of the object in the VE. This process was repeated at a frequency set in a configuration file. The value was set at 8Hz for this project, a value that was considered as a compromise between processing demand on the software against the reliability of tracking a moving object.

Testing the Computer Vision System. To test the vision system an experiment was set up to measure the confidence that the system would correctly identify an object over repeated trials. The Logitech™ camera was mounted on the tripod with the lens pointing towards the work surface and was connected to the Toshiba Satellite Pro notebook computer. Five pencil marks were made at five different positions on the work surface. Four marks were equally spaced to form a 50cm square with a fifth mark at the centre of the square. With the vision system software running the jug was placed on one of the markers. The data file recorded the confidence of a match between the model and the image of the object. This was repeated for each of the four remaining markers. Five measures of confidence for the jug were recorded from which the mean and standard deviation were calculated. This exercise was repeated for each of five objects that were to be detected by the vision system.

Confusion of recognition between objects was of concern. Kitchen items are commonly made of metal or glass with reflective surfaces. These cause a variation in the detected hue making identification of the object erratic. Similarly electrical appliances are commonly white or metallic. Objects were selected for their unique hues. Metal and glass objects were rejected. The objects that were used in the TUI were: a pink water jug, a green plastic electric kettle, a red coffee jar, a blue mug and a yellow spoon. Following the calculation of the confidence of a match between an object and its model a second study was conducted to calculate the ability of the system to differentiate between objects. Each object was placed individually under the camera in turn. The vision system calculated the confidence of a match between the object and every other stored model. This was repeated for each object in turn.

Table 4. Confidence values and descriptive statistics for five samples of each object

	JUG	KETTLE	JAR	MUG	SPOON
Confidence	0.975075	0.836774	0.900000	0.999051	0.991753
	1.000000	0.824477	0.881818	0.919355	0.938144
	0.790739	0.820378	0.853846	0.846300	0.804124
	0.829262	0.791685	0.806993	0.907970	0.940206
	0.997757	0.797980	0.813906	0.999051	0.824742
Max	1.000000	0.836774	0.900000	0.999051	0.991753
Min	0.790739	0.791685	0.806993	0.846300	0.804124
Mean	0.919897	0.814259	0.851313	0.934345	0.899793
S.D.	0.098419	0.018863	0.040838	0.065280	0.081157

Table 5. Confusion matrix for each object matched against each model

MODEL			**OBJECT**		
	JUG	**KETTLE**	**JAR**	**MUG**	**SPOON**
JUG	**0.920738**	0.040692	0.450350	0.441176	0.352577
KETTLE	0.031157	**0.818182**	0.224476	0.040797	0.280412
JAR	0.100698	0.045821	**0.859441**	0.748577	0.354639
MUG	0.050100	0.009076	0.504196	**0.794118**	0.111340
SPOON	0.010219	0.013175	0.167133	0.113852	**0.977320**

The mug and jar show confidence values that are not too dissimilar. Similar values between two objects could cause errors in identification of these objects. Setting the minimum level at which the confidence value is considered to give a true match is therefore critical. A threshold value higher than 0.748577 (see object ‘mug’ compared with model ‘jar’) is required and a value lower than 0.794118 (see object ‘mug’ compared with model ‘mug’) is required. A value of 0.77 is reasonable. In practice the confidence values were improved by re-sampling the objects and creating new models by removing parts of the model that could cause a reduction in the confidence value, for example darker areas caused by shadows.

Sensors for Event Detection. Although the identities and positions of objects in the scene may be computed by the vision system, this is not sufficient to confirm that an action such as pouring has actually been carried out. For example detecting that the spoon is in close proximity to the coffee jar is not the same as detecting that the spoon has been put into the coffee jar. Using proximities as confirmation of action is clearly not adequate, and a robust method of detecting the intended actions was required. A solution was sought using sensor technology. Electrical switches that detect a measurable change (tilt, pressure, continuity) were identified as a potential method of detecting actions and devices incorporating these sensors were constructed (see figure 6).

Pressure sensors used PCB mounted sub-miniature micro-switches. These incorporate a small lever which when pressed make an electrical connection. Being small, the levers alone provided an inadequate target area for patients to push down on. Rigid boards of slightly smaller diameter than the object were attached to the micro-switches and mounted inside the objects forming a plate or diaphragm against which the user could press a utensil. Tilt sensors used non-mercury tilt switches that were mounted inside objects as appropriate, for example objects that are normally used for pouring liquids. Wireless connection was proposed to allow unencumbered freedom of movement that wired sensors do not offer. A radio frequency (RF) system to connect the sensors to the VE was sought. Of concern was the radio frequency band which must be carefully chosen to ensure that interference with hospital communication and medical equipment does not occur. Following consultation with hospital technicians a system operating at 433 MHz was chosen. This is an all purpose license free bandwidth that is used for remote car locking systems.

Radio frequency switches were constructed. The transmitters were type AM-RT4-433 powered by 1.5 volt lithium cells and these were activated by either tilt switches or sensitive micro-switches. An AM-HRR3-433 receiver was used to detect event triggers from the objects.

The reliability of the tilt switches and micro-switches to operate the RF transmitter consistently over a fixed distance was measured. Each transmitter was placed in turn at a measured distance of two metres from the receiver. The receiver was connected to the USB port of a Toshiba Satellite-Pro notebook computer. To test the sensors, each switch was operated repeatedly and sensors were required to complete 100 successful consecutive switching events before they were used.

Prototype Assembly. The RF sensors were designed to detect when an action took place but not the context of the action. The vision system was used to identify those objects that were involved in the action and their location in the workspace but not to detect when an action had taken place. These two systems were complementary and together provided the necessary data to identify the context and timing of user activity. The computer vision system, sensors and virtual environment together comprise the mixed reality system. The VE was designed to monitor user performance and to support the activity by providing prompts and demonstrations. The TUI was the input component of the MR system and the focus of the physical activity. In addition to the system described above a help facility was provided in the form of a large red button that offered a suitable prompt or instruction as appropriate when pressed.

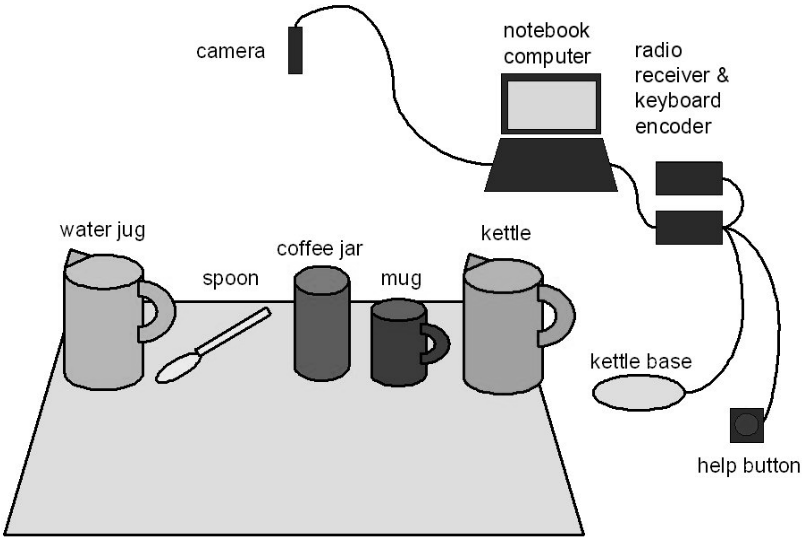

Fig. 7. The complete MR system

Fig. 8. Photograph of the completed mixed reality system

Evaluation of the Mixed Reality System. The MR evaluation study was designed to investigate the practicality of the MR system and through collaboration with stroke survivors on the stroke unit, to iteratively develop the layout and specific requirements of the system.

Method. Over a period of three months stroke survivors who were admitted to the Stroke Unit at QMC, Nottingham, were assessed for suitability to participate in the study. Patients were initially included if they were diagnosed with a stroke and were undergoing rehabilitation with good prospect of returning home. As with the previous study they were excluded if they presented with or had a recorded history of dementia, susceptibility to screen triggered epilepsy, psychiatric illness, inability to speak English, hearing impairment, no upper limb function or were enrolled on another study. Suitability to participate was assessed by the OT who had access to patient's notes.

Patients who fulfilled the selection criteria above were invited to participate. Those who expressed an interest in the study were given a patient information sheet. The sheet was read out to the subjects and they were then asked whether they would like to continue to participate. Participants were informed that at any stage they may refuse to continue. Verbal consent was gained in compliance with ethical requirements. The OT was in attendance at every session. Participants' identities were not recorded for reasons of anonymity. The equipment was set up in the day room of the stroke unit with the utensils and other kitchen hardware positioned towards the back of the work surface. Participants were seated in front of the work space.

The computer issued a verbal prompt to start the task and the patients followed the cue to commence the coffee making activity. Written observation notes were made throughout including unusual occurrences, errors made and problems with the equipment. The computer recorded every action captured by the sensing technologies. The time of each event was added to the sequence record so that events recorded by the computer could be matched against events that were captured by the camcorder. Following the completion of the activity the subjects were interviewed by members of the team. The interview comprised a computer attitude survey and further questions about the user's experience of using the MR system.

A Computer Attitude Scale (CAS) devised by Loyd and Gressard [54] was used for the attitude assessment. The CAS comprised questions associated with themes of anxiety, confidence, usefulness and liking. The CAS used for this study comprised eight questions, four of which were positively worded, the remainder being negatively worded. The responses were scored on a five point Likert scale. For the four positively worded questions five points were allocated to "strongly agree" responses. One point was allocated to "strongly disagree" responses and neutral responses ("don't know") scored three points. For negative worded questions the reverse is true. Five points were allocated to a "strongly disagree" and one point for a "strongly agree" response. Questions were paired so that for each negative worded question there was a positive counterpart, one pair for each of the four themes. The statements are presented below.

Table 6. CAS statements, comprising four themes of paired questions

CAS statement
1. Computers do not scare me at all
2. I am sure I could use computers for learning
3. I will do as little work with computers as possible
4. Learning to use computers is a waste of time
5. Computers make me feel uncomfortable
6. I think using a computer would be very hard for me
7. I think working with computers would be enjoyable and stimulating
8. I am sure I could use computers for work or learning

A further five statements about participants' experiences of the session were rated using a five point scale. Finally participants were offered the opportunity to suggest improvements using a free-text response format.

Video recordings of patient progress were recorded onto DVD. Microsoft Windows™ Movie Maker V6.1 was then used to analyse the DVD contents. As both the VE and Windows™ Movie Maker V6.1 include time stamping it was possible to compare the events that the computer registered with those that the camcorder recorded in the field. For each trial, the video recording was inspected and actions were noted with the time of the event from the start of the activity recorded. Two tables were generated for each participant; one showing the actual events interpreted from the video recording, the other showing events recorded by the computer. The two sets of data were compared. Corresponding events in both tables indicate actual events that were also recorded electronically. Discrepancies between these two sets of data were identified and categorised as either user error or technical error. These errors were then analysed in order to make improvements to the MR system as appropriate.

Results. Fourteen participants were recruited (mean age 70 years, range 50 to 89). Prior experience of using a computer was scored on an ordinal scale in which 1 reflects daily use prior to the stroke and a score of 6 reflects no prior use. Three (21%) participants had used computers daily prior to their stroke and 9 (64%) had never used a computer. Table 7 shows participant, gender, age, CAS score and experience. CAS scores varied with a minimum of 14, maximum of 40 and a median of 31.5.

Table 7. Gender, age, attitude scores and experience scores. In column 1 MR refers to "mixed reality" used as part of the anonymous coding system

Code	Gender	Age	CAS score	Experience score
MR1	M	77	16	6
MR2	M	89	25	5
MR3	M	57	33	6
MR4	M	50	40	5
MR5	M	52	39	1
MR6	F	75	31	6
MR7	M	75	34	1
MR8	F	83	14	6
MR9	M	64	28	6
MR10	M	59	20	6
MR11	M	81	32	6
MR12	F	81	23	6
MR13	M	74	39	1
MR14	F	68	33	6

Data from User Experience Survey. A further five questions were asked about the participants' experiences of using this system. A five point Likert scale was used with positively worded questions, 1 being strongly disagree through to 5 being strongly agree.

Table 8. Participants responses to questions about the MR environment

Statement	**Median**	**Range**
When the computer gave instructions, I could hear them clearly	5	4
When the computer gave instructions, I could understand what was being asked	5	4
I knew what I had to do to carry out the instruction	5	2
The device enabled me to do what was asked of me	5	2
The screen was useful as it showed me what I had done	4	4

The system enabled users to perform the task and users knew what to do to perform the task. Comprehension and clarity of instructions were an issue. Participants were asked whether they would make changes, and if so what would they be. Comments received by the participants are summarised below.

Table 9. Participants comments about changes to the MR system

Patient	**Comments**
MR1	Make sure the actions are as real as possible. Could include lid on jar.
MR2	No improvements.
MR3	None [changes]. Don't normally make coffee.
MR4	Stroke affects memory and this is useful. I didn't use the screen much.
MR5	Possibly a lid on the coffee. The switch was hard with one hand.
MR6	Clear and straightforward. I watched the screen to see if I was doing it right.
MR7	No changes.
MR8	Could be useful. Only change to make the spoon work better otherwise none.
MR9	Its straightforward. There was no milk.
MR10	Different people use different hands. The help button was a good idea.
MR11	Don't know what to change.
MR12	Once or twice I used the screen when I was stuck.
MR13	Not sure if I used the screen.
MR14	No changes.

Table 10. Summary of errors, categorised as user and system errors

User error:	
Kettle to mug: no water	2
Kettle not placed on base	1
Kettle poured into jar	1
Kettle switched on when empty	1
Poured jug directly to mug	2
Repetition of action	1
Difficulty placing kettle on base	5
Placing mug on base	1
Empty spoon to mug	1
Spoon to jar not registered	3
Jug to kettle	2
System error:	
Spoon not recorded	6
Kettle not recorded	2
Jug not recorded	1
Kettle not in scene	2

User errors included errors in selection and inappropriate use or mishandling of equipment. System errors were those in which actions were not recognised and recorded by the software or those for which inappropriate responses were made by the software.

Frequently users did not bring objects into the field-of-view of the camera. Objects were therefore not detected by the vision system in these cases and consequently the software was unable to reliably register user action. A physical problem of placing the kettle correctly on the base was repeated on two occasions. Dexterity in handling the kettle was not measured or required for the touch-screen system other than ability to point to objects on the screen but the MR system was more realistic in simulating the actual hand movements required to achieve the actions. Participants who satisfactorily completed the VE based task using the touch-screen demonstrated an ability to proceed through sequences of actions but this does not necessarily correspond to proficiency in the real task.

On six events the spoon did not register when the video camera clearly identified it as being present within the workspace. This is not a user error in the sense that the user has not actually made a mistake of object selection or handling. It was observed that users frequently held the spoon so that it was occluded by the hand or held sideways and consequently insufficient pixels were available to the camera for colour matching.

System errors were detectable when objects that were registered as being present by the software were not present in the video recording. In one trial the kettle was repeatedly registered by the vision system when it was clearly absent from video analysis. Studying the actions showed that this was most likely due to the green colour of a patients sleeve forming a colour match with the kettle model. This demonstrates the importance of reducing or removing intrusive colour to the workspace beneath the vision system camera. The colours of sleeves and other objects (watches, jewelry) are registered by the vision system and can affect model-image matching.

3 Discussion

Consultation. In the early phase of this study therapists who were consulted identified key features of VR systems that they believed would be important in stroke care. Reproduction of realistic environments that could enable users to practise tasks in safety was considered to be a potential role for VR in stroke rehabilitation.

Consultants suggested that pen and paper exercises have proven to be successful in the detection of visual field deficits and direct replacement of these by VR methods may not necessarily be advantageous. Instead the value of VR was seen as the ability to replicate environments and to embed treatment strategies within these simulations. Consultants added that computer simulations may also facilitate a form of assessment of function that is currently available only with practical tasks.

Stroke survivors resident in the community suggested that VR offered the opportunity to practise activities and reported that this was not always available in the hospital setting.

These studies illustrate differences in perspective of three different stakeholders. Therapists focussed on safety issues. Former patients who are resident in the community were more concerned about the timing and duration of their treatment. Stroke researchers considered wider applications and were able to speculate on a number of different roles for VEs in addition to those demonstrated. This diversity of perspective and insight shows the importance of including different stakeholders in consultations about the design of new treatments and technologies for rehabilitation.

The question of barriers to the regular use of VR to support stroke rehabilitation was posed during the consultation phase. Evidence of effectiveness and cost of implementation were the major concerns raised by the therapists. These practitioners understandably reported that a new strategy, technology or technique must demonstrate proven effectiveness before it is accepted into practice.

With little evidence to suggest that VR could offer a cost effective strategy, development and implementation costs were brought into question. In the lifetime of this project home gaming systems that display three dimensional simulations have become popular and inexpensive, thus cost of equipment is of reducing concern. The concept of a TUI has also become increasingly accepted and commonplace with the introduction of tangible inputs for popular home games consoles that are now operated by increasingly naturalistic body movement (see for example the Nintendo Wii™).

Development costs for highly specialised interactive VEs are of greater concern. The tradeoffs between generic solutions and focused individual problem solving became apparent in the discussions with OTs and consultants. The development of a single VR package that addresses the diverse problems that stroke patients present with was not considered to be practical or particularly desirable.

In order to treat a diversity of cognitive and motor problems a modular approach was recommended by the consultants. This modular approach proved to be an important feature during the development of the VE, allowing for changes in the task and virtual objects to be accommodated as required.

Design requirements. Monitoring the stroke patient's progress through a useful task was considered to be an important design requirement by the therapist consultant group in the early phase of the project. Specifically, a mechanism for objectively and reliably scoring and recording the patient's progress was considered by the focus group as a useful design feature.

Interaction was also discussed in the context of the stroke survivor as the primary user of rehabilitative or assistive technology. A particular design concern for practical tasks was impairment of the dominant hand. Versatility of input was considered by therapists to be of importance due to the mixed physical and cognitive ability of primary users. Therapists were also concerned about issues of presentation of instruction and feedback. Communication impairments are commonly reported following stroke and therapists recommended that needs of dysphasic patients should be considered in the modes of feedback, with exclusion of those patients from VR based treatment in acute cases. Therapists recommended that patients with short term memory problems would respond best to brief instructions that refer to actions comprising single stages.

The former patients in the community expressed concern that being (mainly) elderly and inexperienced of using computers they would not want to have to learn how to use a computer as an additional skill to learning an everyday task. For them ease of use was a major design criteria.

Selecting a Suitable Activity to Simulate. Stroke survivors in the community who attended the meetings were asked to recall activities that they were required to complete as part of their assessment of independence when they were in hospital. Making a hot drink was reported by several participants as a task used as part of their assessment. As an activity to develop into a simulation, the choice of a hot drink appeared to be a sensible and logical choice because it is a common task that requires the participant to identify a variety of household objects. Additionally it requires the participant to be able to understand the purpose and function of these objects.

Making a hot drink involves the use of electrical appliances and the handling of hot liquids, both of these presenting serious hazards to a person with cognitive or motor impairments. The simulation of a hazardous activity was a key driver in the choice of task. Making a cup of coffee appeared to be a familiar and fairly straightforward task. In practice the activity comprises many stages, especially if optional stages (sugar, milk) are added, and the permutations of permitted and disallowed actions add to the complexity. This was evident during the design of the software.

The Design Team. The principles of ISO 13407 [34] identify a multidisciplinary team as key. In the early stages of development different stakeholders were consulted as experts on an ad-hoc basis but they were not recruited as part of a project design team. Apart from identifying essential components of the simulation, the design team’s role involved negotiation between what was desirable and what was practical. The appointment of an OTs was important development for the project. The OT was able to interpret user problems in terms of possible design solutions. Furthermore using her expertise she was able to guide the design specification in terms of layout of the VE and positioning of equipment, and to specify the performance data appropriate for the assessment of the stroke patient. The OT was primarily concerned as a patients’ representative in ensuring that their needs were addressed and incorporated into design solutions. How this was done was not her concern but her expertise did contribute by ensuring that solutions were appropriate for the user.

Design Specification. The modular approach to designing the VE meant that adding an extra object or stage was fairly straightforward. A scoring system for the hot drink making task was developed by the OT for use with both real and simulated scenarios. A record of the details of interaction and intervention was requested by the OT for improved analysis of patient activity. This proved to be invaluable in checking actual patient activity against the score-sheet. The register of input sequences recorded by the computer provided a comprehensive record of activity in the VE. A comparison of computer records and the actual events captured by the digital camcorder were used as a basis for identifying and differentiating between user errors and system errors.

The definition of objects for the VE was straightforward based upon the task analysis. The OT requested that rather than using a tap to supply water, a patient on a stroke rehabilitation unit would be expected to use a pre-filled jug. The virtual objects were modelled on their real world counterparts.

The Mixed Reality System. The tangible user interface component of the mixed reality system used real and varied household objects, remotely sensed, as a means to control the input. Unlike mixed reality systems used previously in rehabilitation [55],[56], each object in our project had different physical properties and had different ways of being handled. Existing vision and sensor technologies were combined and adapted to monitor the position and status of real objects in the mixed reality kitchen task.

In the initial version of the MR system detection of metallic and glass objects proved to be unreliable and in subsequent versions brightly coloured objects presenting a surface of a single hue to the camera (where practical) were used. Confidence scores recorded using the amended equipment demonstrated an increase in reliability of object detection. In effect there has been a compromise between the use of toy objects and real kitchen objects (commonly white or steel) which were not acceptable due to their incompatibility with the vision system.

In the study with the VE, errors of dexterity, initiation, sequence omission, selection and problem solving were more common than with the real world task. The tangible user interface removed the dexterity and selection issues by eliminating the need to select small objects or on a touch-screen using a wand. Developing a TUI that encompasses the entire repertoire of possible actions was originally considered but early prototypes showed that errors of object recognition occur when the workspace within the camera's field of vision is populated with several objects. The confusion matrix shows that real objects have hue spectrums that impinge on that of other objects, giving non-zero readings for other objects for which models exist, even when they are absent from the scene.

Practical Issues of Implementing a Mixed Reality System on a Ward. Safety and storage of equipment were brought into question. The computer was stored securely away from the ward and taken to the ward as required. The OT was able to run the software without assistance and save user performance data. Portability, storage and practical use did not therefore pose major logistical or security problems.

Ironically the TUI objects must be kept apart from the real objects they emulate, and limited to a restricted environment such as a treatment or assessment room so that they are not accidentally used for their real purpose. For example the kettle adapted for the mixed reality system must never be plugged into a 240V mains electrical outlet. In this sense the system has introduced new sources of danger to the task whilst attempting to eliminate others.

The MR system comprised additional equipment that required substantial preparation and it would not be practical for a stroke patient to install the equipment before a training session. The current MR system would not be practical as a self directed learning tool without substantial development to make it easier to operate independently.

The requirement to provide unrestricted movement of the tangible objects has drawbacks. Apart from the cost of each object fitted with a radio frequency switch they are open to misuse or could even be mistakenly used as real objects. The sensors and associated electronics must be robust to stand repeated impact from patients using utensils.

During trials with patients an event occurred that could have implications for the design and implementation of physical interfaces for use in the hospital setting. On one occasion, trials of the VE had to be postponed due to an outbreak of diarrhoea and vomiting on the ward. Microbes can be spread by patient to patient contact, by staff or from a contaminated ward environment. Of the latter, keypads and other equipment are implicated as potential hazards [57]. Sanitisation of equipment with a chlorine based disinfectant is recommended and hardware must be able to withstand such treatment.

Although the MR system showed that the design attributes of real objects were conveyed to the patient by observing how patients handled equipment, one feature of the task that is absent is the change in weight of a vessel when liquid is poured into it. This is difficult to achieve with TUI objects unless real liquids or weights are used. This would impact on the design of the TUI which would necessarily need to be more robust to withstand liquids however a development of this sort places the system closer along the MR spectrum towards the 'real environment' so that it reduces the gulf between the simulation and the real world task.

4 Summary

The VE and MR systems presented in this chapter have followed a user-centred design process. We have investigated errors made by stroke survivors in real and virtual environments. Studies with the mixed reality system have enabled us to identify practical issues of using this kind of technology in the hospital setting.

In the early consultation stages, OTs recommended that the task should allow for a "hands-off" approach in which the patient/user is permitted to attempt the task without the sequence being prescribed. Therapists advised that intervention should only be necessary if the patient perseverates, is unable to proceed, or performs a dangerous action.

Barriers to implementation were identified during the consultation phase as cost and evidence of clinical effectiveness. Therapists would not adopt a new strategy without evidence based research to demonstrate that it was effective and an improvement to current practice.

The reduced cost of desktop VR and increased accessibility to VR has improved with the introduction of gaming consoles, thus also clinical effectiveness remains important, the expense of equipment is progressively of reducing concern.

The formation of the multidisciplinary team marked a turning point in development. Previously stakeholders had been involved as consultants in the design process, playing a passive role in that they were invited to contribute ideas but were not involved actively in the design. The formation of a multidisciplinary design team resulted in increased collaboration and better access to expertise in the diverse and specific professions that this project required.

Constructing the tangible user interface from a minimal starting point enabled the hardware to be tested and constructed iteratively, and for errors and problems to be identified quickly before the interface became too complex.

Inserting RF sensors in vessels such as mugs and jars makes them unusable for their real purpose, although adaptations could be made to permit this. Adapting electrical appliances so that they interface with a computer introduces new dangers if the equipment is mistaken for a real appliance. Thus storage of the equipment and isolation from real equipment is of concern.

The apparatus must be robust enough to withstand treatment by patients who may drop or misuse equipment. Furthermore equipment to be used on a hospital ward must be capable of withstanding disinfection.

The following is a summary of the recommendations for developers of MR systems for stroke rehabilitation based upon our findings:

1. Make the positioning of the objects flexible.
2. Make the sequence in which actions take place flexible.
3. Ensure stakeholders are involved in the design process from the earliest stages.
4. Consider the interface in the context of the environment and make sure it is suitably robust.
5. Ensure that equipment that has been adapted (especially electrical equipment) is not accidentally confused with the real counterpart.
6. The nature of everyday tasks means that there are diverse actions. Consider the construction of the tangible user interface as modular and hybrid.
7. Start the tangible user interface design with a small number of objects and increase gradually through an iterative process.
8. The multidisciplinary team is essential to bring an appropriate skill-mix to the project.
9. Due to the different backgrounds of the multidisciplinary team there will be negotiation between what is desirable and what is practical. Ensure that the team agrees with the design specification at an early stage because major changes can be difficult to implement when a product or system is almost completed.

The mixed reality system we developed allowed us to investigate the feasibility of implementing this technology in the hospital setting. Further development work would be required for a fully functioning system that could be used independently by the stroke survivor. The MR system presented here is unique in that it facilitates naturalistic user interaction without the encumbrance of commercial input devices such as data gloves and HMDs. The work presented here has demonstrated that a mixed reality system is acceptable and feasible as a means of enabling the stroke patient to practise an everyday task in a safe, controlled and monitored environment but there are still some practical issues to overcome for this to be implemented as a viable treatment in the hospital setting.

References

1. Thomson, S.: Rehabilitation of Cognitive and Emotional Problems Following a Stroke. In: Fawcus, R. (ed.) Stroke Rehabilitation, A Collaborative Approach, Blackwell Science, Oxford (2000)

2. Davies, R., Lofgren, E., Wallergård, M., Linden, A., Boschian, K., Minor, U., Sonesson, B., Johansson, G.: Three Applications of Virtual Reality for Brain Injury Rehabilitation of Daily Tasks. In: Proceedings of the 4th International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT), Veszprem, Hungary (2002)
3. Hildick-Smith, M.: Medical Aspects of Stroke. In: Fawcus, R. (ed.) Stroke Rehabilitation, A Collaborative Approach, Blackwell Science, Oxford (2000)
4. Thorvaldsen, P., Asplund, K., Kuulasmaa, K.: Stroke Incidence Case Fatality and Mortality in the WHO MONICA Project. Stroke 26, 361–367 (1995)
5. Kwan, J.: Clinical Epidemiology of Stroke. CME Journal of Geriatric Medicine 3(3), 94–98 (2001)
6. Murray, C., Lopez, A.: Alternative Projections of Mortality and Disability by Cause 1990-2020 Global Burden of Disease Study. The Lancet 349, 1498–1504 (1997)
7. Gladman, J., Radford, K., Walker, M.: The Adjective 'Physical' in the Term 'Physical Rehabilitation'. Clinical Rehabilitation 20, 635–636 (2006)
8. Gladman, J., Jones, R., Radford, K., Walker, E., Rothera, I.: Person-centred Dementia Services Are Feasible, But Can They Be Sustained? Age and Ageing 36(2), 171–176 (2007)
9. Trombly, C., Hui-ing, M.: A Synthesis of The Effects Of Occupational Therapy For Persons With Stroke: Part 1 Restoration of Roles Tasks And Activities For Persons With Stroke. American Journal of Occupational Therapy 56, 250–259 (2002)
10. Edmans, J., Champion, A., Hill, L., Ridley, M., Skelley, F., Jackson, T., Neale, M. (eds.): Occupational Therapy and Stroke. Whurr Publishers, London (2001)
11. Lawton, M.P., Brody, E.M.: Assessment of Older People: Self-maintaining and Instrumental Activities of Daily Living. Gerontologist 9, 179–186 (1969)
12. Khin-Heung Chong, D.: Measurement of Instrumental Activities of Daily Living in Stroke. Stroke 26, 1119–1122 (1995)
13. Carr, J., Shepherd, R.: A Motor Learning Model for Stroke Rehabilitation. Physiotherapy 75(7), 372–380 (1989)
14. Trepagnier, C., Sebrechts, M., Finkelmeyer, A., Woodford, J., Stewart Jr., W.: Virtual Social Environment for Preschoolers with Autism: Preliminary data. In: Proceedings of the 6th International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT), Esbjerg, Denmark (2006)
15. Andersson, U., Josefsson, P., Pareto, L.: Challenges in Designing Virtual Environments Training Social Skills for Children With Autism. In: Proceedings of the 6th International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT), Esbjerg, Denmark (2006)
16. Grillon, H., Riquier, F., Herbelin, B., Thalmann, D.: Use of Virtual Reality as Therapeutic Tool for Behavioural Exposure in the Ambit of Social Anxiety Disorder Treatment. In: Proceedings of the 6th International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT), Esbjerg, Denmark (2006)
17. Hoffman, H., Garcia-Palacios, A., Carlin, A., Furness, T., Botella-Arbona, C.: Interfaces That Heal: Coupling Real and Virtual Objects to Treat Spider Phobia. International Journal of Human Computer Interaction 16, 283–300 (2003)
18. Choi, Y., Vincelli, F., Riva, G., Wiederhold, B., Lee, J., Park, K.: Effects of Group Experiential Cognitive Therapy for the Treatment of Panic Disorder With Agoraphobia. Cyberpsychology and Behavior 8, 387–393 (2005)
19. Piron, L., Turolla, A., Agostini, M., Zucconi, C.: Exercises for Paretic Upper Limb after Stroke: A Combined Virtual-Reality and Telemedicine Approach. Journal of Rehabilitation Medicine 41(12), 1016–1020 (2009)

20. Guo, S., Song, Z.: VR-based a Novel Active Rehabilitation System for Upper Limbs. In: International Conference on Mechatronics and Automation: ICMA, vol. 1 & 2, pp. 229–234 (2008)
21. Ma, M., Bechkoum, K.: Serious Games for Movement Therapy After Stroke. In: IEEE International Conference on Systems, Man and Cybernetics, SMC 2008, vol. 1-6, pp. 1871–1876 (2008)
22. Zhang, S., Hu, H., Zhou, H.: An Interactive Internet-Based System for Tracking Upper Limb Motion in Home-Based Rehabilitation. Med. Biol. Eng. Comput., 241–249 (2008)
23. Kizony, R., Weiss, P., Shahar, M., Rand, D.: TheraGame- A Home Based Virtual Reality Rehabilitation System. In: Proceedings of the 6th International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT 2006), Esbjerg, Denmark (2006)
24. Zheng, H., Davies, R., Zhou, H., Hammerton, S., Mawson, S., Ware, P., Black, N., Eccleston, C., Hu, H., Stone, T., Mountain, G., Harris, N.: SMART Project: Application of Emerging Information and Communication Technology to Home-based Rehabilitation for Stroke Patients. In: Proceedings of the 6th International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT), Esbjerg, Denmark (2006)
25. Clark, R., Bryant, A., Pua, Y., McCrory, P., Bennell, K., Hunt, M.: Validity and Reliability of the Nintendo Wii Balance Board for Assessment of Standing Balance. Gait & Posture 31(3), 307–310 (2010)
26. Brosnan, S.: The Potential of Wii-Rehabilitation for Persons Recovering From Acute Stroke. Physical Disabilities 32(1), 1–3 (2009)
27. Rand, D., Kizony, R., Weiss, P.: Virtual Reality Rehabilitation For All: Vivid GX Versus Sony Playstation II EyeToy. In: Proceedings of the 5th International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT), Oxford, UK (2004)
28. Lallart, E., Machefaux, S., Jouvent, R.: Combining Interactive Multimedia and Virtual Reality to Rehabilitate Agency in Schizophrenia. In: Proceedings of the 6th International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT), Esbjerg, Denmark (2006)
29. Zhang, L., Abreu, B., Seale, G., Masel, B., Chrisiansen, C., Ottenbacher, K.: A Virtual Reality Environment for the Evaluation of a Daily Living Skill in Brain Injury Rehabilitation: Reliability and Validity. Archives of Physical Medicine and Rehabilitation 84, 1118–1124 (2003)
30. Christiansen, C., Abreu, B., Ottenbacher, K., Huffman, K., Masel, B., Culpepper, R.: Task Performance in Virtual Environments used for Cognitive Rehabilitation After Traumatic Brain Injury. Archives of Physical Medicine and Rehabilitation 79, 888–892 (1998)
31. Edmans, J., Gladman, J., Hilton, D., Walker, M., Sunderland, A., Cobb, S., Pridmore, T., Thomas, S.: Clinical Evaluation Of A Non-Immersive Virtual Environment In Stroke Rehabilitation. Clinical Rehabilitation 23, 106–116 (2009)
32. Rizzo, A., Buckwalter, J.: Virtual Reality and Cognitive Assessment and Rehabilitation: The State of the Art. In: Riva, G. (ed.) Virtual Reality In Neuro-Psycho-Physiology: Cognitive, Clinical And Methodological Issues In Assessment And Rehabilitation, IOS Press, Amsterdam (1997)
33. Norman, D.: The Psychology of Everyday Things. Basic Books, New York (1988)
34. ISO: ISO13407 Human Centred Design for Interactive Systems. International Standards Organisation, Geneva, Switzerland (1999)
35. Ehn, P.: Work-oriented Design of Computer Artefacts. Lawrence Erlbaum Associates Inc., Hillsdale (1988)
36. Blomberg, A., Henderson, A.: Reflections on Participatory Design. In: Proceedings of CHI 1990: Human Factors in Computer Systems, New York (1990)

37. Kensing, F., Blomberg, J.: Participatory Design: Issues and Concerns. Computer Supported Cooperative Work 7, 167–185 (1998)
38. Cobb, S., Brown, D.: Promotion of Health and Safety at Work Using a Virtual Factory. In: Proceedings of Virtual Reality in Education and Training, VRET (1997)
39. Brown, D., Neale, H., Cobb, S., Reynolds, H.: Development and Evaluation of the Virtual City. International Journal of Virtual Reality 4(1), 28–41 (1999)
40. D'Cruz, M.: Structured Evaluation of Training in Virtual Environments. University of Nottingham: PhD thesis (1999)
41. Starmer, T.: Design and Development of an Alternative Computer Input Device for Children With Special Needs. University of Nottingham, UK. B. Eng. Thesis (2000)
42. Kuniavsky, M.: Observing The User Experience. Morgan Haufmann, San Francisco (2003)
43. Edmans, J., Webster, J.: The Edmans ADL Index: Validity and Reliability. Disability and Rehabilitation 19(11), 465–476 (1997)
44. Lindgaard, G.: Usability Testing and System Evaluation. Chapman and Hall, London (1994)
45. Kirwan, B., Ainsworth, L.: A Guide to Task Analysis. Taylor and Francis, London (1992)
46. Edmans, J., Gladman, J., Cobb, S., Sunderland, A., Pridmore, T., Hilton, D., Walker, M.: Validity of a Virtual Environment for Stroke Rehabilitation. Stroke 37, 2770–2775 (2006)
47. Milgram, P., Kishino, F.: A Taxonomy of Mixed Reality Visual Displays. IEICE Transaction on Information Systems E77-D(12) (1994)
48. Ullmer, B., Ishii, H.: Emerging Frameworks for Tangible User Interfaces. IBM Systems Journal 39(3-4), 915–931 (2000)
49. Preece, J.: Human Computer Interaction. Addison Wesley, Harlow (1994)
50. Harrison, D., Jaques, M.: Experiments in Virtual Reality. Butterworth Heinemann, Oxford (1996)
51. Ghali, A., Cunningham, A., Pridmore, T.: Object and Event Recognition for Stroke Rehabilitation. In: Proceedings of Visual Communication and Image Processing, Lugano, Switzerland (2003)
52. Swain, M., Ballard, D.: Color Indexing. International Journal of Computer Vision 7(1), 11–32 (1991)
53. Pridmore, T., Hilton, D., Green, J., Eastgate, R., Cobb, S.: Mixed Reality Environments in Stroke Rehabilitation: Interfaces Across the Real/ Virtual Divide. In: Proceedings of the 5th International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT), Oxford, UK (2004)
54. Loyd, B., Gressard, C.: Reliability and Factorial Validity of Computer Attitude Scales. Educational and Psychological Measurement 44, 501–505 (1984)
55. Sharlin, E., Itoh, Y., Watson, B., Kitamura, Y., Sutphen, S., Liu, L., Kishino, F.: Spatial Tangible User Interfaces for Cognitive Assessment and Training. In: Proceedings of First Bio-ADIT 2004, Lausanne, Switzerland (2004)
56. Jacoby, S., Josman, N., Jacoby, D., Koike, M., Itoh, Y., Kawai, N., Kitamura, Y., Sharlin, E., Weiss, P.: Tangible User Interfaces: Tools to Examine, Assess and Treat Dynamic Constructional Processes in Children With Developmental Coordination Disorders. In: Proceedings of the 6th International Conference on Disability Virtual Reality and Associated Technologies (ICDVRAT), Esbjerg, Denmark (2006)
57. Rutala, W., White, M., Gergen, M., Weber, D.: Bacterial Contamination of Keyboards: Efficacy and Functional Impact of Disinfectants. Infect. Control Hosp. Epidemiol. 27(4), 372–377 (2006)

Chapter 11

Design and Development of a Virtual-Reality Based System for Improving Vision in Children with Amblyopia

Paula Waddingham, Richard Eastgate, and Sue Cobb

Virtual Reality Applications Research Team (VIRART)
University of Nottingham, UK
paula.waddingham@ccs.nhs.uk,
richard.eastgate@nottingham.ac.uk,
sue.cobb@nottingham.ac.uk

Abstract. Amblyopia, commonly known as 'lazy eye', is traditionally treated in children by wearing an adhesive patch over the non-amblyopic eye for several hours a day, over a period of many months. A novel treatment method, involving interactive game-play and watching a movie clip presented within a virtual television, has been used to offer a specially developed binocular stimulus to the child. This is achieved by using adapted virtual reality (VR). Uniquely the child has both eyes open for the treatment; there is no covering of the non-amblyopic eye, as per traditional treatments. Preliminary studies indicate positive vision improvement and adaptation of this technology offers potential for a wider range of applications in vision assessment and treatment. This chapter describes the nature of amblyopia and conventional treatment, presents a rationale for application of VR technology to provide a novel treatment method, describes design and development of the I-BiT® system for treatment of amblyopia, and summarises treatment case studies to date.

Keywords: virtual reality, binocular treatment of amblyopia, visual gaming.

1 Introduction

This chapter presents a novel treatment for amblyopia (lazy eye) and the development of a virtual reality (VR)-based system to deliver the treatment. Amblyopia is the term used to describe loss of vision which has occurred as a result of an interruption to the normal development of the visual system. Amblyopia is not correctable with glasses alone or surgery, although a refractive error (the need to wear glasses) and a squint (turn in the eye) may co-exist. The treatment of amblyopia is essentially limited to the wearing of an eye patch for prolonged periods of time, up to a total of 200-400 hours [1]. This is very onerous for both the child and parent and, consequently, compliance with treatment can be poor. The use of eye drops in the good eye to blur the vision and encourage use of the amblyopic eye is another option but this method has side

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 229–252.
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effects and issues with compliance as well. Treatment of amblyopia makes up a significant number of patients in a clinician's pediatric case-load. Having another treatment option available, which is fun for children and does not impact negatively on their schooling or social life, is long overdue. With this in mind, a multi-disciplinary research group comprising ophthalmologists, orthoptists and technology development researchers developed an idea which would not involve the use of patching at all – a treatment which would enable both eyes to be open together in which the amblyopic eye received preferential stimulation.

The team considered virtual reality technology as the ideal method for realisation of this idea; as VR is usually applied by presenting two offset views of the same image to the viewer to provide a composite stereo image, it could be adapted to present differing dynamic images to each eye. The requirement was for the image presented to each eye to have some level of commonality to allow the two images to be perceived as a composite picture, but with preferential stimulation of the amblyopic eye offered by providing additional stimuli to the amblyopic eye only. Two modes of treatment were developed: 1) passive watching of a movie clip in which the movie content provided preferential stimulation and the surround of the virtual television was presented to both eyes, 2) interactive game play in which the background content of the game was presented to both eyes and target objects (tokens) were presented to each eye separately. The child used a joystick to control the game and achieved points for collection of the tokens.

The Interactive Binocular Treatment (I-BiT®) system is novel in three ways. Firstly in that it uses VR technology in a way that it was not intended to be used. Rather than attempting to display a true 3D version of an environment by presenting equal but slightly different images to each eye (as they would see in the real world), for the I-BiT® system the technology is intentionally programmed to provide preferential information (in the form of moving images) to one eye. This is done in order to stimulate that eye and encourage it to work where previously it had been underused or 'lazy'. It is however, important to provide appropriate if less detailed information to the other, good eye so that the two eyes are being stimulated at the same time by the differing but related dynamic images. Secondly, treatment of amblyopia with both eyes open and without penalisation of the good eye (either through patching or use of eye drops) is novel. The third way in which the I-BiT® system is novel is that it uses computer games and movie clips to provide a treatment. In this way it is able to motivate the patients (children) to comply with the treatment, in fact there is evidence to suggest that it may be the fact that the children give this treatment their undivided attention that makes it so effective. .

This chapter presents the story of how we started from a basic idea and the work we had to do in order to arrive at a treatment that could significantly improve an amblyopic child's eyesight. The chapter has several sections; sections 2 and 3 provide an overview of the relevant fields by covering amblyopia and eye treatment, VR and display technologies, and a brief overview of application of these technologies in healthcare. Section 4 describes development of the I-BiT® system for use in the treatment of amblyopia. Three development systems are described; the research prototype used for preliminary case studies and clinical evaluation and two product prototypes for treatment delivery. These prototypes are assessed for ergonomic design and usability and suitability for use as a treatment system. Section 5 describes the clinical evaluation trials which were undertaken in using the I-BiT® system for treating children with amblyopia. These produced very encouraging results even in children beyond the age of 7 years (generally considered to be the age beyond which treatment for amblyopia is thought to be less successful). Finally there is a discussion section which summarises the outcomes of this research and provides recommendations for the future directions that this work should take.

2 Amblyopia and Eye Treatment

2.1 Diagnosis of Amblyopia

Amblyopia is the Greek word for 'dullness of vision' and is the term used to describe a loss of vision which has occurred as the result of a significant interruption of normal visual development. The developing visual system relies on good quality visual images and amblyopia can develop when the image coming into one or both eyes is either blurred or obscured [2]. Therefore amblyopia can be defined as a disorder in which a dysfunction of the processing of visual information exists and this 'dysfunction' results in a deficit of vision [3]. The site of the amblyopia deficit has been debated for over half a century. There has been evidence provided by neurophysiologists to support theories that the deficit is either cortical or retinal [4]. But further animal studies seem to suggest that amblyopia results in anatomical changes within the primary visual cortex (VI) [5].

2.2 Classification of Amblyopia

Amblyopia never occurs in isolation [3] and is always the result of a defect [6] such as strabismus (squint), anisometropia, or media opacity, which predisposes the eye or eyes to amblyopia. Therefore, amblyopia may be either unilateral or bilateral (affecting one or two eyes respectively), although it typically affects one eye only and is present with varying levels of severity [7]. The prevalence of amblyopia as quoted in the literature can vary from 0.2% to 5.3%, this is due to the population selection and the diagnostic criteria used to define amblyopia.

The prevalence of amblyopia is higher in those children who have poor access to medical care [8], presumably due to under-treated underlying eye disease. As a conservative estimate there are ten million children under the age of 8 years who have amblyopia worldwide [9]. If not treated, amblyopia is taken into adulthood. Indeed, it has been estimated that, during the first 45 years of life, amblyopia is responsible for loss of vision in more people than all other ocular disease and trauma combined, and in those aged 20 years and under, the incidence of amblyopia is 10 times more frequent than all other diseases and trauma [10].

It has been estimated that around 90% of patients' visits to children's eye services involve treatment for amblyopia [11], due to the large numbers of children with visual defects who have squints and/or anisometropia. Therefore, amblyopia is an entity frequently encountered by clinicians in the clinic.

2.3 Treatment of Amblyopia

The most common form of treatment for amblyopia involves covering the fellow eye with a patch for a prescribed period of time [12], for weeks to many months [13]. This method of treatment has been advocated for over 200 years (Garzia [14] reports on the first published account of occlusion in 1722 by Saint-Yves). Occlusive patches are inexpensive, readily available and quick and easy to apply [15]. This method is effective in about 30-92% of cases and in varying degree [16]. However, occlusion does not address the problem of binocular function since, whilst the patch is being worn, no fusion of the peripheral fields can be experienced. Many children feel they are stigmatised by the wearing of a patch [17] and because of this many children refuse to wear their patch for the prescribed time.

Other treatment methods include pharmacological penalisation of the non-amblyopic eye which some clinicians only used infrequently such as when conventional occlusion with a patch is not tolerated [18]. The use of chemical occlusion with atropine eye drops has been reported to have good results [19] and tolerability compared with conventional patching, but compliance is still an issue as the parent has to instil the drops several times per week. In a meta-analysis review of atropine occlusion it has been recommended that atropine can be used as a first line treatment for amblyopia [19].

If amblyopia is untreated, or treatment is unsuccessful in childhood either due to failure or non-compliance, an individual will take their amblyopia into adulthood [20]. Amblyopia which is taken into adulthood can result in exclusion from various professions [21]. These professions are those mainly involved with driving, navigating or piloting some form of moving vehicle, or the armed forces [22]. Other occupations such as ophthalmic surgery are excluded to individuals with amblyopia as there is a widespread (but still unsubstantiated) belief that having good binocular vision is important [23].

The effectiveness of early versus late or later treatment in children with amblyopia is still being debated. A recent study in which data from 36 published papers was evaluated confirmed that uncertainties remain about the age which treatment should be given for optimal outcome in vision [24].

3 Virtual Reality and Display Technologies

3.1 Virtual Reality (VR)

Virtual Reality systems comprise computer generated virtual environments, which may be representations of real world environments, simulated or abstract environments [25].

The term virtual reality (VR) is extremely broad and difficult to define as there are many types of VR system and these vary depending upon the hardware used [26]. The hardware comprises not only the computer but also the devices needed to present a visual display to the user and for the user to interact with the virtual environment software. The VR system then, consists of the person using the system, the computer, the virtual environment, the input and the output devices. The latter are sometimes termed peripherals. The virtual environment is the software component of the system and presents a 3-dimensional computer-developed ‘environment’ comprising scenery and objects that may be explored and interacted with. Computer code is written to assign behaviour and interactivity to objects in the virtual environment, and corresponding changes to the virtual environment that result when a user triggers these interactive behaviours. This dynamic interactive ability is one of the features which defines a VR system [27].

VR is computer-generated technology which allows the user to interact with data that is able to simulate the appearance of a three-dimensional environment, although it is not necessary for the display equipment to be capable of rendering in 3-D. The environment can be used to replicate real world settings and objects or to visualise imaginary or abstract concepts. The user is able to interact and navigate as if they are moving around 'within' the virtual environment. Immersive experience of virtual environments (in which the user is 'enveloped' in some way by the visual display, either by wearing a head-mounted display or standing inside a virtual CAVE™) is considered by some to be a true VR experience.

The concept of VR has been around since the early 1960's [28]. However, it has only been since 1990s that VR technology has been affordable and more widely available to research groups, industry and entertainment.

For the I-BiT™ system, the appropriate VR formats and options are described below.

Desktop display option. A desktop computer alone does not provide a true 3D experience or allow each eye to receive a separate image. The computer needs to be attached to a stereo display such as a head mounted display (HMD) to provide a 3D effect and enable a different image to be presented to each eye.

Head mounted display (HMD). An HMD is possibly the most commonly seen method to provide a VR display and in addition can provide auditory simulation. This is a heavy headset to wear, with a weight of 1kg and is more suited to an adult population rather than children**.**

I-BiT® trials were conducted using the lighter Cy-Visor DH-4400 HMD (see Fig. 1) which for our purposes was worn whilst the patient was seated. The headset weighs only 160g and is therefore more suitable for pediatric age groups, even though it was designed for adult use.

Fig. 1. Cy-Visor DH-4400 a binocular headset worn by a 9-year old child (reproduced with parental permission)

Projection systems. Using multiple projectors, images can be projected onto two or more walls of a room or cubicle in stereo [26]. The most sophisticated of these projection systems is the six wall CAVE™. The CAVE™ system consists of a room which has graphics projected from behind each of the six walls (four vertical walls plus the floor and ceiling). This system was invented at the Electronic Visualization Laboratory (EVL), Chicago, Illinois, USA in 1992. The projected graphics are in stereo and fill the users' field of vision (Royal Institute of Technology, Sweden, undated). Stereoscopic glasses are usually worn within the CAVE™. These glasses simulate stereoscopic vision, which is based on the disparity between the viewing perspectives of each eye. This process (stereopsis) gives depth perception and therefore enhances the 3-dimensional effect seen through the glasses. One of the users will wear glasses that are fitted with a tracking device that passes information to the computer to determine alterations in the projected images in accordance with the participant's movements. This tracking will typically be achieved using electro-magnetic or infra-red sensors. Using this method the tracked user is able to correctly perceive virtual objects positioned within the CAVE™ whilst moving around them. Other participants wear glasses which do not have a tracking device but by standing near to the tracked user they may also experience something approximating to realistic stereopsis. As processing power and display frame rates increase it is now becoming possible to track more than one user in a CAVE and provide them each with a realistic stereo view. Simpler projection systems use fewer walls, the simplest being a single wall system. Even a single wall system can provide a very immersive experience if the screen is large and/or curved to wrap around the user, and the rest of the room is dark.

BOOM system. The Binocular Omni Orientational Monitors (BOOM) system consists of a head coupled stereoscopic display, similar to an HMD. Instead of being worn on the head the optical system and screen are all contained within a housing which is attached to a multi-link arm (or boom) which is fixed at the other end to the floor or other suitable surface. The virtual environment is seen via two lenses in the housing. Head tracking is also provided by sensors which are attached to the links of the arm holding the housing [29].

Other VR displays. The most common VR displays are described above, however, there are other displays in use including the Cyberscope which uses mirrors and is described later in section 4 of this chapter. Of the displays not yet mentioned the most notable are the stereo desktop systems which use either stereoscopic glasses (as used with projection systems) or lenticular lenses mounted on the display itself, which allow the user to see a 3D image without using any eye-wear. The disadvantage of these eye-wear free systems is that the stereo image is not as deep or convincing and it can only be seen correctly from certain positions or 'sweet-spots'. Another display system worthy of mention is the virtual retinal display (VRD) which uses low power lasers or LEDs to draw images directly onto the retinas of each eye in a raster scan formation. Eye-tracking technology can be used to locate the users' eyes in order to correctly align the retinal displays. The advantages are that this method can produce very high resolutions and increased numbers of colours whilst consuming very low power. It also has the potential to provide the effect of a large screen stereo display from a very small device. At the time of writing this there are no available consumer devices using this technology.

3.2 VR in Healthcare

VR has been used in many applications in healthcare. These applications include training and teaching [30, 31], VR assisted surgery [32], telemedicine and rehabilitation [33]. A recent examination of literature describing use of VR for virtual rehabilitation indicates that demonstration applications developed in 1990s showing feasibility of the technology are now being evaluated for clinical effectiveness with promising results in a number of areas including stroke rehabilitation and assessment [34]. Use of VR technology for assessment and treatment of patient conditions is increasing as is application of the technology to offer simulation training to medical professionals.

The use of simulators in training can address two of the priority areas highlighted by Rogers et al. [35] for intervention strategies to reduce surgical error, and improving surgeons' ability to perform operations in which they have limited experience. VR simulation is considered to offer further advantages to traditional training methods by providing an interactive, 3D way of learning which is not afforded by books and a relatively inexpensive and more accessible alternative to training using cadavers and animal tissue [36].

In minimally invasive surgery, surgeons are required to develop 3D mental models and engage in problem solving based on these whilst viewing 2D images on TV monitors – thus requiring perceptual motor skills very different to those in open surgery [37]. The use of simulators can help to improve psychomotor skills, hand-eye coordination, improve dexterity and ambidexterity, spatial accuracy, navigation and 3D perception [37, 38]. Simulators can be used to teach specific skills required for specific surgeries and allow evaluation of these skills through objective measures (e.g. task completion times, measuring unnecessary hesitation at different steps in the procedures, and accuracy (e.g. collision errors with anatomical structures which are not supposed to be touched, incorrect sequence of steps, force applied to structures – some of these could be tracked and logged directly by the simulator). These objective measures can be complemented by qualitative measures of non-technical skills [39, 40].

4 Development of the I-BiT® System for Treatment of Amblyopia

It was considered that VR technology could be used for I-BiT® presentation because it offers;

- Control over the content, resolution and contrast of images presented to each eye
- Control over the visual angle to compensate for any deviation of the eyes and IPD.

Whilst a VR system commonly provides a stereo image, it can be adapted to produce non-stereo dynamic images presented to each eye. It was this adaptable aspect of VR that was considered important for amblyopia treatment. The basis of the I-BiT® system is that it is possible to present an image separately to each eye. Not for the purpose of providing a stereo image, but as a means of presenting different visual content to each eye, in which at least one of the images includes dynamic stimuli. Fig. 2 shows an illustration of a fish tank constructed by the authors in an otherwise empty Superscape® 3D environment.

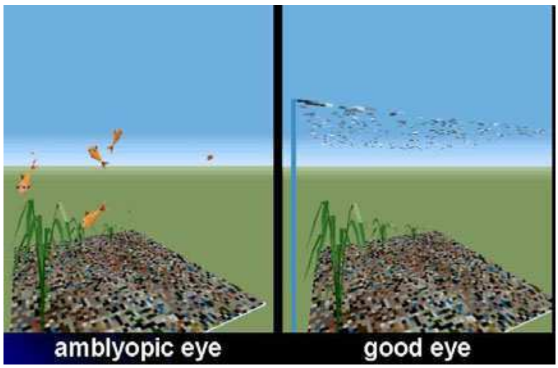

Fig. 2. Illustration of the concept of the I-BiT™ system in which differing but related images are presented to each eye

The basic principle is that the amblyopic or lazy eye is shown the interesting part of the visual scene (in this case, the fish), whilst the good eye is shown the less interesting part (the background). Due to the principles of simultaneous perception, when viewed through a stereo viewer the patient should see the fish in the tank if they are using both eyes at the same time. Therefore, the amblyopic eye receives preferential visual information from the fish moving in the tank, as this is the interesting part of the visual scene. This is to avoid the image seen by the amblyopic eye being 'switched off' or suppressed, by the brain. Suppression would prevent both eyes being used together and the basis of the I-BiT® treatment is that the patient should use both eyes together. Therefore, it is essential that the construction of the images presented to each eye is such that suppression is kept to a minimum. To make sure that the patient is able to fuse the image (i.e. line the two images up correctly) there should be a significant number of elements (e.g. the base of the tank and the plants) that are common to both images. The presentation of two different but related images is achieved by constructing two 'parallel' models of the same visual environment, with each version having significant differences between them (see Fig. 3). A viewpoint for each eye is then set up to view one of the versions, and the viewpoints are linked such that they ensure that they are viewing their respective version of the environment from the same height and angle. To preserve the 3D perception of the images as viewed by the patient an appropriate lateral distance is maintained between the positions of the two viewpoints relative to their version of the environment [41].

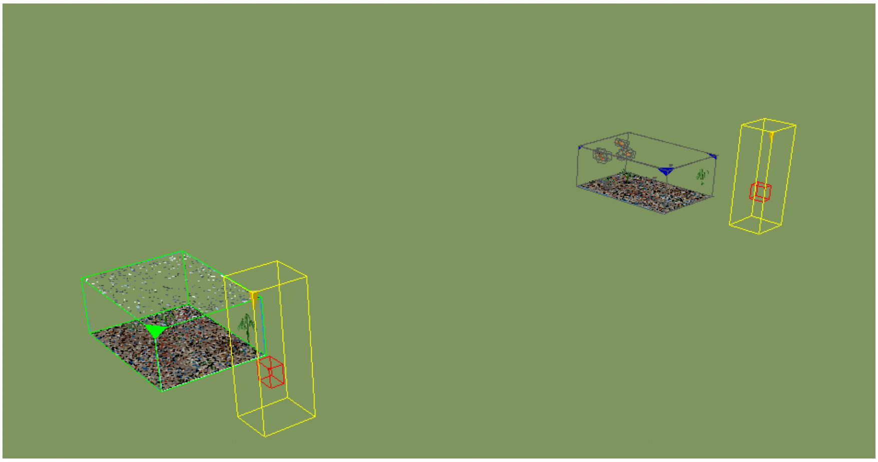

Fig. 3. Two different versions of the same fish tank environment are being viewed from two viewpoints (the red boxes within the yellow rectangles)

Having established that VR could provide separate stimulation to each eye we then had to decide how to implement this treatment using VR. The VR activity would need to keep a patient motivated to look at the stereo display for a long enough time for the treatment to have a positive effect. At this time we did not know how long this would be but given that patching takes about 200-400 hours to improve the vision in the amblyopic eye [1] we expected that our patients might need to be using our treatment for a similar time period. Knowing that children (our expected user population) love to play computer games and watching television we set about devising games and a virtual television for our system.

4.1 The I-BiT® System Multi-disciplinary Development Team

An inherent aspect of the I-BiT® research project was the multi-disciplinary development team comprising a variety of stakeholders and clinical users. The project required different strands of research including: technology design and development, computer programming, human factors (ergonomics) assessment and single case experimental design studies. This necessarily involved input from different members of the project team. Clinicians (orthoptists and ophthalmologists) were engaged directly in the design process as equal partners with the designers which enabled faster iterative development of the software. Fig. 4 shows a simplified representation of the contributions of different team members to the project.

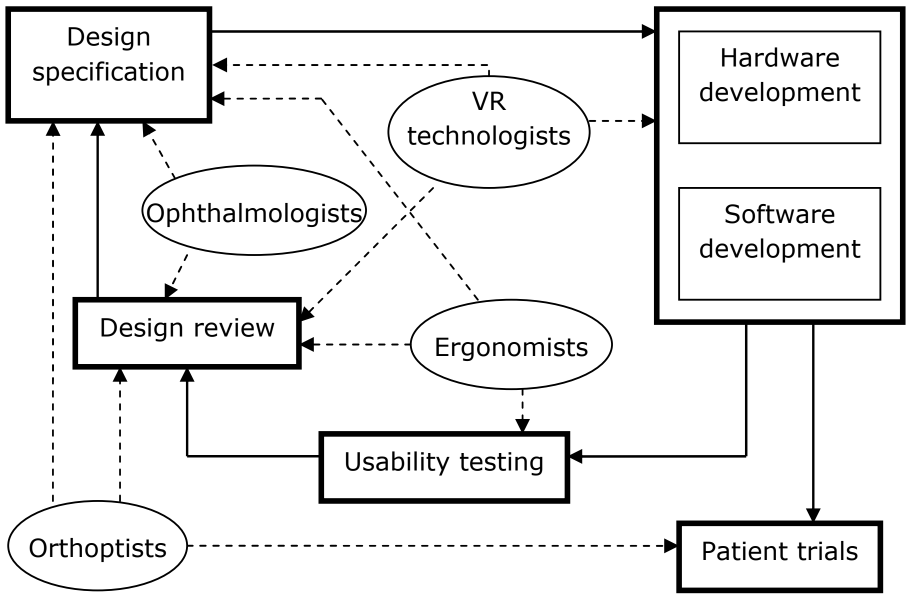

Fig. 4. The I-BiT® System development structure showing integration of expertise from different members of the multi-disciplinary research team

An iterative design process was applied in which a design specification fed into design and development of the hardware and software components of the system. Usability studies were conducted to assess aspects of system performance and interface design. Outcomes from these studies informed system review and the generation of modifications required, leading to new design specifications. The research system prototypes were then used for patient trial studies. VR technologists built the research prototype and the computer games and interface software in accordance with requirements and specifications from other members of the team. The clinicians defined general requirements for the presentation stimuli to each eye and provided design input to the clinician interface. They also made suggestions as to how the games should be constructed. The clinical trial studies were conducted by the research orthoptist (lead author of this chapter PW) within the ophthalmology department, based at the Nottingham University Hospital. Ergonomists provided input to design and interface specifications and conducted usability studies. All project members reviewed prototype designs.

4.2 I-BiT® Interactive Treatment Mode: Game Design

The unique visual configuration for the stereo displays of the I-BiT® system meant that off-the-shelf games could not be utilised and software had to be specifically designed for both compatibility with the system and the specific requirements of the game design.

Requirements for the games were:

- An image to be presented to each eye simultaneously with both eyes receiving separate/different stimuli of interest.
- A significant percentage of common features to allow images to be correctly fused.
- To provide adequate entertainment for a child for approximately 10 minutes.
- To be played on numerous occasions in the same format.

A racing game was designed so that the two viewpoints were largely different but complementary, with each eye seeing images that constructed the full, final, image. The three panels in Fig. 5 show the racing game image as presented to each eye (the left and centre panels) and the composite image when both eyes are being used (the panel to the right). In order to get the child to focus on the game, each eye is presented with half a target and alternating white lines in the centre of the road. This means that one eye sees the nearest white line; the other eye sees the next white line, etc. In order to facilitate fusion some elements, such as the ‘checkpoint’ banner posts, were displayed to both eyes. To play the game, the child is told to focus on the target and to try and drive the car while collecting the icons within the game.

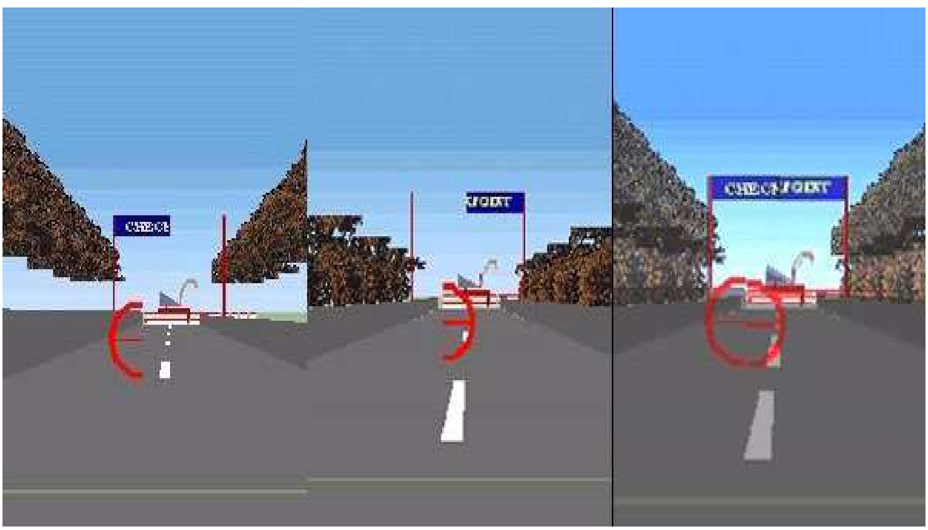

Fig. 5. The driving game. Images seen by right and left eyes are in first two panels. The third panel shows the combined images, which should be seen by the patient if both eyes are being used together during the binocular treatment.

4.3 I-BiT® Passive Treatment Mode: Using Movie Clips

It was considered that the interactive game may be difficult for very young children to do and also may not support maintained interest for the duration of a treatment session. A passive treatment mode was also developed which allowed the patient to watch a movie clip for the remaining duration of a treatment session. It should be noted that, in this context, passive refers to the control activity of the patient – they merely watch the movie but are actively involved in the interactive game play. In both treatment modes the amblyopic eye is actively stimulated in preference to the good eye.

Movie clips were accessible via a menu system selected on the clinician screen and watched on a virtual TV within the virtual environment. The practitioner could select which eye was presented with the video content and which was presented with the blank TV screen. A selection of movie clips, selected to appeal to a range of ages and different gender, were loaded onto the computer, from which the child could choose one. Movies were divided into twenty minute sections.

The design criterion, for the movie clips were:

- Stimuli of interest to be presented to the amblyopic eye
- Peripheral stimulation to the non-amblyopic eye
- An image presented to each eye simultaneously
- A method to allow for the clinician to check if the amblyopic eye is being used.

4.4 Development of the I-BiT® System Research Prototype

Having decided what we wanted the I-BiT® system to do we set about developing a research prototype. The first research prototype (see Fig. 6) of the I-BiT® system used a device called a Cyberscope to provide the separate displays to each of the patient's eyes. This device is mounted onto the front of a monitor and uses four mirrors, two per eye (see cutaway diagram in Fig. 7), to split the display into two halves, the left half being presented to the left eye and the right half being presented to the right eye.

Fig. 6. The I-BiT® system research prototype used by a 6-year old child (reproduced with parental permission)

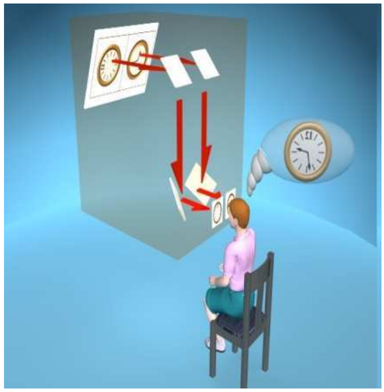

Fig. 7. What's in the box? – illustration cutaway of The I-BiT® system research prototype

A display housing was constructed using expertise within the engineering faculty at the University of Nottingham. This prototype was intended to demonstrate feasibility and proof of concept and was constructed using technology and equipment available. The computer used had two graphics cards installed, one driving the 15" patient monitor inside the wooden housing and another driving a 17" monitor for use by the clinician when controlling the setup of the treatment software. The wooden housing was built so that when mounted on a standard office desk it could be used comfortably by children between the ages of 3 - 8 sat on an appropriate height adjustable chair (shown in Fig. 6).

The software incorporated the control panel (displayed on the clinician's 17" screen), and the games or a video playing virtual TV (displayed via the Cyberscope to the patient). The control panel allowed the clinician to perform a wide range of operations controlling the way that the patient's display was set up. These included selecting the game to be played (or the movie player), selecting which eye is to be treated (which is the amblyopic eye), and controlling the volume level of the accompanying sound for the game or video. They could also monitor the patient's progress through the treatment via a window showing what the patient was seeing.

4.5 Usability Evaluation of the I-BiT® System Research Prototype

Usability observation studies showed that participants were distracted by the clinician screen whilst they should have been immersed in watching the virtual environment through the display unit. The younger children, aged 3-4 years of age, were more easily distracted by the experimenter clicking on the mouse.

Clinician and parental feedback highlighted a number of issues for improvement. These included participant comfort; specifically, the lack of a footrest under the desk to support their feet (this may also reduce fidget movements) and also a chin or headrest to support the head in the correct position in front of the viewing holes. The use of movie cartoons was an engaging stimulus and many of the participants exhibited great pleasure in watching them. The pilot trials with children aged 5-7 showed that the system is easy to use and very well liked by children. However, considerably more activities are required within the system to maintain children's interest over numerous repeated sessions.

It was evident that further work was required to develop both the hardware and software elements of the I-BiT® system before it could be considered suitable for commercial development. The following section describes initial prototyping for a housing to support delivery of the patient and clinician display screens.

4.6 Development of Prototype #1

One of the objectives for a commercially acceptable product was that the elements of the I-BiT® system (patient display, clinician screen and control devices) should be encompassed within a single unit. Prototype #1 built upon the box housing used for the patient display in the research prototype but placed the clinician monitor on the side of the viewer box (see Fig. 8). There were several advantages to this layout; the patient and clinician displays were housed within a single unit, thus the overall system was smaller and neater; the clinician was positioned at the side of the patient rather than next to them. This provided the clinician with a clearer view of the patient so that they could check that they were looking into the viewer box correctly, it also meant that the patient could not see the clinician's screen and so they would not be distracted during treatment. An adjustable chin and forehead rest was added to allow patients to use the system for extended time periods with greater comfort.

Fig. 8. I-BiT® system prototype #1

One of the outcomes from the clinical case studies (described in section 5) was that I-BiT® treatment may not be restricted to children under 8 years old, but that it may also be suitable for older children and possibly adults. A commercial product was therefore required to be suitable for use by all ages. The viewer box developed for prototype #1 was mounted onto a height adjustable table and had wheels for portability.

4.7 Usability Evaluation of I-BiT® Prototype #1

The height adjustable table allowed presentation of the viewer at the correct height for adults and children but created different postural concerns as detailed below.

Adults were not able to position the seat close enough to the table to allow them make use of the chair back support. This was because they needed to place their feet on either side of the height adjustment column. Trying to get close enough to the viewer also meant that the table was sometimes pressed against the upper part of the chest (see Fig. 9).

Fig. 9. Incorrect back support for adults due to the central support column

Children needed to perch on the edge of the seat to get close enough to the viewer and the table was sometimes pressed against the abdomen. Also there was not enough room for them to hold the interaction controller on their laps as the adults could, and so they had to place the controller on the table and then reach up to hold and control it (see Fig. 10).

Fig. 10. A 4-year old child had to sit close to the edge of the chair to reach the chin and forehead rest and joystick (picture reproduced with parental permission)

Having the clinician's monitor fixed to the height adjustable table also caused some problems for clinicians. When the system was set at the lowest height for children, they would have to crouch over the keyboard to control the interface (see Fig. 11).

Fig. 11. Demonstrating that when the system was positioned at the correct height for the child the clinician would have to crouch over the keyboard

Feedback from the clinicians was generally positive, as they felt the system now looked liked an impressive piece of ophthalmic equipment. However, they raised the issue of discomfort for clinicians and also concerns that children may not be able to sit at the viewer for sufficient viewing time (30 minutes). Those clinicians who gave feedback on the equipment also considered it very important for the system to be more compact and portable as the adjustable table did not fit through standard doorways. To make the system more stable so that it could not be knocked over extra weight was added to the base. However, this made the equipment too heavy to be easily moved to and from clinic rooms as required. Further, the illustrated adjustable table (Fig. 8) was too large to go through standard doorways. To reduce the size of the table, the keyboard could be eliminated completely and be replaced by a touch screen. However, a touch screen is significantly more expensive than a keyboard and mouse and would have required some changes to the software.

Usability issues identified

- Both children and adults were not seated in a neutral position which made sitting for long periods uncomfortable. This could be remedied by having the viewer closer to the patient.
- The chin rest was difficult to adjust to the correct position and the forehead rest was incorrectly positioned relative to the chin rest.
- The table protruded too far out towards the patient making it difficult for them to adopt a comfortable position whilst using the system. This would have presented even greater problems for wheelchair users.
- There was nowhere to rest the joystick on the table.

Suggested modifications

- Attach a chin rest to the viewer box instead of the table.
- Rearrange the configuration of the wheels to enable the chair to get closer.
- Attach a flip-out footrest to the central support.
- The joystick could be replaced with a game-pad, preferably a simplified one with less buttons to use (but note that a wireless control would not be an option in a hospital, due to its possible interference with other medical equipment).
- Due to the constraints of clinical rooms it would be useful to offer the option of fitting the clinician's monitor to the right or left of the housing.

4.8 Development of I-BiT® Prototype #2

The need for comfortable presentation of the viewer box for a range of users from small children to adults led to a completely different design in prototype #2. Instead of mounting the viewer box on a horizontal table surface, which required patients to lean forward to look into the viewer, it was now mounted on an articulated arm that could be moved to different angles of presentation to suit the patient (see Fig. 12).

Fig. 12. Showing the side view of Prototype #2 with an adjustable viewing display on articulated specialist arm

The remote controlled articulated arm enabled the system to be used for participants of varying heights, from children (Fig. 13) to adults (Fig. 14). As this viewer could extend a large distance from the stand the problems caused by the central support with regard to sitting comfortably at the system evident in prototype #1 were eliminated.

Fig. 13. 3-year old child using prototype #2 (reproduced with parental permission)

Fig. 14. adult using prototype #2

This allowed patients to sit comfortably in a chair with appropriate back support and the clinician moved the articulated arm to present the viewer box to them at the correct angle. This also eliminated the need for a head or chin rest to support the patient's head. It also meant that the patient should be able to sit for the specified treatment time of 30 minutes without becoming uncomfortable and restless.

As the clinician's monitor screen was not fixed to the height of the patient's viewer box it was also more comfortable for them to access the clinician screen (Fig. 15). In addition the width of the trolley, to which the system was attached, had been reduced to enable it to be moved through a standard doorway.

Fig. 15. Clinician using screen at a comfortable height

4.9 Usability Evaluation of I-BiT® Prototype #2

Usability evaluation of prototype #2 indicated that many of the problems with prototype #1 had been satisfactorily resolved. However, some new problems were presented with prototype #2. These are summarised in Table 1.

Table 1. Summary of usability benefits and problems in I-BiT® prototype #2

Feature	Benefits	Problems
Viewer box mounted on an articulated arm	The arm can be moved with a remote control. System now suitable for all height of patients. Also a better position for the clinician.	The first part of the procedure involves manually unlocking the arm with a specific tool.
System very solid and stable for use in the clinic	Unlikely to be pulled over by patients.	As with prototype #1, this is very heavy for one person to move.
Reduction in width of the table.	Easier to move around from room to room.	The clinician is now based at the other end of the system from the patient. Therefore, it is now difficult to observe the patient and ensure they are looking correctly down into the system. No assistance can be given to the child to help with driving the game.

It is apparent from reviewing these three prototypes that solving one usability problem often results in the creation of new usability issues and that it may be necessary to adopt some compromises in order to arrive at an appropriate solution. For our next design phase we will define a minimum specification that the system must conform to with an additional list of desirable attributes that we would like to see incorporated.

5 Clinical Evaluation Trials

Clinical case study trials were conducted to assess suitability of the I-BiT® system as a viable treatment of amblyopia. These studies examined different aspects of system design and use and were conducted at two different sites by two clinical research teams; the orthoptic unit at Queens Medical Centre, Nottingham and the orthoptic unit at Gartnaval Hospital, Glasgow.

These studies aimed to address the following research questions:

- Is the I-BiT® system suitable for younger children (i.e. those aged 3-7)?
- How effective is the I-BiT® system as a treatment for amblyopia?

There were differences in the study design for the treatment studies conducted in Glasgow and Nottingham relating to patient selection, I-BiT® system configuration and data collection [42, 43]. The Glasgow study had children who had previously received treatment for their lazy eye, but which had failed to improve their vision (either due to patching failure or non-compliance). The I-BiT® system configuration they used was a standard PC with the Cy-Visor Headset viewer (shown in Fig. 1) The Nottingham study recruited children who had not previously had treatment to their eyes, other than the wearing of corrective glasses. The I-BiT® system configuration used at Nottingham was the Cyberscope Desk viewer (shown in Fig. 6) with a laptop.

5.1 Study Results

The first pilot study, carried out in Nottingham [44, 45, 46] conducted to demonstrate proof of concept used the Cyberscope (the research prototype). This study yielded extremely positive results showing exceptional improvement in vision for children with very dense amblyopia. This surprising result demonstrated that children with very poor vision could see, and respond to, the visual display with their amblyopic eye. Moreover, the significant improvement in vision over a relatively short period of time (6 weeks, with an average treatment time of less than 3 hours) compared to traditional occlusion therapy (several months), suggests that the neurology of amblyopia is not time-dependent. A follow-on study [43] provided further indication of this as dramatic improvement in vision was observed after only two sessions (one hour of total treatment). However, although vision improved in 17/19 patients, the degree of improvement was variable, suggesting that children respond differently to the treatment as in traditional patching therapy. There was no pattern of response to the different types of amblyopia.

The Glasgow studies [42] were all conducted using the Cy-Visor headset. A pilot case study carried out in Nottingham verified acceptance and reliability of the Cy-Visor headset as an alternative display, despite the need for a reclined patient posture and adult supervision required to hold the headset in place The Glasgow treatment study corroborated the findings of the Nottingham studies but had a larger sample of occlusion treatment failures and/or refusers. Statistical analysis of change in visual acuity (VA), tracked over time, verified the rapid effectiveness of I-BiT® treatment, in that the effect occurred within two hours of total treatment time or less.

Despite differences between these studies having used different display devices, in studies applied by different research teams at different clinic locations, the overall pattern of results are similar. Some of these patients had previously failed to improve with occlusion treatment, yet displayed improvement in vision using the I-BiT® system.

5.2 Study Outcomes

With regard to the research questions, these results indicate:

- The I-BiT® system can be used by younger children although they have difficulties in playing the interactive computer games.
- The existing headset is unsuitable for children, even the older ones in this study.

- The I-BiT® system appears to be a very effective treatment for amblyopia, producing rapid improvement in VA after only a few hours of treatment.
- Vision has improved dramatically in some cases although there is variability in measures. The system needs to be adapted to better suit the needs and interests of the younger age group.

6 Discussion

The results of the clinical case studies demonstrate improvement in vision even amongst those who may be considered to be ‘difficult’ cases (i.e. they had very poor vision at the start of the trial and they were above the ideal age for successful treatment of amblyopia). Moreover, the rapid improvement in vision suggests that something unique to the I-BiT® system triggers response from the amblyopic eye that is not achievable using traditional treatment methods. We consider that this is due to the affordances of VR that have been adapted for presentation in the I-BiT® system; individual presentation of different, but related, dynamic images to each eye.

The innovation of I-BiT® treatment is that the game is played with both eyes open and the amblyopic eye is given additional visual stimuli to encourage the eye to be used and hence the vision to improve. Traditional amblyopia treatment provides uniocular stimulation only (i.e. stimulating the amblyopic eye on its own, whilst occluding the other eye). Binocular treatment in which both eyes are open and attending to the same task activity (achieved only through assimilation of the combined images presented to each eye) is a world first and this innovative technology has an international patent.

The main outcomes of this research are as follows:

- We have developed a software demonstrator that shows how VR technology can be used to treat lazy eye conditions. This system will be the first of its kind that offers diagnosis and treatment in which the two eyes work together.
- This varies from conventional uses of VR in that the views given to the patient via the stereo display are not a true stereo image of a Virtual Environment (VE). Instead each eye is given an image of a different environment with some common features. It is proposed that, by controlling the content of the two VEs, a lazy eye can be encouraged to work without masking the good eye. The view of the environment(s) given to one of the eyes can be from a different angle to that provided to the other eye.
- We have adapted existing VR software (with our own programming code) to allow us to manipulate the two virtual environments independently (one for each eye) in real time and in 3D (this would not be possible with other graphics technology). We have also developed a software interface that enables the practitioner and/or patient to control the amount of deviation in viewing angle between the two eyes.
- We believe that this system could be further developed to allow us to explore other areas of Ophthalmology in more detail than has been done before, to the benefit of patients everywhere. We view this as an important first step into an important new field.

This chapter looked at the assessment of the I-BiT® technology for amblyopia treatment and included aspects of design, usability, comfort and acceptance. These were assessed using various ergonomic methodologies. A pre-trial usability study was carried out using the research prototype and this was useful in obtaining information which was then used in the clinical studies.

The design specification of the prototype #1 was described along with the changes which were incorporated into its design from feedback of the research prototype. Prototype #1 was then assessed by the experts in the Human Factors Research Group at the University of Nottingham. Further suggestions were made and prototype #2 was then built. This incorporated some of the suggestions made from the assessment of prototype #1.

If the system is to be used by a larger cohort of patients of differing ages, then a greater variety of games would have to be provided to maintain interest. Possibly improved graphics would be necessary, similar to those available on home games consoles. We have now obtained funding to further develop the system to provide a version which is commercially viable and suitable for use within a clinical environment. Further clinical trials will be conducted to assess usability and treatment effectiveness.

Acknowledgements

The authors extend their gratitude to the other members of the I-BiT® research team. From VIRART, University of Nottingham UK: Amanda Moody and Gareth Griffiths. From the University Hospital Trust, Queens Campus, Nottingham UK: Stephen Haworth, Isabel Ash, Richard Gregson, Ian Comaish, Tom Butler, and Sarah Brown. We also thank collaborators from the Ophthalmology Department at Gartnaval Hospital, Glasgow, UK: Gordon Dutton, Marie Cleary and Alison Buchanan for conducting independent review of the I-BiT® system. Original funding was awarded by the William and Mabel Morris Charitable Trust and Sandra Charitable Trust. System. Funding for development and testing of the system prototypes was awarded by Carleton Ltd, UK. VIRART is a sub-group of the Human Factors Research Group at the University of Nottingham and is part of the INTUITION European Network of Excellence in Virtual Reality and the EuroVR Association.

References

1. Cleary, M.: Efficacy of occlusion for strabismic amblyopia: can an optimal duration be identified? Br. J. Ophthal. 84, 572–578 (2000)
2. Powell, C., Porooshani, H., Bohorquez, M.C., Hatt, S.: Screening for amblyopia in children. Cochrane Database of Systematic Reviews (3), 1–11 (2005)
3. Holmes, J.M., Clarke, M.P.: Amblyopia. The Lancet (367), 1343–1351 (2006)
4. Hess, R.F.: Amblyopia: site unseen. Clinical & Experimental Optometry 84(6), 321–336 (2001)
5. Mitchell, D.E., Sengpiel, F.: Neural mechanisms of recovery following early visual deprivation. Philosophical Transactions of the Royal Society of London - Series B: Biological Sciences 364(1515), 383–398 (2009)
6. Taylor, D.: Pediatric Ophthalmology. Blackwell Science, Oxford (1990)

7. Webber, A.: Amblyopia treatment: an evidence-based approach to maximising treatment outcome. Optometry 90, 250–257 (2007)
8. Simons, K.: Amblyopia characterization, treatment, and prophylaxis (major review). Survey of Ophthalmol. 50, 123–166 (2005)
9. Key, D.: The market analysis, segmentation and targeting of VIRART's I-BiT™ technology. Report carried out for the University of Nottingham (2002)
10. Simmers, A.J., Gray, L.S., Spowartb, K.: Screening for amblyopia: a comparison of paediatric letter tests. Br. J. Ophthalmol. 81, 465–469 (1997)
11. Stewart, C.E., Fielder, A.R., Stephens, D.A., Moseley, M.J.: Design of the monitored occlusion treatment of amblyopia study- MOTAS. Br. J. Ophthalmol. 86, 915–919 (2002)
12. von Noorden, G.K. Campus, E.C.: Principals of nonsurgical treatment. Binocular vision & ocular motility theory & management of strabismus. Missouri, Mosby 6th ed., 546-547 (2002)
13. National Eye Institute.: Amblyopia resource guide (2006), `http://www.nei.nih.gov/news/statements/amblyopia.asp` (retrieved October 2006)
14. Garzia, R.P.: Efficacy of vision therapy in amblyopia: a literature review. Am. J. Optom. Physiol. Opt. 64(6), 393–404 (1987)
15. Griffin, J.R.: Management of Strabismus and Amblyopia: A Practical Guide. Optometry & Vision Science 71(6), 411 (1994)
16. Hiscox, F., Strong, N., Thompson, J.R., Minshull, C., Woodruff, G.: Occlusion for amblyopia: a comprehensive survey of outcome. Eye 300–304 (1992)
17. Dixon-Woods, M., Awan, M., Gottlob, I.: Why is compliance with occlusion therapy for amblyopia so hard? A qualitative study. Archives of Disease in Childhood 91, 491–494 (2006)
18. Foley-Nolan, A., McCann, A., O'Keefe, M.: Atropine penalisation versus occlusion as the primary treatment for amblyopia. Br. J. Ophthalmol. (81), 54–57 (1997)
19. Li, T, Shotton, K.: Conventional occlusion versus pharmacologic penalization for amblyopia. Cochrane Database of Systematic Reviews (4), CD006460 (2009)
20. National Eye Institute.: Statement on the success of reduced daily eye patching to treat severe amblyopia (2003), `http://www.nei.nih.gov/news/statements/amblyopia.asp` (retrieved October 2006)
21. Adams, G.G.W., Sloper, J.J.: Update on squint and amblyopia. J. R. Soc. Med. 96(1), 3–6 (2003)
22. Adams, G.G.W., Karas, M.P.: Effect of amblyopia on employment prospects. Br. J. Ophthalmol. 83, 378 (1999)
23. Fielder, A.: Amblyopia and disability. In: Moseley, M., Fielder, A. (eds.) Amblyopia, ch.6. Butterworth Heinemann, Oxford (2002)
24. Schmucker, C., Kleijnen, J., Grosselfinger, R., Riemsma, R., Antes, G., Lange, S., Lagreze, W.: Ophthalmic Epidemiology. Effectiveness of early in comparison to late(r) treatment in children with amblyopia or its risk factors: a systematic review 17(1), 7–17 (2010)
25. Ellis, S.R.: What are virtual environments? IEEE Computer Graphics and Applications 14, 17–21 (1994)
26. Davis, R.: Using virtual reality for participatory design and brain injury rehabilitation PhD Lund University 8-16 (2000)
27. Eastgate, R.M.: The structured devlepment of virtual environments enhancing functionality and interactivity. PhD University of Nottingham (2001)

28. Bell, J.T., Fogler, S.H.: Low cost virtual reality and its application to chemical engineering – part one. Computer Systems Technology Division Communicators, American Institute of Chemical Engineers (18), 1–11 (1994)
29. Beier, K.: Virtual Reality: A short introduction (2004), `http://www.vrl.umich.edu/intro/index.html` (retrieved October 2006)
30. Riva, G., Gamberini, L.: Virtual Reality in Telemedicine. Telemedicine Journal and e-Health 6(3), 327–340 (2000)
31. Early, S.A., Roche-Nagle, G.: Virtual reality technology and surgical training- a survey of general surgeons in Ireland. Irish Journal of Medical Science 174(1), 15–19 (2006)
32. Cameron, B., Robb, R.: Clinical Orthopaedics and Related Research 442, 63–73 (2006)
33. Sveistrup, H.: Motor rehabilitation using virtual reality. Journal of NeuroEngineering and Rehabilitation 1, 10 (2004)
34. Cobb, S.V.G. VR for disability, assessment and rehabilitation. EuroVR-EVE Joint European Meeting, CNRS/LIMSI, University Paris-Sud, Orsay (France), May 6-7 (2010)
35. Rogers Jr., S.O., Gawande, A.A., Kwaan, M., Puopolo, A.L., Yoon, C., Brennan, T.A., Studdert, D.M.: Analysis of surgical errors in closed malpractice claims at 4 liability insurers. Surgery 140(1), 25–33 (2006)
36. Blyth, P., Anderson, I.A., Stott, N.S.: Virtual reality simulators in orthopedic surgery: what do the surgeons think? Journal of Surgical Research 131, 133–139 (2006)
37. Tendick, F., Downes, M., Cavusoglu, M.C.: Development of virtual environments for training skills and reducing errors in laparoscopic surgery. In: Proceedings of the SPIE International Symposium on Biological Optics (BIOS 1998), San Jose, CA, January 24-30, pp. 36–44 (1998)
38. Fried, M.P., Satava, R., Weghorst, S., Gallagher, A.G., Sasaki, C., Ross, D., Sinanan, M., Uribe, J.I., Zeltsan, M., Arora, H., Cuellar, H.: Identifying and reducing errors with surgical simulation. Quality & safety in health care 13, i19–i26 (2004)
39. Healy, G.B.: The college should be instrumental in adapting simulators to education. Bulletin of the American College of Surgeons 87(11), 10–11 (2002)
40. Kneebone, R.: Simulation in surgical training: educational issues and practical implications. Medical Education 37, 267–277 (2003)
41. Eastgate, R.M., Griffiths, D.G.: Development of a computer based system for the treatment of amblyopia: Technical Report, University of Nottingham (2002)
42. Cleary, M., Moody, A.D., Buchanan, A., Stewart, H., Dutton, G.N.: Assessment of a computer-based treatment for older amblyopes. The Glasgow Pilot Study Eye (23), 124–131 (2009)
43. Waddingham, P.E., Ash, I., Cobb, S.V., Eastgate, R.M., Gregson, R. M.: Treating amblyopia using a binocular method of visual stimulation based upon an adapted virtual reality system (in preparation)
44. Waddingham, P.E., Butler, T.K.H., Cobb, S.V., Moody, A.D.R., Comaish, I.F., Haworth, S.M., Gregson, R.M., Ash, I.M., Brown, S.M., Eastgate, R.M., Griffiths, G.D.: Preliminary results form the use of the novel Interactive Binocular Treatment (I-BiT^{TM}) system, in the treatment of strabismic and anisometropic amblyopia. Eye 20, 375–378 (2006)
45. Waddingham, P.E., Cobb, S.V., Eastgate, R.M., Gregson, R.M.: Virtual reality for interactive binocular treatment of amblyopia. In: Proceedings of 6th International Conference on Disability, Virtual Reality and Associated Technologies (ICDVRAT), Esbjerg, Denmark, September 18-20 (2006)
46. Waddingham, P.E., Cobb, S.V., Eastgate, R.M., Gregson, R.: Virtual reality for interactive binocular treatment of amblyopia. International Journal on Disability and Human Development 5(2), 155–161 (2006)

Chapter 12
Doing Play in a Virtual Environment

Denise Reid

Occupational Science and Occupational Therapy
University of Toronto
d.reid@utoronto.ca

Abstract. In this chapter, how children with disabilities are at risk for restricted participation in play opportunities is discussed. Play development in children with and without disabilities is reviewed to provide context and to examine the developmental consequences of not participating in play opportunities. A theoretical perspective is taken to discuss how the person-environment process is influenced by virtual reality. Research studies that relate how children with disabilities engage with virtual reality, and experience enhanced self-efficacy, motivation, playfulness is presented. Concluding remarks are aimed at rehabilitation professionals and others who work with disabled children to enable participation in play.

Keywords: virtual reality, children, play.

1 Introduction

Play possesses characteristics that are believed to be mutually exclusive and that arise from different theoretical perspectives. These have been described by [1] as six factors: intrinsic motivation, focus on means rather than ends, organism-centered rather than object-centered behavior, relation to instrumental behaviors, freedom from externally imposed rules, and active engagement. In play an activity is done for its own sake; it is not ruled by external rules. Play can be spontaneous and is characterized by self-imposed goals. Rubin and colleagues [1] discuss the concept of internal locus of control in viewing play as organism-centered where the organism becomes aroused and stimulated through play. Play does not use real behaviors but pretend ones. Play has been seen by some theorists as being different than games, where there is more flexibility built in. Finally, the player is actively engaged in a play activity.

Parham et al., [2] describe several theories each contributing their own explanation of play. They classify these theories into classical and modern theories. Classical theories attempt to provide reasons for the existence of play and to determine its antecedent conditions and its inferred purpose [3 – 6]. The modern theories address both the causes of play and the role of play in development [1, 7-10]. Through the facilitation of physical and social development, play can enhance a child's self-esteem [11-13]. Vygotsky [14] added an additional dimension emphasizing that the effects of

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 253–268.
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play on a child's development cannot be fully understood without considering the context of the play experience.

1.1 Play as Occupation

Play has been described as both the earliest occupational behavior and the primary occupation of children [15,16] From infancy through to middle childhood play both reflects and contributes to the physical, cognitive, social, language and emotional aspects of child development [10, 15, 17-18]. In the occupational therapy literature, play is also viewed as the primary occupation of children and has been defined as "that which children do"[19]. By engaging in the occupation of play, children learn how to follow rules, communicate effectively with others, and prepare for adulthood by imitating adult roles (e.g. adult occupations). The view of play as an occupation shifts the focus away from just the effects of play on the development of the child, to encompass the transaction between the child and the environment [20]. In the area of physical development, active engagement in physical games and sports has been shown to help children and adolescents learn about their bodies and how to react to the environment [21]. Engagement in physical play also serves to develop self-competence, and, children and adolescents who engage in physical play are more self-confident, outgoing, and socially adjusted [12].

1.2 Play and Children with Disabilities

Play is also important in the development of children with physical disabilities such as cerebral palsy (CP). CP is a neuromuscular disorder characterized by non progressive abnormalities in the developing brain that leads to neurologic, motor, and postural deficits in the developing child [22]. Children who are unable to engage in normal childhood play experiences because of a physical disability, such as with CP, may encounter secondary social, emotional, and psychological disabilities [23]. This can result in an increased dependency on others, decreased motivation, a lack of assertiveness, poorly developed social skills and lowered self-competence [19].

Several studies comparing the engagement in play activities, of children with disabilities and children without disabilities, provide some evidence that children with disabilities may not be developing certain skills due to the barriers in their play experiences [19, 24-25] The study by Hestness and Carroll [25] provides evidence that children with disabilities spend more time in solitary play and on-looking behaviors than their typically developing peers. Qualitative studies looking at the perceptions of play for young people with and without disabilities found that young people with disabilities report environmental and personal barriers as having an impact on their play [20, 31].

This section reviewed theoretical perspectives on the development of play, examines play through an occupational lens, and discusses how the occupation of play is restricted in children at risk. In the next sections, we discuss the theoretical importance of person-environment fit, and illustrate how virtual reality has the potential to influence the person-environment fit to maximize play for children who have physical disabilities. Finally, the impacts of engaging in play in a virtual environment will be discussed.

2 Person-Environment Process

In this section several concepts drawn from the field of occupational therapy and cultural anthropology will be discussed to relate how a virtual environment provides a place and space that enables an experience of a good person-environment fit.

2.1 Person-Environment Fit

The notion of person-environment reflects an occupational therapy view of how the environment and the person engaged in an occupation are sometimes in conflict. The notion of person-environment fit has a place in the work literature [41]. This poor fit between environments and what a person does is often the result of disability when viewed from a rehabilitation perspective. People with disabilities have to constantly renegotiate their view of themselves and what they do as they ascribe meaning to occupation and the environment around them [26]. Concepts drawn from cultural anthropology [27, 28] help us to understand how these relationships exist. Using Figure 1, the relationship between persons, their environment, and their occupations can be demonstrated. Change in any part of the person-environment-occupation interaction will affect the person's occupational performance.

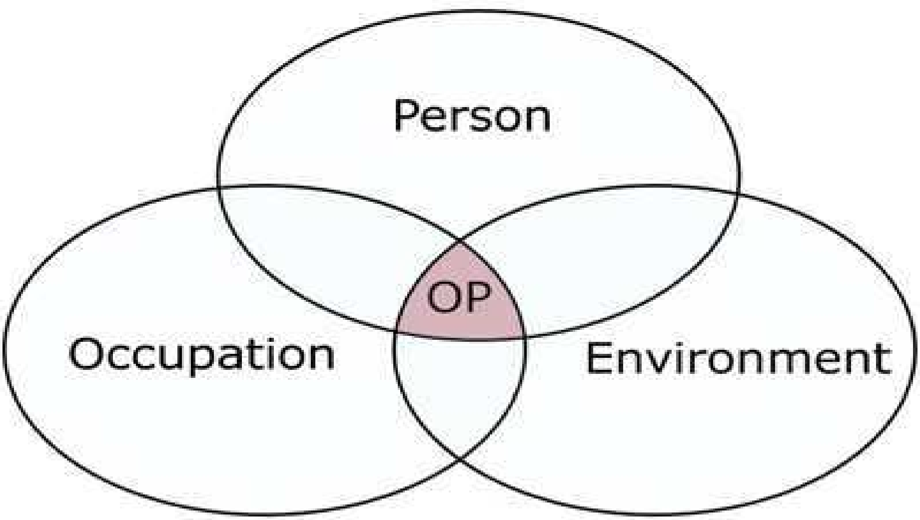

Fig. 1. Person-Environment-Occupation Model (adapted from Law, M., Cooper, B.A., Strong, S., Stewart, D., Rigby, P., & Letts, L. (1996). The Person-Environment-Occupation Model: A transactive approach to occupational performance. Canadian Journal of Occupational Therapy, 63, 9-23, p. 18

2.1.1 Gesture Recognition Technology and a Virtual Environment Process

The 1996 patented *Mandala® Gesture X-treme* IREX Virtual Reality system, developed by Vivid Group Inc., from Toronto,[1] Ontario, Canada is used worldwide.

[1] Vivid Group, 317 Adelaide St. W., Suite 302, Toronto ON, Canada, Phone: 416-340-9290, Fax: 416-348-9809, Email: info@vividgroup.com, Web: www.vividgroup.com

This system uses a video camera as a capturing and tracking device to put the user inside VR experiences. The user sees him/herself on a TV screen and the virtual environment responds to his/her movements. The user does not have to wear, touch or hold anything. Through the use of the system's "video gesture" capability, the movements (e.g., reaching, bending) trigger visible or invisible icons to score points, and manipulate animations (e.g. playing a virtual drum kit, playing volleyball, or painting a picture).

3 A Theoretical Perspective on the Person-Environment Experience

This section discusses how the virtual environment interacts with gesture recognition software of the *Mandala® Gesture X-treme* IREX Virtual Reality system in order for an individual to engage in virtual play experiences. Three concepts illustrate how a person who is disabled can experience a good person-environment fit so that they can participate in play. The concepts are relevant to the ways in which people with disabilities interact with virtual environments (VE).

(i) environmental centralization – refers to the way in which the environment is manipulated over time to accommodate increasing limitations of the body through closing off of peripheral areas and the concentration of living space in central zones. This concept has been studied in the aging literature with respect to how older persons can interact with their features of their home environment [27].

(ii) Entexturement – refers to highlight the individual's awareness of the body in respect to a variety of media with different sensory "textures" such as space, light, color, visual imagery, activity, rhythm, content, pace, ambiance, and sound [27]. Entexturing may be thought of as an individual's regulation of activity, of aural and visual stimuli, and color, and other sensory media that surround the body in order to produce, if possible, a finely articulated and satisfying whole.

(iii) Personalization - refers to taking possession of an environment, completing an environment, or changing it. This concept is discussed in the environmental literature [42].

3.1 Application of the Theoretical Perspective

Drawn from research at the University of Toronto, the concepts environmental centralization, entexturement, and personalization are illustrated with examples to explain positive person-environment interactions related to virtual reality that enable children with cerebral palsy to experience doing play.

3.1.1 Environmental Centralization Case Scenario

A 10-year old boy (JL) with spastic quadriplegic cerebral palsy sits in a manual wheelchair while he engages with a virtual reality system at the University of

Toronto. His cerebral palsy prevents him to stand. He has limited range of motion and spasticity in his upper extremities. The system is the *Mandala® Gesture X-treme* IREX Virtual Reality system. The activities chosen in the virtual environment are children's sport activities such as soccer and volleyball. JL describes his difficulties of managing a ball in the real physical environments of his school and home. He is unable to catch a ball or run and hit a ball. Therefore, he remains usually an observer to ball games such as baseball, soccer and volleyball. The virtual reality applications that are used with JL allow him to see himself inside the specialized soccer virtual environment. It allows him to be centered within the net so that he could see himself, and he is able to control and manipulate balls at will by using gross movements of his arms. This is accomplished by using video projection and gesture recognition technology. The concept of environmental centralization in this virtual environment is the closed off areas to his physical world and the concentration on a "doing" space where JL performs the activity in central zones. In this centralized space, his competence is maintained through the removal of physical barriers. It requires no more than gross arm movements for JL to interact with the soccer balls that are coming towards him in while playing the role of goaltender in a net space.

Fig. 2. Example of Environmental Centralization for Person-Environment Fit in a Virtual Environment

In the other environment – beach volleyball, the concept of centralization is seen by having a virtual environment where there is the projected image of (VA] as she sits in her wheelchair beside a research assistant on a sandy beach near a volleyball net. This is the centralized play space for VA. To play volleyball, VA only has to lift her arms above her head and hit the virtual ball back over the net to a robot. She is capable of these movements and she is successful in playing (see Figures 3).

Fig. 3. Example of Environmental Centralization for Person-Environment Fit in a Virtual Environment

3.1.2 Entexturement Case Scenario

[MR] is a 9 year-old boy with spastic diplegia cerebral palsy. He participates in a painting activity in a virtual environment. He can stand by himself and see himself reaching out to the side to choose a colored paint ball from several arranged in a row, and drags it across a white panel to create a rainbow of colored lines on the screen (see Figure 4). He repeats this reaching movement and selects other colored balls.

MR's movements to this painting activity are spontaneous and free. He responds to the visual stimuli of the colored balls and the auditory stimuli of the sounds that accompany the movement of the balls across the panel while creating a rainbow of colors.

Fig. 4. Example of Entexturement for Person-Environment Fit in a Virtual Environment

Another example is showing a 9-year old girl who is engaged in a program where she listens the sounds of lapping waves on a beach. She blends the sounds of the waves she hears with new sounds as she makes sounds on two xylophones using her hands (see Figure 5).

Fig. 5. Example of Entexturement for Person-Environment Fit in a Virtual Environment

3.1.3 Personalization Case Scenario

An 8 year-old girl [J M] with spastic quadriplegia cerebral palsy and a 10-year old able bodied girl [SR] are shown in Figure 6. JM is able to stand without support for short periods of time in order to participate in a dancing activity. This activity encourages children to move their bodies by bending, reaching, or jumping to create different shapes on the TV screen. They both decide they are making a dance video which is put to music. By personalizing the environment these children took possession of the virtual reality experience and to suit their needs.

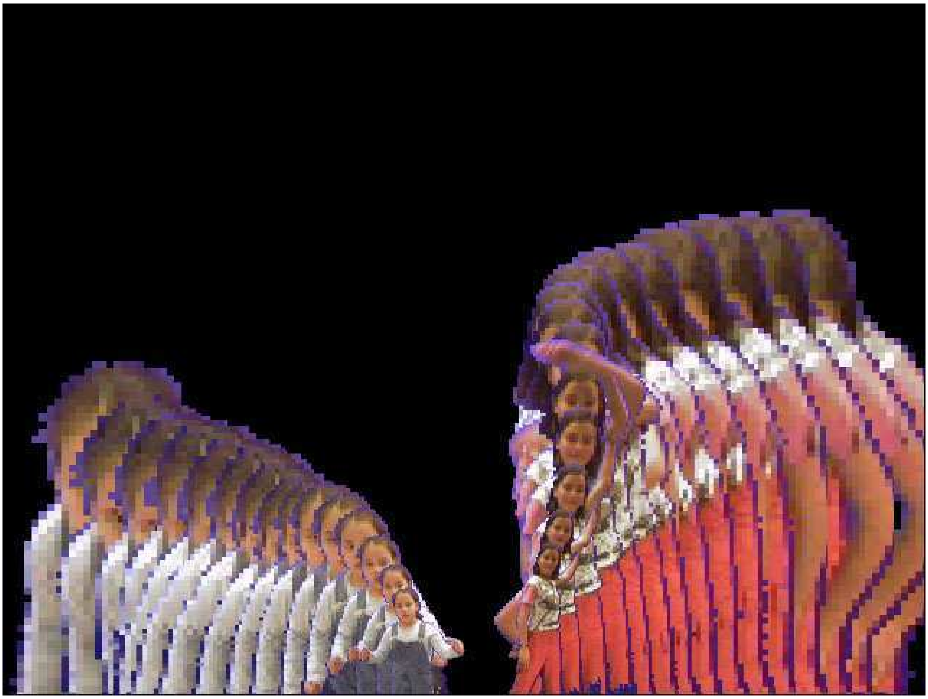

Fig. 6. Example of Personalization for Person-Environment Fit in a Virtual Environment

4 Impact of Engaging in Play in a Virtual Environment

The use of virtual reality for enabling play and exploring its potential for influencing children's self-efficacy, playfulness, and motivation is in its infancy. In the field of occupational therapy these outcomes are relevant as therapists continue to be concerned with people's experiences, feelings and beliefs while they are engaged in occupations as well as enabling a person's occupational performance [29]. Research [30] underscores the advantage of the game-like or play-like experience of virtual reality and is relationship to motivation, performance, and satisfaction with performance among children. In this section, research studies conducted at the Neuro-Rehabilitation and Virtual Reality laboratory at the University of Toronto investigating these outcomes are summarized.

4.1 Personal Perceptions of Engaging in Play in a Virtual Environment

Recent research has found that children can be reliable informants, providing accurate accounts of their experiences. A qualitative study [31] involving in-depth, focused interviews was conducted with 19 children aged eight to thirteen who had a diagnosis of cerebral palsy. Children were interviewed after they experienced at least 8 weeks of playing games in the virtual environment of the *Mandala® Gesture X-treme* IREX Virtual Reality system. The findings indicated that children viewed playing in a virtual world as a way of removing the barriers in real life that prevented their real play experiences. When discussing their experiences of trying to engage in typical play occupations in the real world some children mentioned being restricted to playing only certain positions on the team such as goalie due to their limited mobility. Other barriers were mentioned, for example, the volleyball net at school was positioned so it blocked visual access so children couldn't see their opponents over the other side of the net. Others spoke about their feelings of rejection and being left out, and a sense of loss by peers, due to their difficulties in playing typical play occupations. Children acquire information about their self-efficacy from actual performance and if they are unable to test their abilities this limits their belief in themselves [32]. After engaging in virtual reality play children described experiencing feelings of increased self-worth, confidence and competence in their abilities not only when playing in virtual reality but in everyday life situations. Several children discovered that they were able to do things they never thought they would ever be able to do and began to set goals for self-improvement in virtual reality and real life situations. Overall, children described themselves as being different as a person and had an increased willingness to try new things.

When children with cerebral palsy were asked to list everyday activities that were important to them and that they wished they could perform better, they changed their perceptions of how they felt they could perform these after they were exposed to doing things in a virtual environment [33]. After participating in virtual reality weekly sessions for four weeks playing in a *Mandala® Gesture X-treme* system they rated their perception with performance concerning the everyday activities on a self-efficacy tool. The Canadian Occupational Performance Measure [43] is a tool that is commonly used to evaluate a person's perception and satisfaction with his or her performance. Children rated their perception of performance better after being exposed to virtual reality. Interestingly, the level of change in self-efficacy across children was meaningful. Whether virtual play is influential in changing how people think of themselves needs more careful research.

4.1.1 The Thrill of Competency and Control

Seeing themselves on the screen in [31], and being able engage in whatever virtual play activity added to the interactive quality of the play experience for all children. Seeing themselves helps them to discover their own abilities and reinforces that they could do more than what initially thought they can. "I can do this, I can do this, I can do this" (child quote). Experiencing a sense of control over the play experience is important to all children. Not having to have to rely on others in order to do the activity is also important. Most children mention the shear enjoyment and thrill of being a winner when playing a virtual game. They describe not always experiencing what it feels like to win or be a success at what they do. Virtual reality offers these children an opportunity to be a winner at a play activity fit for their skill level.

4.1.2 Safety First

Virtual reality offers children a safe way for them to play and experience new things. Play should occur in an environment which is secure and where participants feel free to explore without fear of personal harm whether it be physical or emotional [1]. Children with physical disabilities spend more time in self-care and passive activities than children without disabilities because they are not safe [24]. This suggests that children with disabilities may have less opportunity to experience different types of play and be independent as they explore the world around them.

4.2 Influence of Virtual Play on Children's Playfulness

Playfulness is viewed as a key characteristic of play [34]. Virtual reality interactions with disabled individuals create opportunities for playful behavior while engaging in a variety of activities that are typically not done well or safely in real life, with less effort [35]. Playfulness while children are engaged with virtual reality was investigated by Reid [36]. The children played games in the *Mandala® Gesture X-treme* system. The Test of Playfulness (TOP) [34] was used to assess playfulness. Table 1 shows the items grouped according to four subscales. The results confirmed that the children exhibited playfulness while interacting with the virtual reality system. They show engagement. They persist in playing the games and repeat their

Table 1. Playfulness Items Grouped According to Four Subscales

Motivation items
Is actively engaged Repeats actions, activities, stays with same basic theme Engages in process aspects of activity Demonstrates exuberance, manifests joy Tries to overcome difficulties, barriers, or obstacles to persist
Control items
Appears self-directed. Decides what to do and how to do it Engages in challenges (motor, cognitive, social) Negotiates with others to have needs or desires met Plays with others Assumes leadership role Initiates play with others Shares playthings, play equipment
Suspension of Reality Items
Engages in mischief or commits a minor infraction of the implicit or explicit rules Pretends Teases or jokes with others (verbal or nonverbal) Clowns Incorporates objects or people into play in novel, imaginative, creative, unconventional, or variable ways
Framing
Gives facial, verbal, and body cues appropriate to the situation and that say, "This is how you should act toward me" Responds to other's facial or body cues Maintains cohesiveness of play frame

actions to succeed, for example, in hitting the ball over the net in volleyball or blocking the ball in the soccer net. They are exuberant, laughing and shouting much of the time. When the children did not demonstrate manifest joy, they were concentrating very hard on the activity. The children engage in challenging behaviors often requiring them to reach and stretch their arms. When they play in situations where there is more than one player they share the task requirements willingly and play along well with a partner. For example, in the volleyball game, they have to take turns deciding when to hit the ball. Some children engage in pretend play, “I’m an airplane pilot”. They also make jokes and tease the staff. Interestingly, the environments that yield the highest playfulness scores are those with an element of entexturement that enable the individual’s awareness of the body in respect to a variety of media with different sensory “textures” such as color, rhythm, and sound [37]. Understanding which virtual environments and real environments are more conducive to playfulness will better enable play with children with disabilities. Designing new virtual environments with elements that will enhance playfulness is a recommendation for future research.

4.3 Influence of Virtual Play on Children’s Motivation

Motivation is the key element in determining the level of participation an individual will have in an occupation. Since participation in rehabilitation therapy is highly dependent on motivation, and play is the major occupational behavior of children [15], it is important to explore the characteristics in therapeutic play environments that are motivating and that engage children with disabilities as active participants. Following a randomized control trial where virtual reality was used as an intervention for children with cerebral palsy [38], an observational study [39] was conducted to explore the degree of motivation among children with cerebral palsy engaged in virtual activities. Sixteen children with cerebral palsy were videotaped while engaged in playing games in a variety of virtual play environments in the *Mandala® Gesture X-treme* virtual reality system. The Pediatric Volitional Questionnaire (PVQ) [40] was used to measure children’s motivation. The PVQ provides both insight into children’s inner motives as well as how the virtual environment enhances or attenuates children’s motives (see Table 2). The videotaped sessions were scored with

Table 2. Behavioral indicators for the PVQ

Item 1 = Explores Novelty
Item 2 = Initiates Actions
Item 3 = Is Task Directed
Item 4 = Shows Preferences
Item 5 = Tries New Things
Item 6 = Stays Engaged
Item 7 = Expresses Mastery Pleasure
Item 8 = Tries to Solve Problems
Item 9 = Tries to Produce Effects
Item 10 = Practices Skills
Item 11 = Seeks Challenges
Item 12 = Organizes/Modifies Environment
Item 13 = Pursues Activity to Completion
Item 14 = Uses Imagination/Symbolism

the PVQ (see Table 3 for scoring definitions). It was shown that virtual reality influenced children's motivation as measured with the PVQ, and that different virtual environments produced varying levels of motivation behavior. The features of virtual environments that produced higher levels of motivation include: challenge, variability and competition. Overall, the PVQ scores of children with cerebral palsy indicated that VR play is a motivating activity which has the potential to be used as a rehabilitation tool for influencing rehabilitation outcomes.

Aspects of the VR environment can also increase challenge such as when a child cannot predict their next move or when a child has to develop a strategy to better interact with the environment. When a child is challenged they are required to use a higher level of concentration in order for the game to be satisfying. If the game is either too challenging or too easy they may become frustrated. Variability resulted in an unpredictable environment that required continuous concentration and readiness on the part of the child. Games that allowed two players to interact were very motivating.

Table 3. PVQ Scoring System

(4) SPONTANEOUS: shows behavior without support, structure, or stimulation.
…given throughout his/her performance beyond what is allowed for some of the indicators. This rating implies that this behavior comes from within and is independent of any identified external factors (i.e. therapist or teacher assistance, structure, or stimulation).
(3) INVOLVED: shows behavior with a minimal amount of support, structure, or stimulation.
The child needs some attention, encouragement, verbal cues, or structuring of the environment from the therapist or teacher. This rating implies support that might be necessary for a person with adequate volition.
(2) HESITANT: Shows behavior with maximal amount of support, or structure, or stimulation.
The child needs verbal or visual cues to be repeated several times, and/or frequent intervention, such as repeat demonstrations in order to initiate the desired behaviors. This rating implies the obvious volitional difficulty in interacting with the environment. This rating implies some concern about the child's self-confidence, attention to the environment, ability to employ cognition, etc.
(1) PASSIVE: Does NOT show behavior even with support, structure, or stimulation.
The child does not show the behavior and/or may show a brief orientation to the activity given maximum input. This rating implies the judgment that there is a volitional deficit—e.g., very low self-esteem, high anxiety with novelty, very low interest in environment. With no support, structure, or stimulation given, the child remains passive and does not show the behavior.

One of the key elements of engaging in the *Mandala® Gesture X-treme* IREX Virtual Reality system is being able to experience how you are engaging with the virtual objects, which likely influences a person's level motivation and playfulness. These preliminary studies from Reid and colleagues [36, 38-39] suggest this. Ongoing research comparing the effects of the *Mandala® Gesture X-treme* IREX Virtual Reality system with the Nitendo Wii ™ system and other systems will provide us with more information regarding the impact of the gesture recognition software.

5 Summary

A review of relevant literature on children's play is presented in this chapter. How virtual reality has the potential of enabling play in children with disabilities is discussed. The person-environment process is explored within a virtual environment. Theoretical concepts that help to understand person-environment experience while engaged with a virtual reality program are described. These include environmental centralization, entexturement, and personalization. Application examples that illustrate these concepts during engagement in virtual play are shown. It is suggested that the person-environment process discussed in the context of a virtual world has the potential for influencing how disabled children experience doing play. Research is summarized that explores how engaging in virtual play impacts children's playfulness, motivation, and self-perceptions. This chapter provides information for readers to better understand the enabling power of using virtual reality for children with disabilities to engage in play.

References

[1] Rubin, K.H., Fein, G.G., Vandenberg, B.: Play. In: Mussen, P.H., Hetherington, E.M. (eds.) Handbook of Child Psychology, pp. 693–774. Wiley, New York (1983)

[2] Parham, D., Primeau, L.: Play and occupational therapy. In: Parham, D., Mellou, L. (eds.) E. Play theories: A contemporary review. Early Child Development and Care, vol. 102, pp. 91–100 (1997)

[3] Gilmore, J.B.: Play: A special behavior. In: Herron, R.E., Sutton-Smith, B. (eds.) Child's play, pp. 311–325. John Wiley & Sons, New York (1971)

[4] Groos, K.: The value of play for practice and self-realization. In: Muller-Schwarze, D. (ed.) Evolution of play behavior, pp. 16–23. Dowden, Hutchinson & Ross, Stroudsbourg, PA (1978); Groos, K., Baldwin, E.L.(trans.): Reprinted from the play of animals, pp. 16–23. Appleton & Company (1898)

[5] Hall, G.S.: Growth of motor power and function. In: Muller-Schwarze, D. (ed.) Evolution of play behavior, pp. 24–29. Dowden, Hutchinson & Ross, Stroudsbourg, PA (1978); Hall, G.S.: Reprinted from Adolescence, its psychology and its relations to physiology, anthropology, sex, crime, religion, and education, vol. 1, pp. 202–217. D. Appleton & Company (1908)

[6] Spencer, H.: Aesthetics sentiments. In: Muller-Schwarze, D. (ed.) Evolution of play behavior, pp. 10–15. Dowden, Hutchinson & Ross, Stroudsbourg, PA (1978); Spencer, H.: Reprinted from The principles of psychology, vol. 2, pp. 627–632. Appleton & Company (1878)

[7] Berlyne, D.E.: Laughter, humor, and play. In: Lindzey, G., Aronson, E. (eds.) The handbook of social psychology, vol. 3, pp. 795–852. Addison-Wesley, Reading (1969)
[8] Ellis, M.: Why people play. Prentice Hall, Englewood Cliffs (1973)
[9] Sutton-Smith, B.: Children's play: Some sources of play theorizing. In: Rubin, K.H. (ed.) New directions for child development: No. 9. Children's play, pp. 1–16. Jossey-Bass, San Francisco (1980)
[10] Piaget, J.: Play, dreams, and imitation in childhood. In: Gattegno, C., Hodgson, F.M. (trans.). W.W. Norton, New York (1962) (original work published in 1951)
[11] Bjorklund, D.F., Brown, R.D.: Physical play and cognitive development: Integrating activity, cognition, and education. Child Development 69(3), 604–606 (1998)
[12] Eppright, T., Sanfacon, J., Beck, N., Bradley, J.: Sport psychiatry in childhood and adolescence: An overview. Child Psychiatry and Human Development (2), 71–88 (1997)
[13] Erikson, E.H.: Childhood and society, 2nd edn. Norton, New York (1963)
[14] Vygotsky, L.: Play and its role in the mental development of the child. In: Bruner, A., Sylva, K. (eds.) Play: Its role in development and evolution, Basic Books, New York (1976)
[15] Reilly, M.: An explanation of play. In: Riley, M. (ed.) Play as exploratory learning, pp. 117–149. Sage, Beverly Hills (1974)
[16] Vandenberg, B., Kielhofner, G.: Play in evolution, culture, and individual adaptation: Implications for therapy. American Journal of Occupational Therapy 36, 20–28 (1982)
[17] Nicolopoulou, A.: Play, cognitive development, and the social world: Piaget, Vygotsky, and beyond. Human Development 36, 1–23 (1993)
[18] Power, T.G.: Play and exploration in children and animals. Lawrence Erlbaum Associates, Mahwah (2000)
[19] Howard, L.: A comparison of leisure-time activities between able-bodied children and children with physical disabilities. British Journal of Occupational Therapy 59, 570–574 (1996)
[20] Pollock, N., Stewart, D., Sahagian-Whalen, S., Harvey, S., Toal, C.: The meaning of play for young people with physical disabilities. Canadian Journal of Occupational Therapy 64, 25–31 (1997)
[21] Brady, M.: Laying the foundation for girl's healthy futures: Can sports play a role. Studies in Family Planning 29, 79–81 (1998)
[22] Rogers, S.L., Gordon, C.Y., Schanzenbacher, K.E., Case-Smith, J.: Common Diagnosis in Pediatric Occupational Therapy Practice. In: Case-Smith, J. (ed.) Occupational therapy for children, pp. 136–187. Mosby, St. Louis (2001)
[23] Missiuna, C., Pollock, N.: Play deprivation in children with physical disabilities: The role of occupational therapists in preventing secondary disability. American Journal of Occupational Therapy 45, 882–888
[24] Brown, M., Gordon, W.: Impact of impairment on activity patterns of children. Archives of Physical Medicine and Rehabilitation 68, 828–832 (1987)
[25] Hestness, L.L., Carroll, D.E.: The play interactions of young children with and without disabilities: Individual and environmental influences. Early Childhood Research Quarterly 15, 229–246 (2000)
[26] Canadian Association of Occupational Therapists: Enabling occupation: An occupational therapy perspective. CAOT Publications ACE, Ottawa (1997)
[27] Rubinstein, R.L.: The home environments of older people: A description of the psychosocial processes linking person to place. Journal of Gerontology: Social Sciences 44, 45–53 (1989)

[28] Lawton, P.M.: Environmental change: The older person as initiator and responder. In: Datan, N., Lohmann, N. (eds.) Transitions of aging, Academic Press, New York (1980)
[29] Reid, D.: Exploring the Relationship Between Occupational Presence, Occupational Engagement, and People's Well-being. Journal of Occupational Science 15, 43–47 (2008)
[30] Rizzo, A.A., Buckwalter, J.G., Neumann, U., Kesselman, C., Thiebaux, M.: Basic issues in the application of virtual reality for the assessment and rehabilitation of cognitive impairments and functional disabilities. CyberPsychology & Behavior 1, 59–78 (1998)
[31] Miller, S., Reid, D.: Doing play: Competency, Control, and Expression. CyberPsychology & Behavior 6, 623–631 (2003)
[32] Bandura, A.: Self-efficacy: The exercise of control. WH Freeman & Co., New York (1997)
[33] Reid, D.T.: Benefits of virtual play rehabilitation environment for children with cerebral palsy on perceptions of self-efficacy. Pediatric Rehabilitation 5(3), 142–148 (2002)
[34] Bundy, A.: Play and playfulness. In: Parham, D., Fazio, L. (eds.) Play in occupational therapy for children. Mosby-Year Book, St. Louis (1997)
[35] Schultheis, M., Rizzo, S.: The application of virtual reality technology in rehabilitation. Rehabilitation Psychology 46, 296–311 (2001)
[36] Reid, D.T.: The influence of Virtual Reality on Playfulness in Childen with Cerebral Palsy. Occupational Therapy International 11, 131–144 (2004)
[37] Reid, D.: Virtual reality and the person-environment interaction. Cyberpsychology and Behavior 5, 559–564 (2002)
[38] Reid, D., Campbell, K.: The use of virtual reality with children with cerebral palsy: A pilot randomized trial. Therapeutic Recreation Journal 40, 255–268 (2007)
[39] Harris, K., Reid, D.: The Influence of Virtual Reality Play on Children's Motivation. Canadian Journal of Occupational Therapy 72, 21–29 (2005)
[40] Basu, S., Kafkes, A., Geist, R., Kielhofner, G.: Pediatric Volitional Questionnaire. Model of Human Occupation Clearinghouse, Chicago (2002)
[41] Van Harrison, R.: Person-environment fit and job stress. In: Cooper, C.L., Payne, R. (eds.) Stress at work. Wiley, Chichester (1978)
[42] Rapoport, A.: The meaning of the built environment. Sage, Beverley Hills (1982)
[43] Law, M., Baptiste, S., Carswell, A., McColl, M., Polatajko, H., Pollock, N.: Canadian Occupational Performance Measure manual, 3rd edn. CAOT Publications ACE, Ottawa (1998)

Part 3: Virtual Reality and Assessment

Chapter 13

Neuropsychological Assessment Using Virtual Environments: Enhanced Assessment Technology for Improved Ecological Validity

Thomas D. Parsons

University of Southern California,
Los Angeles, California
tparsons@ict.usc.edu

Abstract. Although today's neuropsychological assessment procedures are widely used, neuropsychologists have been slow to embrace technological advancements. Two essential limitations have resulted from this refusal of technological adaptation: First, current neuropsychological assessment procedures represent a technology that has barely changed since the first scales were developed in the early 1900s. Second, while the historical purpose of clinical neuropsychology was differential diagnosis of brain pathology, technological advances in other clinical neurosciences have changed the neuropsychologist's role to that of making ecologically valid predictions about the impact of a given patient's neurocognitive abilities and disabilities on everyday functioning. After a brief discussion of current applications of computer-based neuropsychological assessment, there is a discussion of an increasingly important topic in recent decades—the design of ecologically valid neuropsychological instruments to address real world outcomes. Finally, there is an exploration of virtual reality environments for ecologically valid neuropsychological assessments that make use of current technological advances. It is concluded that a future possible virtual reality-based neuropsychological assessment battery will combine the control and rigor of technologically advanced computerized laboratory measures, the psychometric rigor (i.e., veridicality) of traditional paper-and-pencil assessments, and verisimilitude approximating real life situations.

1 Introduction

Clinical neuropsychology is one of the fastest growing specialty areas in psychology. Clinical neuropsychologists study brain-behavior relationships in both persons with normal cognitive functioning and persons with brain injury or disease. Over the course of the last several decades, clinical neuropsychology has gained increasing recognition as a discipline with relevance to a number of diverse practice areas (e.g., neurology, neurosurgery, psychiatry, and family medicine) as well as neuroscience specific research areas (e.g., behavior, learning, and individual differences). As a result, neuropsychologists must apply a working understanding of psychology, physiology, and

S. Brahnam & L.C. Jain (Eds.): Adv. Comput. Intell. Paradigms in Healthcare 6, SCI 337, pp. 271–289.
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neurology to assess, diagnose, and treat patients with neurological, medical, neurodevelopmental, psychiatric, and cognitive disorders.

1.1 Neuropsychological Assessments

Clinical neuropsychologists take wide-ranging measurements of multiple cognitive domains, including ability to attend and encode information, receptive and expressive language, problem-solving skills, reasoning and conceptualization abilities, learning, memory, perceptual-motor skills (e.g., visuospatial organization; visual-motor coordination), speed of processing, intelligence, academic/vocational skills, behavior, emotions, and personality. As can be seen neuropsychological assessments sample a range of functions. This is an important component in that most neuropsychological measures are not "pure", in that they do not assess one skill only. For example, on a timed task in which the person being assessed is asked to copy figures, a number of domains are being assessed (i.e., motor, visual perceptual, attentional and speed of processing). Take for example, results of a person that showed difficulty on a measure of math skills. These results may reflect limits in, for example, understanding of numerical concepts, remembering math facts, understanding the language of mathematics, remembering which operations to apply when, visualizing concepts, sequencing (e.g., performing the right steps in the right order), and/or attending to visual details (e.g., operational sign, place, columns of numbers). As a result, neuropsychological assessments are structured to investigate aspects or subcomponents of the person's performance that will clarify the nature of their individual strengths and weakness across multiple neuropsychological domains. In addition to using neuropsychological assessments (i.e., tests of neurocognitive, behavioral, and emotional functioning) to form hypotheses regarding a person's neurological functioning, neuropsychologists carefully consider how these factors interact with the individual's psychosocial environment. Data gleaned from these neuropsychological assessments yield a variety of inferences that can be correlated to the person's everyday functioning.

The neuropsychological examination has historically been characterized as both a refinement and an extension of the neurological examination [1]. Much of what is now considered part of neuropsychological assessment originated from attempts of late nineteenth and early twentieth century physicians to improve evaluation of the cognitive capacities of persons with brain disease (e.g., Broca [2] and Wernicke [3] aphasics). Part of this has to do with the fact that many widely used neuropsychological tests were constructed before the advent of neuroimaging and emergence of much of the currently available information relating altered behavior to brain dysfunction. A major problem for the neurological examination is the lack of any standardized method of giving or scoring the neurological exam's procedures. In many cases, the description of administrative procedures is vague. Moreover, neurologists many times change procedures for individual patients. Even when administrative procedures are clear, scoring procedures are not. Scoring is determined by the personal assessment of the neurologist based on experience and knowledge rather than on any normative data. Despite these major problems, the neurological examination clearly possesses a high degree of face validity as well as a strong theoretical foundation. Neuropsychologists have made great strides in proper standardization, scoring, and validation. As such, the revised neurological exam (i.e., neuropsychological assessment) has become a major tool of both clinical and experimental neuropsychology. The work of A. R. Luria, the Russian neuropsychologist, is a good example of a neuropsychological evaluation derived from a neurological approach. According to Luria, performance on a neuropsychological assessment reveals patterns or “functional systems” of interacting neurological areas that are responsible for a given behavior. Each neurological area of the brain participates in numerous such functional systems. Luria aimed to show that the cognitive sequelae of a brain injury reflects an interruption to the execution of any functional system that includes the injured areas(s). The most significant flaw in the original Luria battery is a lack of standard administration and scoring that has precluded an assessment of its validity. However, there have been attempts to overcome these deficiencies by developing an objective form, combining Luria's procedures with the advantages of a standard test battery (i.e., Luria-Nebraska Neuropsychological Battery, also known as LNNB).

The Halstead-Reitan Battery was developed specifically to detect ``organic" dysfunction and differentiate between patients with and without brain damage (e.g., to distinguish ``organic" from ``functional" disorders). Over the years, tests have been designed in concert with evolving information regarding the mediation of behavior by specific structures or circuits provide greater insight into the integrity or disintegration of neurologic function. Extensive experience with these instruments provides a basis for interpreting the tests in neurologic terms. Another widely used battery of tests includes the Wechsler Scales. While commonly used by neuropsychologists, it is important to note that the Wechsler Adult Intelligence Scale (WAIS) and the Wechsler Memory Scale (WMS) were developed without the specific intention of using them as instruments to assess brain function and detect brain disorders, but extensive experience with these instruments has provided a basis for interpreting the tests in neurologic terms. Most current neuropsychological assessment approaches use several of the traditional tests in combination with newer techniques developed specifically to evaluate neurocognitive activities and provide insight into brain function in different disease states. Hence, the range of domains assessed by clinical neuropsychologists has expanded tremendously in recent decades to include areas beyond behavioral neurology and the traditional differentiation between organic and functional conditions in psychiatry. Although there are aspects of neuropsychological assessment that are similar to the conventional evaluation of the behavioral neurologist, neuropsychological measures have the advantage of standardization and psychometric rigor.

1.2 Standardization of Neuropsychological Assessment Measures

An important factor in the development of clinical neuropsychology is the establishment of standardized assessment measures capable of identifying the neurocognitive effects of brain dysfunction. Standardized assessment in neuropsychology is largely due to its historic development from Alfred Binet’s tests of intelligence [4, 5, 6, 7] and the United States’s entry into the World War I in 1917 [8]. During this time Robert Yerkes, Arthur Otis, and the American Psychological Association developed a group administered version of the Stanford-Binet (i.e., Army Alpha), and a novel group administered assessment composed of nonverbal tasks (i.e., Army Beta). Yerkes [9] preferred a point-scale methodology (i.e., tests selected based upon specified functions) over Binet’s age-scale approach (i.e., tasks fluctuate with age and developmental level). Ultimately, the Army group administered measures reflecting an amalgamation of Yerkes's point-scale approach and Binet's task-specific approach to measuring cognitive performance. Further, a performance scale developed by David Wechsler was included in an Army battery, [10] that was made up of subtests developed primarily by Binet and World War I psychologists.

A major shift in testing occurred when Wechsler applied testing procedures (i.e., group and individual) developed for normal functioning persons to the construction of a clinical test battery. Following World War I, Wechsler assembled the Wechsler-Bellevue battery, which included both Verbal and Performance Scales. By the 1940s a number of specialized neurocognitive tests were available to clinicians for assessing the mental capacities of persons with brain disease [11, 12, 13, 14, 15, 16] The additive effects of these tests provided the foundation for today's neuropsychological assessment procedures [17, 18, 19, 20, 21, 22].

1.3 Psychometric Rigor of Neuropsychological Assessment Measures

Neuropsychologists tend to emphasize the psychometric rigor of neuropsychological assessments though their emphasis upon reliability and validity. By reliability, neuropsychologists are referring to the consistency with which the same information is obtained by a given neuropsychological test or set of neuropsychological tests. For scores to be reliable, they should (in the absence of intervening variables like illness, injury, new learning) remain stable. Some examples of reliability include: 1) Interrater reliability: the reliability of test scores when administered by different examiners; 2) Intra-rater reliability: the reliability of test scores when the test is given by the same examiner on more than one occasion; and 3) Test-retest reliability: the reliability of test scores when given to the same patient on different occasions. Hence, reliability of tests refers to the consistency with which the same information is obtained if the test is given by different examiners (interrater reliability), by the same examiner on more than one occasion (intrarater reliability), or to the same patient on different days (test-retest reliability). It is important to note that the reliability for neuropsychological tests of memory is consistently lower than for other types of neuropsychological tests. In such cases, the clinician must bear in mind that conclusions drawn from the tests may be more variable than is desirable.

When neuropsychologists refer to validity, they are referring to how well the test measures what it purports to measure. Specific types of validity that may be questioned include the following: 1) Construct validity: validity of the test to measure what it is supposed to measure; 2) Concurrent validity: strength of the correlation of a new test with existing tests or independent measures of the construct in question; 3) Face validity: appearance ("looks like") of a test to measure what it is supposed to measure; 4) Localization validity: validity of a test to localize focal lesions accurately; and 5) Ecologic validity – validity of the test to predict real life ability and performance on activities of daily living. Hence, validity data can be used by the neuropsychologist to answer questions of psychometric rigor: construct validity (do memory tests assess memory?), concurrent validity (do new tests come to the same conclusions as established tests?), localization validity (do test results localize focal lesions?), diagnostic validity (do tests accurately diagnose disease?), and ecologic validity (do test results predict real life performance?). It is important to note that the neuropsychologst is careful in the use of the terms reliability and validity. When a neuropsychologist refers to reliability as a concept, it is best to understand this as a reference to scores not to tests and when the neuropsychologist refers to validity, it is to the interpretation of performance on tests and not to tests themselves. For example, the question, “Is a given neuropsychological test a valid test?" is not something that can be readily answered. Instead, the neuropsychologist asks about interpretation of performance. As such, much of what is discussed within validity is in fact a reference to ecological validity (more on this below).

As mentioned above, much of what is now considered part of neuropsychological assessment originated from attempts of late nineteenth and early twentieth century physicians to improve evaluation of the cognitive capacities of persons with brain disease. As such, during a period focusing on localization, neuropsychologists received referrals from neurosurgeons to psychometrically localize brain damage. As a result, developed measures were based upon a localization paradigm that focused upon double dissociation—two neocortical areas are functionally dissociated by two behavioral measures, each measure is affected by a lesion in one neocortical area and not the other [23, 24]. Given the importance of neuropsychological assessment for lesion localization it became increasingly important that neuropsychological assessment have enhanced psychometric rigor. In addition to the reliability and validity issues mentioned above, this also includes issues of sensitivity and specificity. By sensitivity, neuropsychologists are referring to a test’s ability to detect even the slightest expression of abnormalities in neurological (primarily central nervous system) function. Sensitivity is understood as a reflection of the neuropsychological test’s ability to identify persons with a disorder. This is often referred to as true positive rate. By specificity, neuropsychologists are referring to the ability of a neuropsychological test to differentiate patients with a certain abnormality from those with other abnormalities or with no abnormality. This is often referred to as true negative rate. A score on any test can be a true positive, false positive, true negative, or false negative. For a score to be true positive, it must have high sensitivity to dysfunction, allowing dysfunctions to be detected. If a score on any test is false positive, it indicates sensitivity to dysfunction, but lacks specificity to a particular dysfunction. A score on any test can be a true negative if it has high specificity, allowing negative to be distinguished from others. If a score on any test is false negative, this indicates a lack of sensitivity, without regard to specificity of the test. For any evaluation, it is important to understand the rates of each of the four categories of results. The ability to identify brain dysfunction varies greatly among neuropsychological tests and is determined by the fidelity with which the neuropsychological test distinguishes normal from abnormal function and by the specific type of deficit that the patient exhibits. The WAIS, for example, has no memory subtests and is necessarily insensitive to memory-related deficits, whereas it has demonstrated sensitivity to disorders affecting visuospatial, calculation, and attentional abilities. In general, tests that are timed, requiring the patient to complete the test in a specified period, have greater sensitivity to diffuse or multifocal cerebral changes than untimed tests.

In summary, in a number of ways, clinical neuropsychology can be viewed as representing a synthesis of the best features of neurological, psychiatric, and psychological examination procedures, whereby the systematic neurological assessment of functional cortical and subcortical systems is combined with the precise scaling of psychometric measurement. Neuropsychological assessment allows the examiner to reduce the subjectivity in traditional neurological examinations by conducting assessments that lead to quantifiable standardized scores, thereby increasing the reliability of the assessment as well as allowing for a more sensitive baseline for comparisons across time. Further, availability of normative data and use of standardized administration procedures allow neuropsychological evaluation to be more sensitive than unstructured mental status testing in the detection of mild cognitive disturbances.

1.4 Paradigm Shift in Neuropsychological Assessment

It is important to note, however, that with the advent of neuroimaging, the need for neuropsychologists to localize brain damage has been greatly reduced. Unfortunately, many neuropsychologists continue to rely on "localization" as the chief basis for validating neuropsychological tests. As Ronald Ruff has contended, although neuroimaging caused the role of neuropsychology to shift from localization to documentation of neuropsychological deficits for prediction of real world functioning, clinical neuropsychologists many times fail to develop ecologically oriented assessments and continue to use localizationist-developed test batteries [25].

Although today's neuropsychological assessment procedures are widely used, neuropsychologists have been slow to adjust to the impact of technology on their profession. Two essential limitations have resulted from this refusal of technological adaptation: First, current neuropsychological assessment procedures represent a technology that has barely changed since the first scales were developed in the early 1900s (i.e., Binet and Simon's first scale in 1905 and Wechsler's first test in 1939). In order for neuropsychologists to fully embrace the development of new batteries that take real world functioning (i.e., ecological validity) seriously, there is a need for them to move beyond cosmetic changes to standardized tests to computerized measures. However, neuropsychologists have historically resisted embracing technological advances in computation. While neuropsychology emphasizes its role as a science, its technology is not progressing in pace with other science-based technologies. Second, while the historical purpose of clinical neuropsychology was differential diagnosis of brain pathology, technological advances in other clinical neurosciences (e.g., the development of neuroimaging) have changed the neuropsychologist's role to that of making ecologically valid predictions about the impact of a given patient's neurocognitive abilities and disabilities on everyday functioning.

The organization of this chapter is as follows. In section two, a brief discussion of current applications of computer-based neuropsychological assessment are described. In section three, there will be a discussion of an increasingly important topic in recent decades—the design of ecologically valid neuropsychological instruments to address real world outcomes. The utility of a virtual environment (VE) for ecologically valid neuropsychological assessments that make use of current technological advances is discussed in section four. A summary of concluding remarks is given in section five.

2 Computer-Based Neuropsychological Assessment

In this section, a brief discussion of current applications of computer-based neuropsychological assessment is described, as follows.

2.1 Automated Neuropsychological Assessments

Computer-based neuropsychological assessments offer a number of advantages over traditional paper-and-pencil testing: increased standardization of administration; increased accuracy of timing presentation and response latencies; ease of administration and data collection; and reliable and randomized presentation of stimuli for repeat administrations [26]. It is important to note that neuropsychology as a field has not embraced anarchoprimitivism. In fact, in the 1980s there was some initial interest in computerization of various assessment measures and neuropsychologists transferred a number of paper-and-pencil measures to the personal computer platform. Initial attempts at assessing the equivalence of these measures to traditional tests were made [27]. A few examples of computerized versions of traditional paper-and-pencil neuropsychological tests include: the Raven's Colored Progressive Matrices [28]; the Peabody Picture Vocabulary Test [29]; Category Test subtest of the Halstead Reitan Battery [30]; and the Wisconsin Card Sorting Test [31]. In the past decade, a number of computerized tests on neurocognitive function have been developed: CogSport [32], ImPACT [33], ANAM [34], and HeadMinder [35].

Perhaps the most widely used computerized neuropsychological assessment battery is the Automated Neuorpsychological Assessment Metrics (ANAM) battery, which has been given widely to civilian and military populations. In fact, the ANAM battery has been given to over 400,000 predeployed soldiers. The ANAM battery is the result of 30 years of computerized psychological test development sponsored primarily by the U.S. Military—decedent of the joint services Unified Tri-Service Cognitive Performance Assessment Battery (UTCPAB). Currently, ANAM is a major focus on neuropsychological assessment for Military Service Members. Much of this emphasis comes from injuries resulting from conflicts in which Service Members may be injured by explosions, resulting in concussions (mTBI). The ANAM is a validated computer-based tool designed to detect speed and accuracy of attention, memory, and thinking ability. It records a Service Member's performance through responses provided on a computer. It is being conducted prior to deployment and can be used to identify and monitor changes in function. A specialized neuropsychological battery for use in blast injury cases has been developed. The ANAM Traumatic Brain Injury (TBI) Battery is a selection of tests from the ANAM library designed to aid in the assessment of general cognitive function following a head injury. Some of the most useful research on ANAM and TBI has evolved from an ongoing project conducted by the Defense and Veterans Brain Injury Center (DVBIC). DVBIC has extensive databases on selected ANAM tests and has been using the precursor to the ANAM TBI Battery for a number of years. One normative study of ANAM TBI Battery test modules with over 2,000 paratrooper recruits and another study based on over 5,000 recruits revealed consistent results. These studies have provided some of the largest and finest neuropsychological assessment databases for military personnel available and attest to the cost-effective leveraged value of DoD-sponsored ANAM test development and application.

Recently, customized modifications to the ANAM TBI Test Battery made by the University of Oklahoma's Center for the Study of Human Operator Performance (C-SHOP) for the U.S. Army have resulted in the ANAM4 TBI MIL Battery. The ANAM4 TBI and the ANAM4 TBI MIL Batteries do not differ with regard to the actual ANAM4 test modules presented or the order of test module presentation. The differences between these test modules reside in customized demographic features and characteristics of the ANAM Performance Report, which provide relevance and ease of integration with unique DoD medical records systems and clinical applications. The ANAM4 TBI MIL Battery provides precise, objective, automated measures of fundamental neurocognitive functions including response speed, attention/ concentration, immediate and delayed memory, spatial processing, and decision processing speed and efficiency. Importantly, these qualities of the ANAM4 TBI MIL Battery are consistent with past applications of computer-based testing and TBI, with normative work conducted by DVBIC, and with the Clinical Practice Guidelines and Recommendations published by the Defense and Veterans Brain Injury Center Working Group on the Acute Management of Mild Traumatic Brain Injury in Military Operational Settings.

2.2 Outdated Technology

Despite these computerized versions of traditional paper-and-pencil neuropsychological tests, the vast majority of current neuropsychological assessment procedures represent a technology that has not changed since the first scales developed in the early 1900s (e.g., Binet and Simon's first scale in 1905 and Wechsler's in 1939). For the past few decades, the Wechsler scales (in various manifestations; e.g., WAIS-R, WAIS III) have been the most widely used neuropsychological tests [36, 37, 38]. While automated versions were developed of the original WAIS [39] in 1969 and again in 1980 [40], these automations provided only rudimentary stimulus presentation and limited data recording. Since the 1980s, the automated versions are all but abandoned and now the focus is upon slight revisions of the paper-and-pencil versions with computerized scoring. In fact, the latest revisions of the Wechsler scales (e.g., Wechsler Adult Intelligence Scale—Third Edition [41]; Wechsler Intelligence Scale for Children—Fourth Edition [42]) offer little more than cosmetic change and improved standardization. This lack of technological advancement of the Wechsler scales is important because according to a 2005 study surveying assessment practices and test usage patterns among 747 North American, doctorate-level clinical neuropsychologists, the Wechsler Scales were the most frequently used tests in their neuropsychological assessments [43].

Robert Sternberg pointed out over a decade ago the discrepancy between progress in cognitive assessment measures like the Wechsler scales and progress in other areas of technology [44]. Sternberg used the example of the now obsolete black and white televisions, vinyl records, rotary-dial telephones, and the first commercial computer made in the United States, UNIVAC I to illustrate the lack of technological progress in the standardized testing industry. According to Sternberg, currently used standardized tests differ little from tests that have been used throughout this century. For example, while the first edition of the Wechsler Adult Intelligence Scale appeared some years before UNIVAC, the Wechsler scales (and similar tests) have hardly changed at all (aside from primarily cosmetic changes) compared to computers. Although one may argue that innovation in the computer industry is different from innovation in the standardized testing industry, there are still appropriate comparisons. For example, whereas millions of dollars spent on technology in the computer industry typically reflects increased processing speed and power; millions of dollars spent on innovation in the testing industry tends to reflect the move from multiple choice items to fill-in-the-blank items. Sternberg's statements are as true now as they were over a decade ago. While neuropsychology emphasizes its role as a science, its technology is not progressing in pace with other clinical neurosciences. Sternberg also points out neurocognitive testing needs progress in ideas, not just new measures, for delivering old technologies.

3 Ecologically Valid Neuropsychological Instruments

The historical development of clinical neuropsychology reveals that while the initial purpose of neuropsychological assessment was diagnosing persons with brain injury or disease, and then describing brain-behavior relationships, today clinical neuropsychologists are increasingly being asked to make prescriptive statements about everyday functioning [45]. This new role for neuropsychologists has resulted in increased emphasis upon the ecological validity of neuropsychological instruments. To establish ecological validity of neuropsychological measures, neuropsychologists focus on demonstrations of either (or both) verisimilitude and veridicality [46]. By verisimilitude, ecological validity researchers are emphasizing the need for the data collection method to be similar to real life tasks in an open environment. For the neuropsychological measure to demonstrate veridicality, the test results should reflect and predict real world phenomena [47, 48, 49].

3.1 Ecological Validity: Need to Incorporate Advanced Technology

In addition to the controversy related to whether or not current indices found on commonly used paper-and-pencil neuropsychological tests give us sufficient detail for prediction of the potential everyday difficulties likely to be faced by patients [50], a dearth of research has addressed the degree to which neuropsychological testing is ecologically valid [51]. There is also the issue of how should neuropsychologists go about improving the ecological validity of neuropsychological tests. Some neuropsychologists prefer a veridicality approach, in which results gleaned from neuropsychological measures are combined with behavioral observations, rating scales, and self-report measures (e.g., Everyday Memory Questionnaire [52]). A problem for this approach, however, is that while rating scales tend to have satisfactory reliability, they have weak correlations with performance measures (i.e., relatively low validity) [53]. Other neuropsychologists take the verisimilitude approach, in which completely new measures are developed that more closely approximate everyday activities and behaviors (e.g., Rivermead Behavioral Memory Test [54]; Behavioral Assessment of the Dysexecutive Syndrome [55]; and the Test of Everyday Attention [56]). Review of the ecological validity of neuropsychological tests has provided support for the superiority of verisimilitude tests as the results from these measures tended to be more consistently related to the outcome measures than the traditional paper-and-pencil tests. However, a problem for the verisimilitude approach is that these instruments do not appear to be migrating from research laboratories into the applied settings of clinical neuropsychologists [57]. An additional problem for this approach is that although these neuropsychologists have developed instruments that more closely approximate skills required for everyday functioning, have not made use of advances in computer technology. As a result, they are in danger of continuing the negative trend that deemphasizes psychology's role as a science. As Sternberg has contended, neurocognitive testing needs progress in ideas, not just new measures, for delivering old technologies.

4 Virtual Environments Offer Advanced Ecological Validity

While standard neuropsychological measures have been found to have adequate predictive value, their ecological validity may diminish predictions about real world functioning. Traditional neurocognitive measures may not replicate the diverse environment in which persons live. Additionally, standard neurocognitive batteries tend to examine isolated components of neuropsychological ability, which may not accurately reflect distinct cognitive domains [58, 59] Although today's neuropsychological assessment procedures are widely used, neuropsychologists have been slow to adjust to the impact of technology on their profession. While there are some computer-based neuropsychological assessments that offer a number of advantages over traditional paper-and-pencil testing (e.g., increased standardization of administration; increased accuracy of timing presentation and response latencies; ease of administration and data collection; and reliable and randomized presentation of stimuli for repeat administrations), the ecological validity of these computer-based neuropsychological measures is less emphasized. As mentioned above, only a handful of neuropsychological measures have been developed with the specific intention of tapping into everyday behaviors like navigating one's community, grocery shopping, and other activities of daily living. Of those that have been developed, even fewer make use of advances in computer technology.

Virtual reality (VR) is as an advanced computer interface that allows humans to become immersed within a computer-generated simulation. Potential VR use in assessment and rehabilitation of human cognitive processes is becoming recognized as technology advances. Since VEs allow for precise presentation and control of dynamic perceptual stimuli (visual, auditory, olfactory, gustatory, ambulatory, and haptic conditions), they can provide ecologically valid assessments that combine the veridical control and rigor of laboratory measures with a verisimilitude that reflects real life situations. Additionally, the enhanced computation power allows for a range of the accurate recording of neurobehavioral responses in a perceptual environmental that systematically presents complex stimuli. Such simulation technology appears to be distinctively suited for the development of ecologically valid environments, in which three-dimensional objects are presented in a consistent and precise manner. As a result, subjects are able to manipulate three dimensional objects in a virtual world that proffers a range of potential task demands.

Virtual reality applications that focus on component cognitive processes, including attention processes [60, 61, 62], spatial abilities [63, 64, 65] memory [66], and executive functions [67], are now being developed and tested. The increased ecological validity of neurocognitive batteries that include assessment using virtual scenarios may aid differential diagnosis and treatment planning. Within a VE, it is possible to systematically present cognitive tasks targeting neuropsychological performance beyond what are currently available using traditional methods [68]. Reliability of neuropsychological assessment can be enhanced in VEs by better control of the perceptual environment, more consistent stimulus presentation, and more precise and accurate scoring [69]. Virtual Environments may also improve the validity of neurocognitive measurements via the increased quantification of discrete behavioral responses, allowing for the identification of more specific cognitive domains [70]. Virtual environments could allow for neurocognition to be tested in situations that are more ecologically valid. Participants can be evaluated in an environment that simulates the real world, not a contrived testing environment [71].

According to Rizzo et al [72], the application of VR to neuropsychological assessment is distinctively important because it represents the potential for more than a simple linear extension of existing computer technology for human use. For Rizzo, it is important that VR does more than simply automate the paradigms of the past. Instead, VEs provide a paradigm shift for the future. Here, Rizzo is reflecting Neisser's [73] contention that the findings from many traditional cognitive assessments have not been demonstrated to generalize beyond the narrow laboratory context. However, there is an essential tension between persons striving for ecological validity and persons interested in maintaining experimental control. For example, Banaji and Crowder [74] have contended that the ecological approach to neurocognitive research is inconsequential and that scientific progress necessitates greater emphasis on experimental control. This seems to hold especially true for much of the work that has been done in virtual and augmented reality because the focus of ecological validity tends to be upon verisimilitude and not veridicality. As Banaji and Crowder have challenged, if neurocogitive measures fail to establish internal validity, then one can conclude nothing from study findings. Likewise, if VR-based neuropsychological assessments do not take seriously the importance of veridicality, we have attractive simulations (i.e., verimilitude), but do not have an ability to reliably and validly predict a person's performance on real world activities (i.e., veridicality).

There are a number of neuropsychology researchers would agree with Neisser that there are legitimate concerns about the verisimilitude (or ecological validity) of neuropsychological assessments. However, while the issue of ecological validity has been discussed in the literature, little has been done to remedy this situation. Instead, there are attempts to simply enhance the external validity of neuropsychological assessments. The concepts of external and ecological validity are related but not interchangeable. External validity involves the extent to which findings from research studies can be generalized across a variety of persons, times, and settings as well as to generalizations to specific persons, times, and settings. Given that traditional paper-and-pencil neuropsychological measures were developed for localization and the focus was upon double dissociation, enhancements tend to reflect endeavours to increase external validity. Hence, they do not typically require experimental conditions to mirror real life conditions. Neuropsychological measures are quite basic in their presentation and do not appear concerned with the level of verisimilitude found in VEs. Instead, they strive to be externally valid—to be consistently predictive of behavior exhibited in the real world.

As mentioned above, though, Banaji and Crowder have contended that the ecological approach to neurocognitive research is insignificant and that scientific progress necessitates greater emphasis on experimental control. Unfortunately, much VR research supports this dichotomy. While verisimilitude is a major emphasis in reported studies using VR for psychology and neuropsychology, much less emphasis is placed upon veridicality—reliability, validity, and psychometric properties. In a recent meta-analysis of VR studies, Parsons and Rizzo [75] sought to examine the magnitude of changes in affective functioning that occurred following virtual reality exposure therapy (VRET). Although the results of the meta-analysis revealed that VRET had statistically large effects across affective domains, findings must be interpreted with caution given the inconsistencies in the research designs across studies. Many of the VRET studies did not include control groups, and many were not randomized clinical trials. As a result, the authors had diminished confidence that affective enhancements were directly related to or caused by VRET. Additionally, even though Parsons and Rizzo attempted to identify possible moderators of affective improvements, this was not possible because necessary information was either not reported or on occasions where it was reported it was done so in insufficient detail. This lack of information related to affective improvements and presence, immersion, anxiety and/or phobia duration, demographics (e.g. age, gender, and ethnicity) may reflect a limited range of values given the selection criteria employed by most studies. Thus, the findings of this meta-analysis may not generalize to patients with anxiety disorders in general. Similarly, a host of other factors that could not be directly analyzed might moderate affective regulation, including differences among treatment centers in terms of beliefs about best practices concerning VRET, timing of sessions, and concurrent psychopharmacological treatment.

It could be argued that the challenge for neuropsychologists using VEs is to develop techniques that simultaneously satisfy the demands of internal validity, external validity, and ecological validity. Hence, the development of an ecologically valid VE should include psychometric rigor (i.e. internal validity, external validity) as well as verisimilitude and veridicality (i.e. ecological validity). Achieving such standards requires consideration of a number of issues: 1) Correspondence: the tasks performed within VEs should correspond to the pertinent aspects of real world activities and environments; 2) Representativeness: the tasks developed should be representative of persons who are performing the tasks; 3) Expedience: research problems should have practical consequences on real world functioning if they are to be components of verisimilitude and veridicality; and 4) Relevance: outcome measures need to have relevance to the practical problem being investigated.

4.1 Correspondence

The tasks performed within VEs should correspond to the pertinent aspects of real-world activities and environments. This is reflected in attempts by neuropsychologists to establish the ecological validity of their measures through demonstrations of verisimilitude. Within a VE, it is possible to systematically present cognitive tasks targeting different domains of performance beyond what are currently available using traditional methods. Verisimilitude of cognitive assessment can be enhanced in VR by better control of the perceptual environment, more consistent stimulus presentation, and more precise and accurate scoring. The validity of VR-based neuropsychological measurements may be improved via the quantification of more discrete behavioral responses, allowing for the identification of more specific cognitive domains. It may also be possible that VR-based neuropsychological assessments will allow for neurocognition to be tested in situations that are more ecologically valid. Participants can be evaluated in an environment that simulates the real world, not a contrived testing environment. Neuropsychological evaluations that include VR technology will bring verisimilitude—the quality or state of appearing to be true—to synthetic experiences. Verisimilitude emphasizes the need for the data collection method to be similar to real life tasks in an open environment. Neuropsychologists interested in such VR-based measures will design immersive experiences that proffer compelling interactive narratives that simulate the real world.

4.2 Representativeness

The tasks developed should be representative of persons who are performing the tasks. In addition to consideration of tasks and outcome measures, it is also important to consider subject populations. Specifically, it is important to ensure that these populations are representative of persons performing the tasks. A crucial aspect of quality VR-based neuropsychological studies is that authors adequately report the sampling strategy used so that readers may assess whether the sample reported upon is representative of the target population. This aspect of study design is critical because poor sampling will undermine the generalizability of the study and/or reduce the validity in situations where sampling bias is introduced. For study findings to be generalizable to the population as a whole, the sample must be representative of the population from which it is drawn. As such, the ecologically valid assessment should be culturally sensitive and have a design that reflects appropriate language—language-appropriate interventions that emphasize greater familiarity with cultural knowledge. Also, the visually mediated environments found within virtual reality emphasize the need for VR researchers to develop environments that make use of symbols and concepts shared by the population in question. This is an important issue for VR researchers in a multicultural society. Therefore it is important that neuropsychological assessments adequately handle cultural information (e.g. values, customs, and traditions). In addition to the development of future virtual simulations, there may also be need that existing treatment manuals be adapted to incorporate cultural values and validate the uniqueness of the particular ethnic group [76] While typical neuropsychological tests make efforts at such generalizability, an ecologically valid assessment will align the neurocognitive assessment with the target population's or the assessed person's socioculture mileu.

4.3 Expedience

The research problems should have practical consequences on real world functioning if they are to be components of veridicality. For the neuropsychological measure to demonstrate veridicality, the test results should reflect and predict real world phenomena. Research problems should be expedient instruments whose worth is measured by something more than the mere verisimilitude standard, in which the concepts and theories somehow mirror reality. For veridicality, the standard of measurement is more an issue of pragmatic instrumentalism, in which significance is measured by how effective VR-based neuropsychological assessment results are at explaining and predicting future neurocognitive performance and activities of daily living. A common methodological procedure for establishing the veridicality might be to ensure the construct validity of virtual reality-based neuropsychological measures using the multitrait-multimethod matrix, in which a given construct is measured by multiple methods to develop a method-by-measure matrix [77]. The multitrait-multimethod matrix offers a method for assessment of the convergent and divergent validity of a measure by examining its pattern of correlations with other measures. In a VR-based neuropsychological study, for example, all the included scales might measure the construct of memory, but vary either on the level of memory impairment or the aspect of memory being assessed. Convergent validity coefficients (assessing memory domain) derived from the VR-based memory score and the traditional neuropsychological measures of memory could be assessed to see if they are significantly (statistical significance) larger than correlations of different measures assessing domains other than memory within the same array of measures. Evidence for discriminant validity would be indicated when correlations of different scales assessed using different measures were lower than the convergent validity coefficients [78].

4.4 Relevance

A condition essential for obtaining ecologically valid answers to neurocognitive assessment questions regarding real world functioning, is the inclusion of criterion tasks that include significant aspects of real world tasks and environments. While computerized assessments are helpful in examining performance on laboratory tasks, these measures are insufficient when attempting to obtain resolutions to practical problems. It is important to note that current neuropsychological tests (paper-and-pencil as well as computerized tests) do help provide insight into the source or nature of individual differences in performance. However, exclusive reliance on laboratory measures is rarely sufficient to gain insight into the types of problems neuropsychologists encounter when receiving a referral for a neuropsychological assessment. Hence, for VR-based neuropsychological measures to meet the ecological issue of relevance there is need for neuropsychologists to understand that experience includes both particulars and relations between those particulars. Therefore both the particulars of the neurocognitive domains and the relations between these domains that result from interaction within the real world deserve a place in our explanations. Any VR-based neuropsychological measure is flawed if it stops at assessing a neurocognitive domain and fails to explain how meaning, values, intentionality, and activities of daily living can arise from that.

In general, ecologically valid VR research should focus on real world practical problems such as issues related to return to work, driving competence, self-care, education and training, interface design, and treatment. A valid research question might look at the ways in which individual differences (within a given clinical population) impact VR-based neuropsychological assessments for determining the patient's ability to perform activities of daily living.

5 Conclusions

Much of this manuscript has dealt with two essential limitations that have resulted from neuropsychology's refusal of technological adaptation: First, current neuropsychological assessment procedures represent a technology that has barely changed since the first scales were developed in the early 1900s. Second, while the historical purpose of clinical neuropsychology was differential diagnosis of brain pathology, technological advances in other clinical neurosciences have changed the neuropsychologist's role to that of making ecologically valid predictions about the impact of a given patient's neurocognitive abilities and disabilities on everyday functioning.

Within this manuscript, virtual reality-based neuropsychological assessments have been presented as technologically advanced and ecologically valid neuropsychological instruments that may be used to address real world outcomes. A primary focus of this manuscript has been the explication of the necessary characteristics for ecologically valid VR assessment of neuropsychological functioning. To design such ecologically valid VR tools one must identify representative real world tasks. Following the identification of representative tasks, the characteristics of these tasks must be defined and a set of goal-directed activities established. Next, a virtual scenario that represents the task may be developed so that neuropsychological performance may be investigated within ecologically valid research environments. Neuropsychologists will need to subject these VEs to techniques that simultaneously satisfy the demands of internal validity, external validity, and ecological validity. Again the achievement of such standards requires insurance that the tasks performed within VEs correspond to the pertinent aspects of real world activities and environments. The tasks developed should be representative of persons who are performing the tasks. The research problems should have practical consequences on real world functioning if they are to be components of verisimilitude and veridicality. Finally, the outcome measures need to have relevance to the practical problem being investigated.

In conclusion, the advanced computer interfaces found in virtual reality allow humans to become immersed within a computer-generated environment. Enhanced accuracy in recording, coding, and storing of a range of neurobehavioral responses elicited from complex stimuli will allow for improved data analytics and predictive validity. It is argued that virtual environments may be uniquely suited for assessment of daily activities, allowing for presentation of three-dimensional objects in a consistent and precise manner, which subjects can then manipulate depending on a range of task demands. The precise presentation and control of dynamic perceptual stimuli (visual, auditory, olfactory, gustatory, ambulatory, and haptic conditions) in the virtual environment allows neuropsychologists the opportunity to develop statistically and clinically significant tasks within a virtual world. It is believed that a future possible neuropsychological assessment battery will make use of virtual reality to combine the control and rigor of technologically advanced computerized laboratory measures, the psychometric rigor (veridicality) of traditional paper-and-pencil assessments, and approximate the verisimilitude of real life situations.

References

1. Benton, A.L.: Some problems associated with neuropsychological assessment. Bulletin of Clinical Neuroscience 50, 11–15 (1985)
2. Broca, P.: Sur le siège de la faculté du langage articulé. Bulletine de Société Anthropologique 6, 337–339 (1865)
3. Wernicke, C.: Der Aphasische Symptomkomplex. Cohn & Weigart, Breslau (1874)
4. Binet, A., Henri, V.: La psychologie individuelle [Individual psychology]. L'Annee Psychologique 2, 411–465 (1896)
5. Binet, A., Henri, V.: La fatigue intellectuelle [Intellectual tiredness]. Schleicher, Paris (1898)
6. Binet, A., Simon, T.: Methodes nouvelles pour le diagnostic du niveau intellectuel des anormaux [New methods to diagnose the intellectual level of abnormals]. L'Annee Psychologique 11, 245–366 (1905)
7. Binet, A., Simon, T.: Le developpement de l'intelligence chez les enfants [The development of intelligence in children]. L'Annee Psychologique 14, 1–94 (1908)
8. Anastasi, A., Urbina, S.: Psychological testing, 7th edn. McMillian, New York (1997)
9. Yerkes, R.M.: Behaviorism and genetic psychology. Journal of Philosophy, Psychology, and Scientific Methods 14, 154–160 (1917)
10. Yoakum, C.S., Yerkes, R.M.: Army mental tests. Holt, New York (1920)
11. Conkey, R.: Psychological changes associated with head injuries. Archives of Psychology 33, 5–22 (1938)
12. Shipley, W.C.: A self-administered scale for measuring intellectual impairment and deterioration. Journal of Psychology 9, 371–377 (1940)
13. Benton, A.L., Howell, I.L.: The use of psychological tests in the evaluation of intellectual function following head injury. Psychosomatic Medicine 3, 138–151 (1941)
14. Goldstein, K., Scheerer, M.: Abstract and concrete behavior: an experimental study with special tests. Psychological Monograph 43, 1–151 (1941)
15. Wells, F.L., Ruesch, J.: Mental Examiner's Handbook. Psychol. Corp., New York (1942)
16. Hunt, H.F.: A practical clinical test for organic brain damage. Journal of Applied Psychology 27, 375–386 (1943)
17. Halstead, W.C.: Brain and Intelligence. Univ. Chicago Press, Chicago (1947)
18. Reitan, R.M.: Investigation of the validity of Halstead's measure of biological intelligence. Archives of Neurology 73, 28–35 (1955)
19. Lezak, M.D.: Neuropsychological Assessment, 3rd edn. Oxford University Press, New York (1995)
20. Spreen, O., Strauss, E.: A compendium of neuropsychological tests: Administration, norms and commentary, 2nd edn. Oxford University Press, New York (1998)
21. Mitrushina, M.N., Boone, K.L., D'Elia, L.: Handbook of normative data for neuropsychological assessment. Oxford University Press, New York (1999)
22. Heaton, R.K., Grant, I., Matthews, C.G.: Comprehensive norms for an expanded Halstead–Reitan Battery: Demographic corrections, research findings, and clinical applications. Psychological Assessment Resources, Odessa (1991)
23. Teuber, H.-L.: Physiological psychology. Annual Review of Psychology 6, 267–296 (1955)
24. Pribram, K.H.: Languages of the brain. Prentice-Hall, Englewood Cliffs (1971)
25. Ruff, R.M.: A friendly critique of neuropsychology: Facing the challenges of our future. Archives of Clinical Neuropsychology 18, 847–864 (2003)

26. Schatz, P., Browndyke, J.: Applications of computer-based neuropsychological assessment. Journal of Head Trauma Rehabilitation 17, 395–410 (2002)
27. Eckerman, D.A., Carroll, J.B., Forre, C.D., Guillen, M., Lansman, M.: An approach to brief field testing for neurotoxicity. Neurobehavioral Toxicology & Teratology 7, 387–393 (1985)
28. Waterfall, R.C.: Automating standard intelligence tests. J. Autovisual. Media Med. 2, 21–24 (1979)
29. Space, L.G.: A console for the interactive on-line administration of psychological tests. Behav. Res. Meth. Instr. 7, 191–193 (1975)
30. Beaumont, J.G.: The validity of the Category Test administered by on-line computer. Journal of Clinical Psychology 31, 458–462 (1975)
31. Heaton, R.: Wisconsin Card Sorting Test: Computer Version 3 for Windows. Psychological Assessment Resources, Lutz (1999)
32. CogSport. Parkville, Victoria, Australia: CogState, Ltd (1999)
33. Lovell, M.R., Collins, M.W., Podell, K., Powell, J., Maroon, J.: ImPACT: Immediate Post-Concussion Assessment and Cognitive Testing. NeuroHealth Systems, LLC, Pittsburgh (2000)
34. Johnson, D.R., Vincent, A.S., Johnson, A.E., Gilliland, K., Schlegel, R.E.: Reliability and construct validity of the Automated Neuropsychological Assessment Metrics (ANAM) mood scale. Archives of Clinical Neuropsychology 1, 73–85 (2008)
35. Erlanger, D.M., Feldman, D.J., Kutner, K.: Concussion Resolution Index. HeadMinder, Inc., New York (1999)
36. Hartlage, L.C., Telzrow, C.F.: The practice of clinical neuropsychology in the US. Archives of Clinical Neuropsychology 2, 200–202 (1980)
37. Guilmette, T.J., Faust, D., Hart, K., Arkes, H.R.: A national survey of psychologists who offer neuropsychological services. Archives of Clinical Neuropsychology 5, 373–392 (1990)
38. Lees-Haley, P.R., Smith, H.H., Williams, C.W., Dunn, J.T.: Forensic neuropsychological test usage: an empirical survey. Archives of Clinical Neuropsychology 11, 45–51 (1996)
39. Elwood, D.L., Griffin, R.: Individual intelligence testing without the examiner. Journal of Consulting and Clinical Psychology 38, 9–14 (1972)
40. Vincent, K.R.: Semi-automated full battery. Journal of Clinical Psychology 36, 437–446 (1980)
41. Wechsler, D.: Wechsler Adult Intelligence Scale, 3rd edn. WAIS-3. Harcourt Assessment, San Antonio (1997)
42. Wechsler, D.: Wechsler Intelligence Scale for Children—, 4th edn. WISC-IV. Harcourt Assessment, San Antonio (2003)
43. Rabin, L., Barr, W., Burton, L.: Assessment practices of clinical neuropsychologists in the United States and Canada: A survey of INS, NAN, and APA Division 40 members. Archives of Clinical Neuropsychology 20, 33–65 (2005)
44. Sternberg, R.J.: Intelligence and lifelong learning: What's new and how can we use it? American Psychologist 52, 1134–1139 (1997)
45. Long, C.J.: Neuropsychological tests: A look at our past and the impact that ecological issues may have on our future. In: Sbordone, R.J., Long, C.J. (eds.) Ecological Validity of Neuropsychological Testing, pp. 1–14. GR Press/St. Lucie Press, Delray Beach, FL (1996)
46. Franzen, M.D., Wilhelm, K.L.: Conceptual foundations of ecological validity in neuropsychological assessment. In: Sbordone, R.J., Long, C.J. (eds.) Ecological validity of neuropsychological testing, pp. 91–112. St Lucie Press, Boca Raton (1996)

47. Chaytor, N., Schmitter-Edgecombe, M.: The Ecological Validity of Neuropsychological Tests: A Review of the Literature on Everyday Cognitive Skills. Neuropsychology Review 13, 181–197 (2003)
48. Silver, C.H.: Ecological validity of neuropsychological assessment in childhood traumatic brain injury. Journal of Head Trauma Rehabilitation 15, 973–988 (2000)
49. Ready, R.E., Stierman, L., Paulsen, J.S.: Ecological Validity of Neuropsychological and Personality Measures of Executive Functions. Clinical Neuropsychologist 15, 314–323 (2001)
50. Wilson, B.A.: Ecological validity of neuropsychological assessment: Do neuropsychological indexes predict performance in everyday activities? Applied and Preventive Psychology 2, 209–215 (1993)
51. Nussbaum, P.D., Goreczny, A., Haddad, L.: Cognitive correlates of functional capacity in elderly depressed versus patients with probable Alzheimer's disease. Neuropsychological Rehabilitation 5, 333–340 (1995)
52. Sunderland, A., Harris, J.E., Baddeley, A.D.: Do laboratory tests predict everyday memory? A neuropsychological study. Journal of Verbal Learning and Verbal Behavior 22, 341–357 (1983)
53. Larrabee, G.J., Crook, T.H.: The ecological validity of memory testing procedures: Developments in the assessment of everyday memory. In: Sbordone, R.J., Long, C.J. (eds.) Ecological validity of neuropsychological testing, pp. 225–242. GR Press/St. Lucie Press, Delray Beach, FL (1996)
54. Wilson, B.A., Cockburn, J., Baddeley, A.: The Rivermead Behavioral Memory Test. Thames Valley Test Co./Gaylord/National Rehabilitation Services, Reading/England MI (1985)
55. Wilson, B.A., Alderman, N., Burgess, P., Emslie, H., Evans, J.J.: Behavioural Assessment of the Dysexecutive Syndrome (BADS), Thames Valley Test Company. Bury St. Edmunds, England (1996)
56. Robertson, I.H., Ward, T., Ridgeway, V., Nimmo-Smith, I.: The Test of Everyday Attention. Thames Valley Test Co./Gaylord/National Rehabilitation Services, Suffolk/UK/MI (1994)
57. Rabin, L.A., Burton, L.A., Barr, W.B.: Utilization rates of ecologically oriented instruments among clinical neuropsychologists. Clinical Neuropsychologist 5, 727–743 (2007)
58. Parsons, T.D., Rizzo, A.A., van der Zaag, C., McGee, J.S., Buckwalter, J.G.: Gender and cognitive performance: a test of the common cause hypothesis. Aging, Neuropsychology, & Cognition 12, 78–88 (2005)
59. Parsons, T.D., Rizzo, A.A., Buckwalter, J.G.: Backpropagation and regression: comparative utility for neuropsychologists. Journal of Clinical & Experimental Neuropsychology 26, 95–104 (2004)
60. Parsons, T.D., Bowerly, T., Buckwalter, J.G., Rizzo, A.A.: A controlled clinical comparison of attention performance in children with ADHD in a virtual reality classroom compared to standard neuropsychological methods. Child Neuropsychology 13, 363–381 (2007)
61. Parsons, T.D., Cosand, L., Courtney, C., Iyer, A., Rizzo, A.A.: Neurocognitive Workload Assessment using the Virtual Reality Cognitive Performance Assessment Test. LNCS (LNAI), vol. 5639, pp. 243–252 (2009)
62. Parsons, T.D., Rizzo, A.A.: Neuropsychological Assessment of Attentional Processing using Virtual Reality. Annual Review of CyberTherapy and Telemedicine 6, 23–28 (2008)

63. Parsons, T.D., Larson, P., Kratz, K., Thiebaux, M., Bluestein, B., Buckwalter, J.G.: Sex differences in mental rotation and spatial rotation in a virtual environment. Neuropsychologia 42, 555–562 (2004)
64. Wolbers, T., Weiller, C., Buchel, C.: Neural foundations of emerging route knowledge in complex spatial environments. Brain Research Cognitive Brain Research 21, 401–411 (2004)
65. Morganti, F., Gaggioli, A.: A virtual reality extended neuropsychological assessment for topographical disorientation: a feasibility study. Journal of NeuroEngineering and Rehabilitation 4(26) (2007)
66. Parsons, T.D., Rizzo, A.A.: Initial Validation of a Virtual Environment for Assessment of Memory Functioning: Virtual Reality Cognitive Performance Assessment Test. Cyberpsychology and Behavior 11, 17–25 (2008)
67. Elkind, J.S., Rubin, E., Rosenthal, S., Skoff, B., Prather, P.: A simulated reality scenario compared with the computerized Wisconsin Card Sorting Test: an analysis of preliminary results. CyberPsychology & Behavior 4, 489–496 (2001)
68. Rizzo, A.A., Schultheis, M.T., Kerns, K., Mateer, C.: Analysis of assets for virtual reality applications in neuropsychology. Neuropsychological Rehabilitation 14, 207–239 (2004)
69. Rizzo, A.A., Buckwalter, J.G.: Virtual reality and cognitive assessment and rehabilitation: the state of the art. In: Riva, G. (ed.) Virtual reality in neuro-psycho-physiology, pp. 123–146. IOS Press, Amsterdam (1997)
70. Rizzo, A.A., Kim, G.: A SWOT analysis of the field of Virtual Rehabilitation and Therapy. Presence: Teleoperators and Virtual Environments 14, 1–28 (2005)
71. Giuseppe, R., Fabrizia, M., Andrea, G.: Presence and rehabilitation: toward second-generation virtual reality applications in neuropsychology. Journal of NeuroEngineering and Rehabilitation 1(9) (2004)
72. Neisser, U.: Memory: What are the important questions? In: Gruneberg, M.M., Morris, P.E., Sykes, R.N. (eds.) Practical Aspects of Memory, pp. 3–24. Academic Press, San Diego (1978)
73. Banaji, M., Crowder, R.G.: The bankruptcy of everyday memory. American Psychologist 44, 1185–1193 (1989)
74. Cook, T.D., Campbell, D.T.: Quasi-experimentation: Design & analysis issues for field settings. Houghton Mifflin, Boston (1977)
75. Parsons, T.D., Rizzo, A.A.: Affective Outcomes of Virtual Reality Exposure Therapy for Anxiety and Specific Phobias: A Meta-Analysis. Journal of Behavior Therapy and Experimental Psychiatry 39, 250–261 (2008)
76. Bernal, G., Bonilla, J., Bellido, C.: Ecological validity and cultural sensitivity for outcome research: Issues for the cultural adaptation and development of psychosocial treatments with Hispanics. Journal of Abnormal Child Psychology 23, 67–82 (1995)
77. Campbell, D.T., Fiske, D.W.: Convergent and discriminant validation by multitrait-multimethod matrix. Psychological Bulletin 56, 81–105 (1959)
78. Parsons, T.D., Rizzo, A.A.: Initial Validation of a Virtual Environment for Assessment of Memory Functioning: Virtual Reality Cognitive Performance Assessment Test. Cyberpsychology and Behavior 11, 17–25 (2008)

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