The Design of Virtual Reality Applications for Psychological Interventions

A Thesis Submitted to the University of Kent for the Degree of PhD in Digital Arts

By
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This thesis is dedicated to my family who have been a great source of encouragement and support

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Abstract

Virtual Reality is an emerging technology with a variety of potential benefits in research, assessment and treatment. The ability to create and control the dynamic 3-dimensional environments within which behavioural responses can be measured and recorded, allows this technology to offer ways of psychological assessment that traditional methods may not be capable of providing. Although plenty of research has been carried out to explore the use of VR in psychology, little was done to further the understanding of the processes of VR design. Considering the potential possibilities of VR in the area of psychological treatments, it is necessary to investigate how VR applications can be designed to meet the needs of psychologists, researchers and end-users. To achieve this, the use of co-design approach is recommended. It is also important to provide stakeholders with the co-design pipeline and technical guidelines on how to create these applications.

In the first stage of the research, a series of case studies for pain management and anxiety disorders were carried out to investigate the design opportunities and challenges in the development of mobile VR psychotherapy applications. This includes the description of the development and design process of VR applications, as well as the tools and techniques used for it. Specifically, a mobile VR application for pain management research, where I took part as a designer/developer, and another mobile VR application for anxiety disorders were developed. A study was conducted to examine the innovative use of mobile VR technology to deliver a form of cognitive bias training for anxiety disorder. Forty-two students high in trait anxiety completed one session of either virtual reality cognitive bias modification of interpretations training (VR-CBM-I) or standard CBM-I training for performance anxiety. Overall, the results showed that based on post-training, the VR-CMB-I training reduced perceived anxiety significantly more than the standard CBM-I training. Moreover, the increase in anxiety response in the VR-CMB-I training condition after the stressor task was also significantly less when compared to the standard training. Thus, there was a significant increase in positive interpretations and a significant decrease in negative interpretations in both conditions after the training. The results from this stage allowed to identify some key co-design phases as well as techniques and components needed for a successful mobile VR application development.

In the second stage of the research, the more advanced system was developed. The use of Multi-User Virtual Reality (MUVR) as a tool to offer effective intervention for representative users at high-risk of eating disorder (ED) was explored. Fourteen females deemed at high risk of ED completed one session of either MUVR intervention based on Acceptance and Commitment Therapy (ACT) or MUVR intervention based on Play Therapy (PT). The use of VR for remote psychotherapy was explored, and the impact of such intervention on both therapists and participants was observed. In addition, the design opportunities, pitfalls, and recommendations for future deployment in psychological interventions were presented.

The findings from this thesis help extend the knowledge regarding the design, development and implementation of VR applications in psychotherapy. Contributions within the study can help psychologists, developers and researchers in identifying how these VR applications can be best designed and applied for psychological treatments. Additionally, these findings were formed into a set of guidelines to aid developers and psychologists in creating better VR applications to facilitate psychological interventions.

Keywords: Virtual Reality, Multi-User Virtual Reality Intervention, Pain management, Anxiety disorders, Eating Disorders, co-design.

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List of Acronyms

ACT: Acceptance and Commitment Therapy
API: Application Programming Interface
AR: Augmented Reality
AVFS: Alter Visual Feedback Strategy
BMI: Body Mass Index
CBM: Cognitive Bias Modification
CBM-I: Cognitive Bias Modification of Interpretations
CBT: Cognitive Behaviour Therapy
CGI: Computer-Generated Imagery
CPU: Central Processing Unit
DOF: Degree of Freedom
DTC: Direct-to-Consumer
ED: Eating Disorder
EDDS: Eating Disorder Diagnostic Scale
ET: Exposure Therapy
FCDS: Figurative Cognitive Fusion Scale
FOV: Field of View
fps: Frames Per Second
GPU: Graphics Processing Unit
HCI: Human-Computer Interaction
HMDs: Head Mounted Displays
IB: Interpretation Bias
ICT: Information and Communication Technology
IEQ:Immersion Experience Questionnaire
LOD: Level of Details
ME: Mirror Exposure Therapy
mHealth: Mobile Health
MMO: Massive Multiplayer Online
MUVR: Multi-User Virtual Reality
OBS: Open Broadcaster Software
OIF: Operation Iraqi Freedom
PBC: Private Body Consciousness
PPI: Patient and Public Involvement
PT: Play Therapy
PTSD: Post-Traumatic Stress Disorder
PUN: Photon Unity Networking Engine
SDK: Software Development Kit
STAI: State-Trait Anxiety Questionnaire
SUS: Slater-Usoh-Steed Questionnaire
SUS: System Usability Scale
UI: User Interface
UNET: Unity Multiplier and Networking System
VE: Virtual Environment
VPL: Visual Programming Language Research Inc
VR: Virtual Reality
VR-CBM-I: Virtual Reality Cognitive Bias Modification of Interpretations

VRET: Virutal Reality Exposure Therapy
VRH: Virtual Reality Hypnosis
VR-SCT: Virtual Reality Social Cognition Training
VRTK: Virtual Reality Tool Kit
WCS: Weight Concerns Scale
WIM: World-in-Miniature
WIMP: Windows Icons Menus and Points Interface
WIP: Walking in Place
WMR: Windows Mixed Reality

Chapter 1

Introduction

1.1 Background and problem

Recently, there has been a move towards applying new computer technologies, such as Virtual Reality (VR), in therapeutic treatments and rehabilitation. A particularly exciting field in which VR is emerging is psychological interventions. The growth of publications and scientific research devoted to the psychological effect of VR systems shows great interest in this field of new computer technologies. For instance, the use of VR technology in Exposure Therapy (VRET) for mental health treatment and within clinical research shows the added benefits and long-term effects for different types of anxiety disorders, phobias, and post-traumatic stress disorder (Motraghi, Seim, Meyer, & Morissette, 2014; Opriş et al., 2012; Parsons & Rizzo, 2008b; Powers & Emmelkamp, 2008; Valmaggia, Latif, Kempton, & Rus-Calafell, 2016). More recently, VR has also been extended as an additional treatment of psychosis, cognitive rehabilitation and social skills training interventions (Rus-Calafell, Garety, Sason, Craig, & Valmaggia, 2018; Veling, Moritz, & van der Gaag, 2014).

In essence, VR allows generating natural realistic and imaginary environments. Inside these recreated virtual environments (VE), researchers and clinicians can introduce more relevant stimuli incorporated in an important and recognisable setting for patients (Rizzo, Schultheis, Kerns, & Mateer, 2004). In the early days, one of the disadvantages of using VR systems was their financial cost. The first immersive generation of VR platforms was limited to industries or research centres where the high cost of the hardware and software development was justified (Tougaw & Will, 2003). However, in the past decade, the price of VR systems has been decreasing rapidly and is likely to continue to do so. In this regard, an understanding of the low-cost VR, especially smartphone VR, application development and its implementation for psychological interventions may be potentially useful in providing an effective VR training platform which could be accessed by a large number of users.

Although VR technology is still undergoing its developmental phase, the possibilities for VR and its implementation in psychology could be broad. It is exciting to see what future advances in VR could bring to psychological health and therapeutic treatment. Nowadays, technologies such as the internet and video teleconferencing, are becoming common methods for diagnosis, therapy, education, and training (Simonson, Smaldino, & Zvacek, 2014; Martin-Khan et al., 2012). Videoconferencing and other forms of telecommunication are now used in a variety of health care settings (e.g., forensic and correctional centres), applications (e.g., renal dialysis), and other medical fields (e.g., ophthalmology, oncology, dermatology and psychiatry) in addition to psychological interventions (Rees & Stone, 2005). One of the interesting and new directions will be the integration of these telecommunication technologies and VR together. This could allow people to interact in shared virtual environments regardless of their physical location (Riva, 2005); thus theoretically it could be possible to provide remote VR psychological interventions.

As VR could potentially be part of the future of psychological interventions, it is crucial to develop new approaches for VR therapy and investigate the possibilities of application of these tools into therapists' day-to-day practice. Such knowledge would be invaluable for designers and psychologists in creating effective VR applications for psychological interventions to support people. To ensure appropriate development of VR therapy, psychologists and clinicians must have a clear understanding of the opportunities and challenges in the design of the application for psychological interventions.

1.2 Aim and research questions

To help expand the knowledge of VR in psychology, this PhD research aims to investigate the problem of collaborative design (co-design) and development of VR systems, and the creation of a new generation of remote Multi-User VR systems (MUVR) in this area of application. It can primarily show the importance of applying the co-design method to VR psychological interventions, as well as solve problems in the development of VR applications to make it easier for psychologists and developers to approach the design of these systems. In addition, this research could lead to the further introduction of not only PC-based VR systems for psychotherapy but also mobile VR, in particular. Finally, the development of a new generation of MUVR systems will further advance the application and development of VR in psychotherapy.

In order to achieve the aims of the research, three iterative co-design studies were conducted to examine the design opportunities and pitfalls of mobile VR and Multi-User VR (MUVR) systems. It allowed to develop and provide a co-design framework for psychological interventions. Co-design is an approach where a range of specialists contribute creatively towards formulation and solution of complex problems in a variety of areas, including healthcare (Sanders & Stappers, 2008). Such approach typically requires multiple stakeholders (internal-people from the area of the problem; and external-people from other sectors) to come together and actively create, in order to improve the systems and services.

This research aimed to help psychologists, developers and researchers in identifying how VR systems can be co-designed and implemented in practice as well as showing possible future directions in VR treatment. This thesis will address the following research questions:

1. *Why is a co-design approach important for designing effective psycho-therapeutic VR applications?*

   The first research question attempts to explore why the application of the co-design approach is necessary for implementation during the development of VR applications for psychotherapy. Understanding the application of co-design for VR in psychotherapy is the first step in developing an effective application. Chapters 3 and 5 describe the co-design process applied for the development of the VR applications for pain management, anxiety disorder and eating disorders studies.

2. *What are the potential benefits and challenges of using mobile VR tools in psychological treatment?*

   The second research question aims to examine the potential opportunities and pitfall in applying mobile VR tools in psychotherapy. Chapter 3 describes the co-design and development of mobile VR applications for pain management and anxiety disorder studies. It also provides suggestions on how to optimise a mobile VR application for better performance, as well as demonstrates a set of tools and techniques used for its development. In addition, the results of the application testing are discussed, and guidelines for its testing are suggested.

   Chapter 4 provides the results from the anxiety disorders research study. This study was aimed to examine the feasibility of using mobile-based stereoscopic-3D VR technology in a Cognitive Bias Modifications of Interpretations training paradigm (VR-CBM-I) for performance anxiety. Having co-designed and developed the VR application in chapter 3, it was then used to improve users' experience with the training program, and potentially enhance the training effects on state anxiety, emotional reactivity, and interpretation bias. The developed VR-CBM-I training was compared to the standard training paradigm (standard CBM-I). This study used questionnaires to gain a better understanding of the system usability, differences in anxiety levels and interpretations after the sessions. In addition, Chapter 4 provides suggestions based on the findings and literature from the study for future reference in designing and developing of mobile VR systems for Cognitive Bias Modifications of Interpretations training (CBMI). Once, the potential steps in designing the effective VR application were discovered, we moved to the third research question.

3. *What are the benefits and design challenges of remote Multi-User VR psychotherapy?*

   Chapters 5 and 6 describe the third research study which aims to examine the feasibility of designing a MUVR for remote psychotherapy based on the ideas of Play Therapy, Acceptance and Commitment Therapy and Exposure Therapy. The study makes contributions towards the growing research in VR healthcare. It describes the software and hardware used in the study as well as the development and co-design of a MUVR platform for psychotherapy. It also identifies the design factors which work (or do not work) in MUVR psychotherapy together with the challenges of deployment of such systems in real-life psychotherapy sessions.

4. *What design guidelines could be derived for the co-development of VR applications in psychotherapy?*

The final research question is answered by combining the knowledge from the studies reported in chapters 3, 4, 5 and 6. Based on the findings from these studies, suggestions are made on how VR applications can be designed to support psychological health. The results are summarised in Chapter 7, which provides the co-design guidelines on how to develop, test and deploy a VR application for psychological interventions. This guideline aims to bridge the gap between developers and psychologists so that the co-design process can be more productive and lead to a successful implementation of the application. It also gives proposals for designers and developers about the elements they need to focus on while developing a VR application.

1.3 Scope

This thesis deals with the co-design process and development challenges of VR applications for psychological interventions via a number of case studies. Its focus lies specifically on the fully immersive VR systems which are meant to be used with immersive displays, i.e. Head-Mounted Displays (HMDs) with 3D input devices (e.g. controllers). Traditional Cave immersive VE systems, normally room-sized cubic systems with wall/floor projections (Ihrén & Frisch, 1999), are not within the scope of this research. This research focuses on low-cost, commercially available devices that are accessible by a large number of people, such as Samsung Gear VR[1] for mobile devices and Oculus Rift[2] for PC-based systems.

It should also be noted that the goal of this thesis is not to prove the impact VR systems have on psychotherapy. Instead, this thesis focuses on investigating how VR applications for PC and smartphone systems could be co-designed and improved to support psychological health, given the current level of development in computer technologies. This is done by investigating the iterative co-design process of a number of case studies. Firstly, two studies demonstrate how mobile VR tools could be designed and applied as part of Pain Management and Cognitive Bias Modification training (see chapter 3). Previous studies utilising the use of VR technologies have tended to focus on the PC-based VR systems that were used as part of Exposure Therapy (ET) for Depression, Anxiety, Social Phobias, Post-Traumatic Stress Disorder (PTSD), Pain Management etc. (Difede & Hoffman, 2002; Gonçalves, Pedrozo, Coutinho, Figueira, & Ventura, 2012; Parsons & Rizzo, 2008a; Price, Mehta, Tone, & Anderson, 2011; Riva, 2005; Rothbaum, Hodges, & Kooper, 1997; Rothbaum, Hodges, Watson, Kessler, & Opdyke, 1996; Wiederhold & Wiederhold, 2005). Secondly, a third study (see chapters 5, 6) investigates the design opportunities and deployment challenges of introduced MUVR system to facilitate remote psychotherapy. Challenges and practical recommendations for designing effective MUVR applications for both therapists and patients were also discussed.

Although behavioural and emotional issues (e.g. aggression, hostility, fears, etc.) are essential in research which explores the use of technology in psychological treatments, such issues are not the main focus here. The main focus of this thesis is to explore the design challenges faced in the process of co-creation of

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[1] https://www.samsung.com/global/galaxy/gear-vr/

[2] https://www.oculus.com/rift/?locale=en_GB

psychological VR applications.

1.4 Contribution

The contributions of this thesis are as follows:

1. Demonstrate how VR systems can be designed collaboratively (co-design) with stakeholders for effective psychotherapy treatments.
2. Demonstrate the co-design process and provide the technical implementation of mobile VR applications for pain management and anxiety disorders case studies as well as insights into the limitations of this technology (Chapter 3).
3. Demonstrate the results from the case study on how mobile VR tools can be used as well as how they can influence the experience, effectiveness and engagement of the Cognitive Bias Modification of Interpretations training to reduce the anxiety level of participants (Chapters 4).
4. Introduce and provide an understanding of how Multi-User VR systems could be designed to support psychological health. Provide findings from the various observations, group discussions and interviews carried out during the Eating Disorder study process with therapists and participants. Thus contributing further knowledge regarding the interactions between users with Multi-User VR system (Chapters 5, 6).
5. Provide a practical set of guidelines on how VR systems can be co-designed to be effectively applied in psychotherapy (Chapter 7).

During this research, I designed and developed different VR applications in collaboration with psychologists, clinical psychologists, therapists and human-computer interaction (HCI) experts from different countries (Netherlands, Cyprus, Japan, UK). The results of the conducted studies were published in a number of peer-reviewed journals/conferences (see Table 1.1), and one publication is under review (publication 2 in Table 1.1).

Chapter	**Journal/Conference**	**Title**	**Citation**
3,4	Journal of Medical Internet Research (JMIR) Mental Health	Believing is Seeing: A proof-of-concept study on using mobile Virtual Reality to boost the effects of Interpretation Bias Modification for anxiety	Otkhmezuri, B.*, Boffo, M.*, Siriaraya, P., Matsangidou, M., Wiers, R. W., Mackintosh, B., Ang, C. S. & Salemink, E. (2019).
5,6	Human Computer Interaction (HCI) Journal	"Now I Can See Me: A Virtual Representation revealed the Real Self". Multi-User Virtual Reality Remote Psychotherapy for Eating Disorders	Matsangidou M*, Otkhmezuri B.*, Ang, C. S., Avraamides, M. N., Riva G., Gaggioli A., Iosif D. & Karekla M. (under review)
3	INTERACT: Conference on Human-Computer Interaction	How Real Is Unreal? Virtual Reality and the Impact of Visual Imagery on the Experience of Exercise-Induced Pain.	Matsangidou, M., Ang, C. S., Mauger, A. R., Otkhmezuri, B., & Tabbaa, L. (2017, September).
3	Psychology of Sport and Exercise	Is your virtual self as sensational as your real? Virtual Reality: The effect of body consciousness on the experience of exercise sensations.	Matsangidou, M., Ang, C. S., Mauger, A. R., Intarasirisawat, J., Otkhmezuri, B., & Avraamides, M. N. (2018).

(* Shared first authorship)

Table 1.1: A list of publications arising directly from this Ph.D. thesis

1.5 Structure

The structure of the thesis is laid out as follows:

- Chapter 2 provides a literature review on the topics related to this thesis: such as history and development of VR technology, application of the technology in various areas as well as its potential use in psychology.

- Chapter 3 presents the co-design process for two case studies, as well as describing the tools and techniques used for the mobile VR application development for pain management and anxiety disorder therapy. In addition, it provides technical implementation and testing guidelines for mobile VR systems.

- Chapter 4 presents the results from the study carried out to help understand the implementation of mobile VR as part of Cognitive Bias Modification training. Quantitative analysis was performed to examine students' anxiety level, changes in interpretations and attitudes towards the mobile VR system use. Following this, the study compared the results between the PC-based version of Interpretation Bias training and the mobile VR version to determine the benefits of mobile VR systems. The results of the study provide a key understanding of the particular design for the application, which would be suitable for integration into psychological interventions.

- Chapter 5 presents a third study which highlights the process of designing a Multi-User PC-based VR system. The system for eating disorder therapy was co-designed, developed and refined based on the iterative development process with clinical psychologists.

- Chapter 6 presents the results from the eating disorder study, which included four therapists and fourteen students with high risk of eating disorders. The aim of the study was to explore the use of remote VR systems in treatment, user engagement, as well as to assess the potential practical use of the system. Through the use of questionnaires and interviews, the study examined students' and therapists' perceptions towards the overall design, quality and usability of the system, as well as user satisfaction after the sessions. This data provided valuable information for the design framework.

- Chapter 7 provides an overall discussion and conclusion to the thesis where mobile and PC-based VR applications were designed, developed and tested to support psychological health. Based on these results, the Co-Design VR Application Development Guidelines is presented, which aims to help psychologists and developers to co-design a therapy-specific VR application. Finally, some possible future research directions in this field are presented.

Chapter 2

Literature Review

The present chapter contains a review of the existing literature for a range of topics that are directly related to this thesis. More specifically, definitions to key terms and concepts, such as “Virtual Reality” (VR), “Virtual Environment” (VE), “Head-mounted Display” (HMD) technology, “Presence and Immersion”, “Interactive Devices” and “Co-design approach” are given and discussed. Also, the use of VR technology and VR interventions in general, and specifically in psychotherapy, is examined. In addition, the co-design approach and its application are described. Finally, a summary of the key points is presented.

This chapter is divided into five sections: Section 2.1 discusses VR technology and its development; Section 2.2 describes the concepts of Presence and Immersion and provides information about interactive devices; Section 2.3 discusses the use of VR technology in different areas and particularly in healthcare; Section 2.4 describes co-design approach; and Section 2.5 provides a summary.

2.1 Virtual Reality

Over the past few decades, several researchers have tried to define Virtual Reality (VR). If we consider behavioural science, VR is described as a computer interface that immerses the user in a three-dimensional virtual world that the user perceives as real (Schultheis & Rizzo, 2001). The term virtual reality was described for the first time by Jaron Lanier (Lanier, 2017) as a collection of technological devices, such as position trackers, computers, head-mounted displays (HMDs) and interaction controllers. McCloy and Stone in their review shared the same vision and described VR in healthcare as a “collection of technologies that allow people to interact efficiently with 3D computerised databases in real time using their natural senses and skills” (McCloy & Stone, 2001). All these definitions describe VR from a certain point of view. However, they all have something in common, namely the users’ experiences in a virtual world.

Virtual world, also called Virtual Environment (VE), is a computer-generated, three-dimensional environment which surrounds the user when he or she is immersed in VR (Wann & Mon-Williams, 1996). In VE, the user plays an important role and his or her actions directly affect the content of the entire VE. A VE is often accompanied by visual and audio effects and sometimes by olfactory and other effects. Although the ideas and concepts of VR have not undergone radical changes in the past few decades, the technology has made a dramatic leap in terms of software development and the variety of VR devices available.

2.1.1 History of the technological development of VR systems

The history of immersive VR devices goes back to the first “Link Trainer” simulator (Jerald, 2015). The Link Trainer is a flight simulator created by Edwin Link in 1929 for the US military and it can be considered the first prototype of a VR system. The Link Trainer was used to train thousands of pilots by simulating real flight conditions. The Link simulator consisted of a fuselage with a cabin mounted on an air-pumping mechanism which responded to the pilot’s controls and simulated the appropriate flight manoeuvres (see Figure 2.1). The flight simulator simultaneously reproduced the readings of flight instruments and movement in three dimensions.

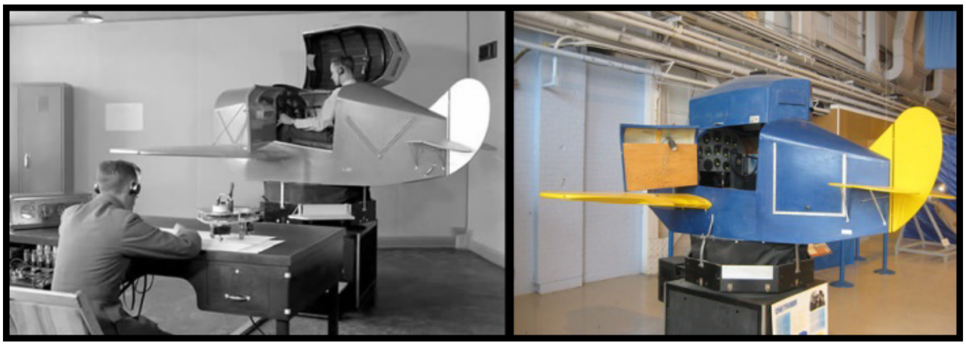

Figure 2.1: The first flight simulator “Link Trainer” (retrieved from Zuk, 2010)

In 1955, an American filmmaker and inventor Morton Heilig proposed involving not only sight and hearing but all the other senses in the filmmaking process. In 1957 he finished his work on the experimental theatre called “The Sensorama” (see Figure 2.2), the first virtual reality machine (Jerald, 2015).

Figure 2.2: The Sensorama machine (retrieved from Martirosov & Kopecek, 2017)

The Sensorama consisted of several mechanical parts. Users sat on a chair that moved with the device, and a large stereoscopic screen and speakers formed visual and sound patterns. The machine also used a wind tunnel to create air effects as well as a scent sprayer. However, The Sensorama was way ahead of its time and could not attract investors. The apparatus did not go beyond the prototype stage (Heilig, 1992).

The Sensorama was not the only VR device Heilig was working on in the 1950s; he was also working on the development of a portable head-mounted display (HMD) or helmet (see Figure 2.3). According to the specifications, this device, which looked very similar to modern VR headsets, used lenses with a horizontal and vertical viewing angle of 140 degrees. The device included stereo headphones and an air outlet nozzle to simulate a wind blowing in the face. By analogy with The Sensorama, this device was able to transmit various smells to simulate different environments. Although Heilig received a patent for his invention in the 1960s, he did not create a working model of this headset.

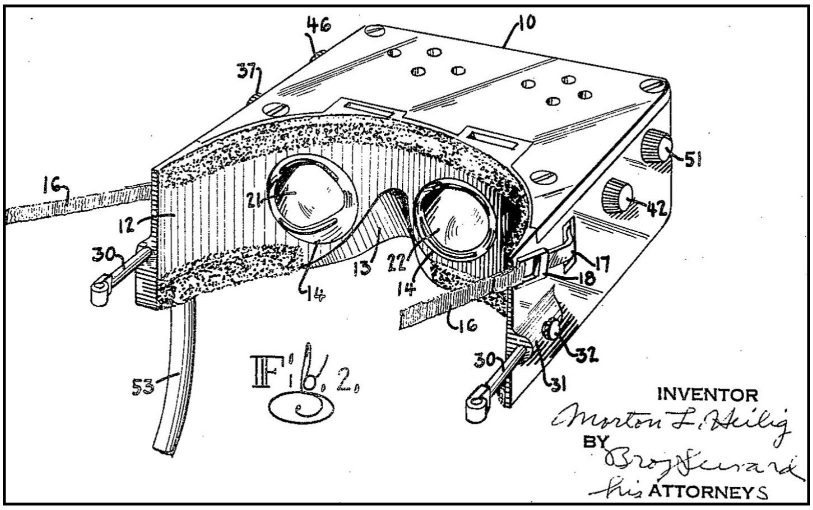

Figure 2.3: Heilig's 1960 Stereoscopic Television Apparatus (retrieved from Heilig, 1960)

In 1961, engineers working in the American company Philco invented a device called "Headsight" (Greenwald et al., 2017). Headsight (see Figure 2.4) was designed for video surveillance and showed a live image from a nearby security camera on the screen. It used a single light source and a magnetic motion tracking system. Depending on the movement of the operator's head, it was able to send a signal to rotate the camera. This device is considered to be the first head-tracking HMD.

Technically, the device had nothing to do with VR, since the image on the screen was displayed from an ordinary camera, but it made a substantial contribution to the technological development of subsequent VR devices.

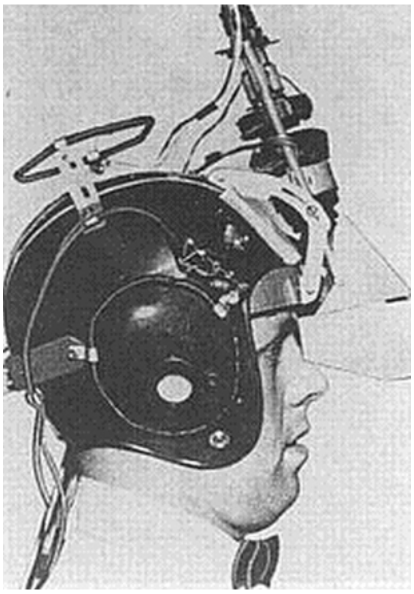

Figure 2.4: The Philco Headsight from 1961 (retrieved from Comeau & Brian, 1961)

Achievements in visualisation and advances in human-computer interfaces led to the emergence of VR systems which allowed the creation of artificial reality using computer technology. In 1965, American computer scientist Ivan Sutherland described an ideal VR system (Sutherland, 1965).

Sutherland's concept included:

1. A computer that creates and displays in real-time a 3D virtual world.
2. The virtual world would be seen through an HMD and appear real to an observer, complemented by three-dimensional sound and tactile stimuli.
3. This system would enable users to manipulate objects, and change their shape and position on the screen as simply as they would do it in real life.

Sutherland understood that at that time technology was not advanced enough to implement his concept, so he tried to create a simpler device which would incorporate some of the features. In 1968, therefore, Sutherland created the first HMD which displayed a computer-generated image as opposed to earlier versions where the device was connected to external cameras (Oakes, 2007).

Due to its substantial weight, the device had to be suspended from the ceiling, which gave it its name: The Sword Of Damocles (see Figure 2.5). The images, generated by a computer and displayed on the stereoscopic screen, created an illusion of depth. Stereo sound was played simultaneously with the image. To track the rotation of the head and synchronise it with the image, movement sensors were also installed. Thus, for the first time there was an opportunity to immerse a person in an artificial world, where the user was not just an observer, but also an active participant. This invention gave a great impetus to the subsequent development of virtual reality.

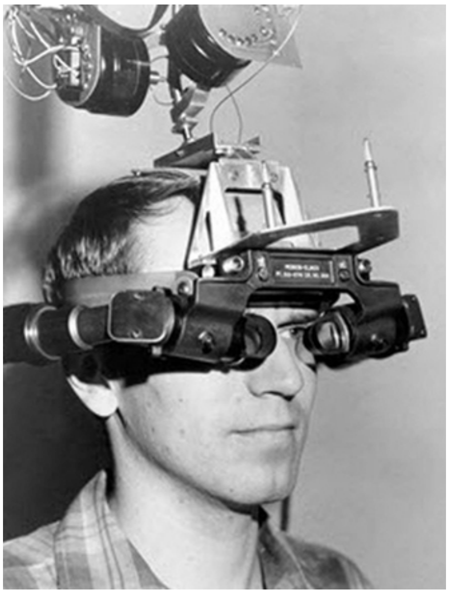

Figure 2.5: The first VR display with an artificial environment: The Sword Of Damocles (retrieved from Elaine, 1970)

In the late sixties, American computer artist Myron Krueger began experiments with human-computer interaction systems. Krueger assumed that any benefit of HMDs in terms of visual engagement was negated by the cumbersome equipment which could distance users from the world in which they were meant to be engaged. Having taken into consideration the direction of development of HMDs, Krueger proposed an alternative concept of perception and immersion in a virtual environment.

During the mid-1970s Myron Krueger developed a computer technology called “The Videoplace” (Krueger, Gionfriddo, & Hinrichsen, 1985). “The Videoplace” was designed to respond to user actions with the help of cameras, projectors and specially designed hardware (see Figure 2.6). In practice, “The Videoplace” was a number of interconnected rooms, each of which housed a large screen with a video projector located behind it. Upon entering the room, the user saw his or her own image projected on the screen, albeit in a somewhat primitive form. It was possible to move around the room, interact with images of other people, and change the size and colour of your own silhouette. It was also possible to interact with computer-generated objects on the screen for the first time. This was the first projection-based system.

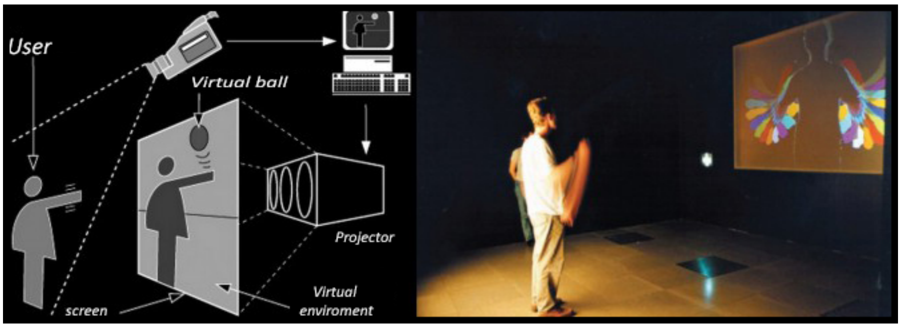

Figure 2.6: The VideoPlace by Myron Krueger: principle of operation and example of the device in action (retrieved from Lee & Lee, 2014)

Later, in 1992, students of the University of Illinois improved this technology and the first working prototype of the "CAVE system" was developed (see Figure 2.7). The CAVE is a multi-user, projection-based VR system where the user is surrounded by stereoscopic computer-generated images projected onto the walls of the room (cubicle) (Cruz-Neira, Sandin, & DeFanti, 1993). Users are required to wear shutter glasses which work by blocking either one or the other eye in synchronisation with the projected image. An electromagnetic tracking system and a sensor attached to the glasses help create the correct perspective of the image. The user can walk naturally and freely within the CAVE system (Cruz-Neira et al., 1993).

Figure 2.7: The first CAVE system (retrieved from Leigh et al., 2012)

Starting from 1984, Visual Programming Language Research Inc. (VPL), created by Jaron Lanier and Thomas Zimmerman, was engaged in the development and production of VR devices. Employees of the company designed the first primitive virtual reality system. It consisted of a VPL VR HMD and VPL Data Glove (see Figure 2.8 B). VPL Data Gloves were designed to manipulate objects in virtual space (Zimmerman, Lanier, Blanchard, Bryson, & Harvill, 1987).

In addition, the same company released the first virtual reality suit, the VPL Data Suit (see Figure 2.8 A). The VPL Data Suit was a complete body suit that was designed to measure the degree of flexion of the major joints of the body. Thus, with the help of the VPL Data Suit it was possible to digitise the movement of arms, legs and torso. The position of the body in virtual space was measured using a system of four additional tracking sensors called "Polhemus" (Ojha, 1994).

Figure 2.8: A) VPL Data Suit; B) VPL HMD and Data Glove (retrieved from Pape, 2007; MacKenzie, 1995; Codognet, 1998)

In the late 1990s, interest in VR technology declined. Most VR devices released in the 1990s ultimately proved to be unsuccessful and in the next few years only a few companies made any attempts to continue working in this area. However, in the last decade interest in VR has gained momentum again.

2.1.2 VR systems today

The development of the computer game industry and computer technology brought back demand for VR systems. VR has never been more popular than it is today. VR systems are becoming more portable and affordable (Slater, 2018). Based on the platform, VR systems can be grouped into mobile and PC-based VR (Paulus, Suryani, Wijayanti, Yusuf, & Iskandarsyah, 2019).

2.1.2.1 PC-based VR systems

Today the most popular PC-based virtual reality systems are the Oculus Rift[1] and HTC Vive[2] released in 2016 (see Figure 2.9). Both these systems operate according to the Sutherland concept described earlier (see Section 2.1.1).

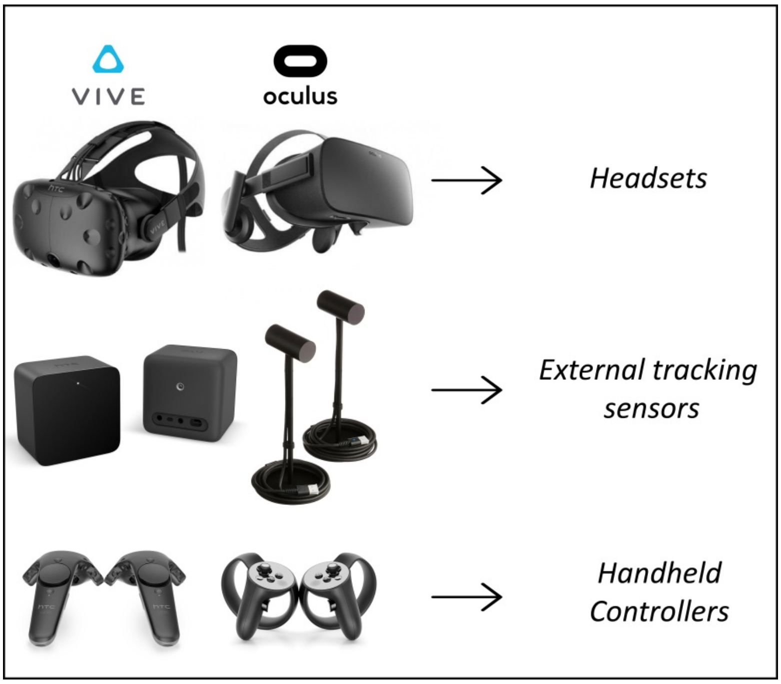

Figure 2.9: HTC Vive and Oculus Rift VR systems

The HMDs of these two systems are equipped with a screen displaying the image for the left and the right eye separately. The person focuses on computer-generated images that appear on the screens. The HMDs cover the eyes fully so that the real world is completely shut out (see Figure 2.10). Sensors inside the headset allow changes to the virtual point of view according to the movement of the user's head. The external tracking sensors track the user's physical position and allow his or her virtual representation to move accordingly in the virtual world. The technical characteristics of the HTC Vive and Oculus Rift VR systems are relatively similar. The resolution of both displays is 1200 x 1080 pixels and

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[1] https://www.oculus.com/rift/?locale=en_GB

[2] https://www.vive.com/eu/

both headsets have a field of view (FOV) equal to 110 degrees. The FOV is the region observable by the human eye (B. Sekuler, Patrick J. Bennett, Mor, 2000).

However, the main difference between the two models is the size of the tracking area. The Oculus Rift tracking sensors cover a distance of 5 or 8 m^2 for two or three sensors, respectively, whereas the HTC Vive sensors cover a distance of 15 m^2 (Borrego, Latorre, Alcaniz, & Llorens, 2018). For a successful run of these systems, PC specifications have to exceed or match the minimum requirements specified on the official company's web pages.

Figure 2.10: Side view of the Oculus rift headset (retrieved from OQPlay, 2019)

In 2015, Microsoft released its own VR platform: Windows Mixed Reality (WMR). WMR became the first standardised platform for VR headsets, which led to an increase in manufacturing of VR headsets by various brands (e.g. Acer Inc[3], HP Inc[4] etc.) in the next few years. Instead of tracking sensors, WMR uses in-built cameras (see Figure 2.11), which analyse the environment and track the hand controllers. This feature is advantageous in terms of the unlimited tracking area; however, hand tracking becomes compromised when the user places his or her hands in an area not covered by the cameras, such as behind him or herself. After HTC and Oculus, WMR became the third VR platform to support room tracking and hand controllers.

Figure 2.11: Dell WMR system (retrieved from Warren, 2017)

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[3] https://www.acer.com/ac/en/US/content/series/wmr

[4] https://www8.hp.com/us/en/campaigns/mixedrealityheadset/overview.html

2.1.2.2 Mobile VR systems

With the rapid development of mobile technologies, manufacturing of portable VR headsets has become possible. The most popular designs of portable VR systems are Google Cardboard[5] and Samsung Gear VR[6], but there is a great variety of such headsets (see Figure 2.12). The principle of operation of such devices is that a smartphone, which acts as the display, central processing unit (CPU) and graphics processing unit (GPU) of the VR system, is inserted into the headset. Although the in-built smartphone sensors (accelerometer and gyroscope) allow tracking of the rotation of the user's head, the mobile VR systems do not support tracking of the whole of the user's body and its physical position.

Figure 2.12: Mobile VR headsets

Over the past decade, rapid development in the area of digital technologies has seen a significant reduction in the cost of computers and other IT devices. VR equipment has become a common and widely available product. The price of a VR headset has dropped significantly from 50,000 US dollars (Riva, 2003) to 400 US dollars (e.g. Oculus Rift). Nowadays, most users wishing to experience VR have a better chance of doing it than ever before. The future of VR is looking bright. Currently available systems are capable of simulating highly realistic virtual environments, thus allowing users to experience the sense of presence and immersion in VR.

2.2 Presence and immersion

Due to technical developments in the field of VR, which were discussed in the previous sections, the quality of visual information presented in the VE, and the VEs themselves, have significantly improved. These improvements not only boosted VR technologies in the game industry (Zyda, 2005), where this technology is very popular, but also opened possibilities in research. In the field of psychotherapy, this means that it is now possible to create a more realistic exposure in a 3D environment, thereby potentially influencing the impact of a therapy/intervention. The main aspects influencing the user experience in VR are immersion, presence and interactivity (Schuemie, Van Der Straaten, Krijn, & Van Der Mast, 2001).

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[5] https://vr.google.com/cardboard/

[6] https://www.samsung.com/global/galaxy/gear-vr/

Immersion. Immersion is an objective measure and generally refers to a person's feeling of being involved in the experience (Qin, Rau, & Salvendy, 2009). In VR, it also refers to physical immersion. "Immersion describes the technical capabilities of a system; it is the physics of the system" (Slater & Sanchez-Vives, 2016). Physical immersion involves manipulating human sensory systems (especially the visual system) to create the effect that a user is surrounded by a real world.

The level of immersion depends on the specifications of the VR system. HMD parameters, such as FOV and frame-rate, affect the level of immersion in VR. The frame-rate is the number of frames per second that the computer graphics system can produce (Sanchez-Vives & Slater, 2005). In the case of a complex VE where the visual load puts a great deal of pressure on the graphics, rendering delay can sometimes appear. This can result in a jittering of the image which will ultimately have an impact on the level of immersion.

Experts distinguish three types of VR system depending on the nature of the human interaction with it: non-immersive, semi-immersive and fully immersive (Ma & Zheng, 2011). A non-immersive VR system is generally a system with average graphic parameters where a 3D VE is reproduced on a flat screen and can be controlled by the input devices (e.g. mouse and/or keyboard). A semi-immersive VR system is a PC-based system with higher level specifications where the content is shown on a larger monitor or single/multiple screen projectors. The system provides the user with limited interaction via the tracking of body movement; an example of such a system is CAVE. A fully immersive VR system is a high-specification system where the user wears a HMD and is provided with additional devices for interaction in VE, e.g. data gloves and full body motion recognition systems. Perception of one's own body plays an important role in creating a high level of immersion in VR: it is a representation of oneself, the basis of one's interaction with VR and a means of communication with other virtual objects (Slater, Usoh, & Steed, 1994).

Presence. Immersion can lead to presence through stimulation of the participant's sense of "being" in the VE (Slater & Sanchez-Vives, 2016). Originally, VE was defined by the technical components used for its implementation, however, in the course of time the main definition distinguishing it from three-dimensional graphics became the phenomenon called presence (Pettifer, 1999). Presence is defined as an illusion of being in the environment created by the means of computer-generated graphics (Witmer & Singer, 1998). The level of presence depends on one's personal perception of the content and other factors in the VR system. Users can experience different levels of presence with the same system at different times (Wilson & Soranzo, 2015).

The concept of presence and its derivatives, for example, social presence became a subject of intense psychological research. Social presence can be distinguished and defined as a level of awareness of co-presence of another human, being or intelligence (Biocca & Nowak, 2001). Researchers distinguish three levels of social presence: perceptual, subjective and intersubjective (Biocca & Harms, 2002). The perceptual level focuses on the awareness and detection of the collective presence of another person's body in VE. The subjective level concentrates on being able to access another person's thoughts and emotions, and the intersubjective level measures to which degree one or both persons perceive the social presence as mutual (see details in Biocca & Harms, 2002).

Interactivity. Another key component in the definition of virtual reality is interactivity. Virtual reality is often associated with the ability of the user to move within the virtual world, and interact with virtual objects, characters and places in the virtual environment. In order to provide this interactivity and facilitate a level of immersion and presence, a high level of realism in one's body representation in VR is necessary. In the past decade, a variety of VR devices have been developed to aid with this task (see Figure 2.13).

Figure 2.13: Examples of body tracking systems. On the left is a hand and fingers tracking system attached to a HMD, in the middle is an example of a full-body tracking system and on the right is an example of a feet tracking system (retrieved from Lang, 2016; Lang, 2013; James, 2015)

2.2.1 Head tracking

As a major contributing factor for an effective VR experience, head tracking exists in every commercially available VR system. The system generally includes external tracking sensors and a gyroscope to determine the position of the user's head. In mobile systems, due to the absence of external tracking sensors, the function of head tracking is done through the use of the gyroscope and accelerometer in a smartphone. Such systems are referred to as having three degrees of freedom (3DOF) (Papaefthymiou, Plelis, Mavromatis, & Papagiannakis, 2015). Degrees of freedom (DOF) is the number of directions in which an object can move in a three-dimensional space. This means that mobile VR systems only support tracking of the rotation of the head.

Figure 2.14: The infrared sensors of the Oculus Rift headset (retrieved from Lang, 2016)

In contrast, PC-based VR systems support tracking of the position as well as rotation of the user's head. These systems are referred to as having six degrees of freedom (6DOF) and the Oculus Rift and HTC Vive headsets have, for example, in-built infrared sensors (see Figure 2.14). External tracking sensors (see Figure

2.9) are then used in order to detect infrared sensors and thus track the position of the user's head.

2.2.2 Hand tracking

VR developers are constantly trying to improve the quality of the simulated environment in the virtual space. The controllers used for interaction with the virtual world are just as important for immersive VR as the visualisation tools. Currently, input devices range from simple devices, such as joysticks and remote controllers to more sophisticated electronic gloves (Bowman, Wingrave, Campbell, & Ly, 2001).

In order to provide the user with a way to interact with virtual objects in VR, hand movement tracking is required, which is generally done with or without tracking of the fingers. The user's hand can be tracked with a wrist tracker or through the use of a tracked handheld device (Vinayagamoorthy, Garau, Steed, & Slater, 2004). If more detailed information is required such as the shape and movement of the hand, a data glove can be used (Sherman & Craig, 2003). To track the position of the user's fingers and other flexions of the hand, these data gloves include additional sensors, while the wrist tracker sensor is usually installed directly on the glove (see Figure 2.15) (Sherman & Craig, 2003).

Figure 2.15: Manus VR glove input device

Handheld controllers are another type of interface used in VR. Although some handheld controllers, such as joysticks, can be designed as a generic interface for a variety of different applications, others, such as gaming guns, are constructed specifically for a particular application (see Figure 2.16). The use of handheld devices leads to an indirect tracking of the user's hands. Indirect tracking refers to the use of physical objects rather than body parts to estimate the position of the user and his or her hands in particular. For example, the movement of a handheld device, such as a joystick or gun, serves as an indicator of the position of the user's hands (Vinayagamoorthy et al., 2004).

Figure 2.16: Examples of handheld devices. On the left: motion tracking system with gun; on the right: joystick (retrieved from Benson, 2013)

2.2.3 Eye tracking

Eye tracking technology allows a system to track the direction in which the user's eyes are pointing in relation to his or her head. Given its relatively recent development, it is yet to be tried in a greater variety of VR applications (Duchowski et al., 2000; Skulmowski, Bunge, Kaspar, & Pipa, 2014). There are two basic areas in which eye tracking can be used. One such area is monitoring of the direction of the gaze, for instance, the point on a screen that the user's eyes are looking at is called the focus point. The focus point is an important feature widely used in several domains. In video games (Smith & Graham, 2006), the focus point is used to display a higher level of detail of an object which the user is looking at - this can be useful in VR development.

Another area where eye tracking could be used is in the interaction with the user interface and objects in VR. Based on movement of the user's eyes, objects in VR could be selected or moved around. The eye-gaze interaction for a flat screen has been studied extensively (Vidal, Bulling, & Gellersen, 2013; Ehmke & Wilson, 2007). For instance, Smith and Graham (2006) experimented with the first-person navigation mode in a video game by changing the orientation of the camera to match it with the direction of the viewer's gaze. In the third-person navigation mode, it was proposed to automatically move the user's virtual representation (avatar) to the position the user is looking at. With the development of new affordable eye-tracking systems for VR, such as Fove[7] researchers have an opportunity to explore new VR interaction techniques (Piumsomboon, Lee, Lindeman, & Billinghurst, 2017).

2.2.4 Walking in VR

Control of movement in VR is often achieved through the use of handheld devices. There are, however, devices that allow the user to move in VR naturally, using his or her legs. The aim of such devices is to imitate the user's movement in different directions in VR whilst maintaining his or her position in the real world.

In 2006 Powered Shoes (see Figure 2.17) were introduced at a multimedia and graphics technologies conference SIGGRAPH (Iwata, Yano, & Tomioka, 2006). To imitate walking in VR, Powered Shoes had three motorised computer-

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[7] https://www.getfove.com/

controlled rollers attached to the soles of the shoes. Powered Shoes allowed the user to walk naturally through a VE without moving away from the spot they were actually standing on in the real world. One of the disadvantages of Powered Shoes was the inability to step sideways.

Figure 2.17: Virtual Reality Powered Shoes (retrieved from Iwata, Yano, & Tomioka, 2006)

Alongside Powered Shoes, the omni-directional treadmill (Darken, Cockayne, & Carmein, 1997) is another technology worthy of attention (see Figure 2.18). The treadmill allows for multi-directional movement whilst retaining the position of the user. This device resembles an ordinary treadmill, the belt of which changes its direction according to the direction of the user's movement. The device is equipped with a system of movement control which alters the speed of the moving belt and thus prevents the user from getting too close to the edge.

Figure 2.18: A person immersed in VR with HTC Vive and omni-directional treadmill technology (retrieved from Streeter, 2018)

The current capabilities of HMDs and related equipment are far from ideal. With the technical development of input and tracking devices it is possible to improve interaction in the virtual environment, which directly affects the user experience as a whole, expanding the boundaries of the immersion level.

2.3 Application of VR systems

The recent surge in media coverage of VR has revived an interest amongst the general public in regard to the potential of the technology. The coverage mainly focused on the entertainment industry, and specifically video games and immersive film. Previous studies showed that VR technology can also be applied in other areas, such as education and training (Jensen & Konradsen, 2018), and also to research in psychology (Botella, Fernández-Álvarez, Guillén, García-Palacios, & Baños, 2017). Combining the renewed interest in VR with its possibilities for applications in other fields could be an exciting prospect.

2.3.1 VR in entertainment and news

One of the areas where VR has seen success is the entertainment industry (Bowman & McMahan, 2007). The Disneyland attraction called Pirates of the Caribbean (Sehell & Shochet, 2001), provides visitors with an immersive VR adventure experience. It allows four people to simultaneously interact in a VE which is provided on a wraparound 3D screen accompanied with 3D sound effects while standing on a motion platform. The development of such a complex system was undertaken to achieve better immersion. This experience is incomparable with the first-person flat-screen desktop PCs and console-gaming systems. Despite the fact that the experience is immersive, this type of entertainment was limited in gameplay time and the number of installations due to its high cost (Bowman & McMahan, 2007). Nonetheless, the entertainment industry, and especially video games, is still one of the main areas where VR is emerging.

In addition, several news services, such as ABC News and the New York Times have experimented with filming and produced work within VR (Jones, 2017). The New York Times developed an application which allowed users to watch news stories through mobile 360-degree films. Millions of Google Cardboards were distributed to subscribers that allowed them to use their smartphones to experience a virtual world; the Cardboard was used to diversify its audience in a challenging news environment (Jones, 2017).

2.3.2 VR in education

Many professions require the expertise of specialists not only with good knowledge, but also practical experience. That is why education has become one of the areas of application of VR, as it can provide an opportunity to gain experience whilst minimising the consequences of possible errors. VR has been explored as a practical training tool for medical students. In the study (O'toole et al., 1999), a VR surgical simulator was used as a means of training and assessment. This simulator comprised surgical tools with feedback on force, a 3D graphics display, anatomy-based computer simulations, and the software to measure and evaluate a trainee's performance. In the study, 12 medical students performed a VR suturing task. The simulator was used to measure and compare students' skills with those of experienced surgeons. The results indicated that the average performance of a surgeon was significantly higher than that of a student. It also showed that students improved in six out of the seven parameters for which they received feedback during the training; the surgeons also saw a significant improvement in four out of the seven parameters.

2.3.3 VR in architecture

Another area of application of VR technologies is architecture. The most popular and one of the main applications of VR in architecture is architectural design. Due to the development of 3D-modelling tools and VR, designers have the opportunity to visualise and immerse themselves in their projects, which allows them to better understand the space (Bouchlaghem, Shang, Whyte, & Ganah, 2005). Using intuitive interactive modelling tools, designers can estimate the proportions and scale of projects (Kurmann, 1995), calculate lighting, acoustics and ventilation in rooms (Nimeroff, Simoncelli, Badler, & Dorsey, 1995; Shinomiya et al., 1994) and also help in the design of fire escape routes (Spearpoint, 1994). Visualisation is also used as a tool to convey ideas from the designer to the client (Ormerod & Aouad, 1997).

In addition to architectural design, VR is gradually being applied as a simulation tool in landscape design (Regenbrecht & Donath, 1997; Grabowski, 1996; Portman, Natapov, & Fisher-Gewirtzman, 2015; Orland, Budthimedhee, & Uusitalo, 2001). A number of visualisation technologies have already been applied in practice such as during the development of the simulation computer model of the surroundings for the Tower of London (Counsell & Phillip, 1997).

2.3.4 Potential of applying VR in psychotherapy

Due to the gradual decrease in the cost of VR systems and, as a result, their wide commercial distribution, the use of VR in healthcare has become more widespread. One of the areas of VR application is Cognitive Behavioural Therapy (CBT). The aim of CBT is to improve emotional and functional wellbeing through identification and revision of the thought patterns, beliefs, and behaviours associated with a psychological disturbance in order to achieve positive life objectives (Hofmann, Asnaani, Vonk, Sawyer, & Fang, 2012). A number of sessions that focus on a specific problem can help the patient to identify, recognise and change disturbing memories, thoughts and feelings which lead to negative or destructive beliefs and behaviours. Research has proven CBT to be effective for treatment of a variety of disorders, such as anxiety, eating disorders (ED), depression and insomnia (S. K. Cheng & Dizon, 2012; Stallard, Richardson, Velleman, & Attwood, 2011; Barazzone, Cavanagh, & Richards, 2012).

For instance, the therapeutic effect of CBT on depression has been studied by Charkhandeh et al. (2016). The effectiveness of CBT in reducing symptoms of depression was tested on 120 participants aged between 12 and 17 years. The results showed an improvement of over 40% in their depression scores and it was concluded that CBT could be used as a treatment for reducing adolescent depression.

VR CBT is closely linked with exposure therapy (ET), which gradually encourages patients to face troubling thoughts and fears directly. ET is an adaptation of behavioural therapy and has been classified as a powerful technique of confrontation with anxiety or a specific type of phobia (Craske et al., 2008; Norton & Price, 2007). A specific type of phobia is characterised by a marked and persistent fear of a particular object or situation that causes significant life interference or distress (e.g. fear of flying, fear of heights, claustrophobia, arachnophobia, fear of public speaking, etc.) (Riva, 2005). There are a number of variations of ET that work effectively in the treatment of specific phobias.

VR exposure therapy (VRET) is gaining popularity as one of the methods of delivering ET. During a VRET session, the patient is immersed in a highly realistic virtual environment. Whilst undergoing VRET, the patient safely interacts with the object or situation that he or she finds frightening, learns to control its negative effect, or applies relaxation techniques. Gerardi et al. (2008), studied the possibility of using VRET in the treatment of Post-traumatic stress disorder (PTSD). In his experiments, Gerardi investigated the therapeutic effect of the interactive VR application "Virtual Iraq", developed to aid soldiers who took part in military interventions. The developed application used in the VRET of PTSD for the veteran, who took part in the Operation Iraqi Freedom (OIF), resulted in the considerable decrease of PTSD symptoms (Gerardi, Rothbaum, Ressler, Heekin, & Rizzo, 2008).

Another use of VRET was demonstrated in a study by Pertaub et al. (2002), which addressed the use of VR in the treatment of people with public speaking anxiety. The study showed that using the standard Personal Report of Confidence as a Public Speaker (PRCS) at post-test, it was possible to generate different anxiety levels in participants according to the immersive virtual environments (neutral, positive or negative).

The meta-analysis of VRET applications in the treatment of anxiety disorders concludes its high effectiveness. VRET can be seen as an alternative to behavioural or cognitive-behavioural therapy in its classical form since, in general, there is no significant difference between the two methods (Opriş et al., 2012). Being highly sensitive to any technological obstacles and flaws, VRET requires precision and accuracy in its operation (Pallavicini et al., 2013). Without the feeling of deep presence, the advantages of VRET are reduced dramatically. A reduction in the ability to evoke an intense emotional response is reflected in the results being below those achieved with low-cost therapeutic treatments (e.g. text and audio-based therapies).

Another use of VR is in the treatment of persons with ED. Through the use of VR, therapists can identify which stimuli, social situations and contexts are difficult to control in real life and can lead to anxiety, ED and food addiction. For instance, patients can visit a VR restaurant which is reconstructed in VE to reflect a real restaurant along with staff and other visitors. In that restaurant the patient may be offered the opportunity to order and try new food. As the correct eating behaviour develops, new objects and scenarios can be added into the VE. For example, different type of desserts, offers from the virtual characters to try them and other provocative situations which the patient needs to be able to cope with. Using the imitation of a real setting, a therapist teaches the patient methods to change his or her behaviour, cope with stress and try cognitive reaction strategies and by doing so encourages the patient to practise those skills in real time (Bordnick, Carter, & Traylor, 2011).

Current research studies also mention the high therapeutic effectiveness of Virtual Reality Social Cognition Training (VR-SCT). These studies directed towards the improvement of social cognition and social functioning for patients with Autism Spectrum Disorder confirmed their high effectiveness. Over a five-week period the participants took part in ten therapy sessions. The study was performed with the help of the "Second Life™" virtual environment. Both participants and therapists had virtual avatars which resembled their appearance in the real world. As the training progressed the participants learnt various social scenarios. These scenarios were constructed so the participants could gain experience of social interaction in different situations for example, meeting new people, a conflict with a roommate, business negotiations, a job interview, etc. (Kandalaft, Didehbani, Krawczyk, Allen, & Chapman, 2013).

Another area of VR application in psychology is Virtual Reality Hypnosis (VRH). This kind of therapy is commonly referred to in pain management. VRH is initiated though the playing of calming audio with the consequent immersing of the patient into a VE. An experiment was conducted in a similar fashion for patients who had received severe burns. The VR software SnowWorld (Patterson, Wiechman, Jensen, & Sharar, 2006) was used for the experiment. All patients reported a decrease in their levels of pain and anxiety (Oneal, Patterson, Soltani, Teeley, & Jensen, 2008).

VRH is also recommended as a treatment for patients with chronic pain. Although the majority of VR research studies show it is highly effective, there are also contrary opinions. Konstantatos et al. (2009), researched the effectiveness of relaxation and immersion in VR combined with treatment with Morphine for pain control during bandage changes. Instead of using a programme utilising a distraction technique, such as SnowWorld, the researchers developed a consecutive VR relaxation VE based on hypnotherapy. A sequence of calming visual scenery was used in the experiment. At the end of the sequence the patient was encouraged to concentrate on the vision of a moving spiral. It was thought that in some patients this can induce a trans-like state. In contrast to the previous results, this experiment showed an increase in the level of pain felt by patients. These mixed results may be related to the characteristics of the development of the VE, the level of immersion and/or the different methodology used by the researchers.

Overall, the possibilities of applying VR in psychology is quite broad, however, it is worth mentioning that in practice VR is rarely used as a therapeutic treatment. Schwartzman et al. (2012) note that reluctance to apply this technology in practice is related to the inadequate level of preparation of therapists, lack of necessary equipment and the expenses associated with it. It can be assumed that this technology is still at its development stage and is mostly applied in scientific research centres and laboratories. Furthermore, at the present time, VR is predominantly used as part of a complex set of treatments and its possibilities as a self-sufficient therapy are currently being discussed. As can be seen, a lot of research nowadays in VR and psychology is conducted with the use of single user, PC based versions of VR systems. There are not so many studies looking at the application of mobile VR systems, that could potentially be more suitable in use for psychological interventions. In addition, little research has been done to investigate the remote VR psychotherapy.

2.4 Co-design approach

As was discussed in the previous section, VR technologies have their potential in the application to psychology. VR has unique aspects that could be beneficial in psychological interventions, aspects that flat screen applications cannot provide. Several digital psychological interventions (Christensen, Griffiths, & Korten, 2002; Craske et al., 2009; Titov et al., 2011; Merry et al., 2012) have been studied for many years and psychologists know how to design them, however, VR is quite new in this area. There are several skills needed to build VR but at the same time application of it in psychological intervention should satisfy the requirements of the therapy.

Over the past six decades, the user-centred design approach has been well established and practised in production practice and education. This approach, which was widely adopted by the 1990s, demonstrated its effectiveness in the design and development of consumer products (Sanders, 2002). The method involves observing and/or interviewing passive users/participants performing assigned tasks and expressing their opinions about product concepts that have been created by others (Sanders & Stappers, 2008).

Nowadays, a variety of participatory research frameworks has been described in the literature. Participatory design approaches have recently drawn greater attention in the field of design. One of such approaches is co-design. The move from user-centred design to co-designing is having an impact on the roles of the players in the design process. Unlike user-centred design, in co-design, the roles of participants in the study are mixed. Designers, developers, researchers and users work together to create a product, generate ideas and concepts (Sanders & Stappers, 2008). Thus, it may be beneficial to use a co-design approach when designing VR for psychological interventions in order to bridge the gap between developers, researchers, psychologists and other stakeholders.

As co-design has gained in popularity, various interpretations of its meaning have emerged (Steen, Manschot, & De Koning, 2011). Saunders and Stappers (Sanders & Stappers, 2008) describe co-design as a process for transformative design which involves the participation of stakeholders. In turn, Steen (2013) further described this approach as “a process of collaborative design thinking: a process of joint inquiry and imagination in which diverse people jointly explore and define a problem and jointly develop and evaluate solutions.”

In general they all consist of a similar series of consecutive steps. For instance, Bratteteig and colleagues identified six phases of the design process: “opportunity identification”; “generation of explicit and implicit knowledge”; “identification of needs and desires”; “description of delivery requirements”; “envisaging the intervention” and “prototype testing, pilot testing and evaluation” (Bratteteig, Bodker, Dittrich, Mogensen & Simonsen, 2012, p.137).

One of the areas where co-design is gaining momentum is social and community services (Briggs et al., 2011). In designing for these services, the participation of users is not limited to just a survey of opinions, the user involvement takes place at a much higher level in the design process. People can participate in the generation of ideas, discuss the nature of proposed services and be involved in the testing process. Participation in the design process is not limited to users and service providers; professional designers may also be involved in the process between service providers and/or service users (Burkett, 2012).

Ingrid Burkett (2012), outlined five features of the co-design procedure for services. First, focus on the person. Users and service providers must present themselves in each other’s place in order to design or update the service. The second is to begin with the final target in mind. During co-design, the team is looking for ways of development based on desired results (goals). The third is to focus on “developing practical, real solutions to problems”. In collaborative design, prototyping is a method of testing ideas in practice (Blomkvist & Holmlid, 2012). The verification process will take place as long as the solutions that have been developed satisfy both consumers and service providers. The fourth feature is the visualisation of ideas. With the help of various media and graphics tools, it is possible to present complex information to a wider range of people who may have different opinions on the system. Finally, as follows from the previously described terms of the co-design approach, it “relies on many points of view, people, experts and discipline” (Burkett, 2012).

A number of benefits were found in the application of the co-design approach to services and system design projects. For instance, it was found that user involvement in Information and Communication Technology (ICT) led to improvements in the system according to user needs, achieving higher system quality and improving user and customer satisfaction (Kujala, 2003). Similarly, in service design, user involvement sanctioned the development of unique services for users, reduced development time, and provided an opportunity for teaching users the attributes and specifications of new services, which made it possible to quickly spread these services and gain recognition in the market (Alam, 2002).

A co-design approach has also been explored in education to develop products that can fit into real classroom contexts (Penuel, Roschelle, & Shechtman, 2007). In such cases, technologies are generally used to support teachers and the development process is carried out in conjunction with them. Products developed in this way include teaching materials for mathematics (Hand, Underwood, & Nielsen, 2001; Roschelle et al., 1999), assessment materials to help students track their progress (Atkin, 2001; Edelson, 2002) and products to help teachers in learning adjustment (Shepard, 1997).

Several studies examined the application of the co-design approach with children and adolescents (Steen et al., 2011; Walsh et al., 2010; Vaajakallio, Lee, & Mattelmäki, 2009). When children/adolescents act as stakeholders, specific methods should be applied (Dodero, Gennari, Melonio, & Torello, 2014). One of the well-known co-design methods that can be used in the design process, in this case, is informant design (Druin, 1999). Informant design permits the involvement of all stakeholders in different stages of the design process with maximum benefit (Scaife, Rogers, Aldrich, & Davies, 1997). For example, an informant design method was studied for the design of serious mini-games to improve adolescent literature in advertising (De Jans, Van Geit, Cauberghe, Hudders, & De Veirman, 2017). Various stakeholders took part in the co-design process, including industry experts, academic experts, pedagogical experts, game developers and end-users (students). The design process was divided into four phases, each of which involved the participation of various stakeholders. In the first “definition domain” phase only industry experts and academic experts participated. All project stakeholders took part in the second “brainstorming and definition requirements” phase and the third “design game scenarios and feedback” phase. In the last “Alpha game and usability testing” phase, game developers and end-users took part. In the course of this research, a serious mini-game set was developed. As the authors emphasise, the creation and development of serious mini-games can be quite challenging due to the large number of stakeholders. However, use of the informant design method allowed the strong qualities of the stakeholders to be applied at certain stages of the project and reduced investment time from the stakeholders. At the same time, a large number of end-users were involved in the co-design process.

As can be seen, substantial research has been undertaken with users in industries such as technical design and collaborative design of services, where the co-design method has been applied for quite some time (Boyd, McKernon, Mullin, & Old, 2012). However, its application in the development of VR applications has received far less attention. Traditional digital media, services, and even computer games are very different from creating VR applications. Although there are small similarities and some content could be ported to VR, the design of such applications is primarily designed for a 2D screen. The concepts described earlier in Section 2.2 (such as head tracking, hand tracking, presence and immersion) are key elements for the VR experience that should be considered from the very beginning of the development.

On the other hand, applications must meet not only these requirements but also have psychological meaning and aspects. With this in mind, creating VR applications and even more VR applications for psychological interventions requires a multidisciplinary approach in application design. This research aims to bridge the gap in the literature of VR development for psychological purposes and study the application of the co-design approach for designing VR applications for psychological interventions.

2.5 Summary

In this chapter, topics related to the technological development and key aspects (presence, immersion and interactivity) of VR have been presented. Due to the development of technologies, less expensive VR systems have appeared on the market. Modern VR HMDs can be used with personal or laptop computers or smartphones. In addition, it was found that several interactive devices, such as handheld controllers, joysticks, data gloves and omni-directional treadmills have been adapted to VR HMDs. This technological development allowed developers to create more immersive VR content.

In addition, the application of VR technology in different areas and the potential importance of a co-design process were discussed. A number of studies related to the use of VR in psychotherapy were reviewed. VR is used in the treatment of anxiety, PTSD, addictions, ED and pain management (Powers & Emmelkamp, 2008; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001; Bordnick et al., 2004; Perpiñá et al., 1999; Li, Montaño, Chen, & Gold, 2011). More often, VR is used as part of behavioural or cognitive-behavioural therapies. A uniquely important aspect of VR therapy is the possibility of safe interaction between the patient and an object which poses a threat to him or her in the real world.

However, there is an absence of literature to date regarding how to co-design VR applications for psychological intervention. It is important to provide a guide for future developers/researchers who are considering the application of this technology and these methods. The design studies presented in Chapters 3 and 5 will look at the co-design process with regard to the development of VR applications. Chapters 4 and 6 will describe experimental studies where the applications developed were applied in practice. Chapters 3 and 4 of this thesis will focus on the development and implementation of the mobile VR systems. Chapters 5 and 6 will look at the potential future development direction in VR psychological interventions.

Chapter 3

The Design and Development of Mobile VR Applications for Psychological Interventions

In the previous chapter, the potential of applying VR as a tool for psychological interventions and how these tools could be used were discussed. Although the use and deployment of VR technology is gaining momentum in psychotherapy, the design processes of creating effective and user-friendly VR applications have not been studied extensively. In this chapter, I explored the application of the co-design approach, which has proven useful in other Information and Communication Technology (ICT), for the development of mobile VR applications for psychological interventions.

The rapid growth in the use of smartphones has opened new opportunities in psychological health care. Mobile health (mHealth) is a term which refers to the use of mobile devices and wireless technology for medical care, as well as the promotion of a healthy lifestyle (Kumar et al., 2013). Mobile phone software applications are available for a variety of useful tasks including symptom assessment, psycho-education and tracking of the treatment progress (Plarre et al., 2011; Burns et al., 2011; Bexelius et al., 2010; Patrick et al., 2009). This area is expanding quite rapidly due to the increase in the number of devices owned by all population groups. Thus there is a growing need to consider co-design methods in mHealth.

The vast majority of VR systems discussed in psychotherapy literature are PC based. Although PC based VR seems to be an effective tool for psychological interventions, it has been found that it requires a significant amount of time for the clinical staff to prepare, set up and clean the equipment, as well as the provision of technical support for the staff (Markus et al., 2009). Moving towards low-cost, accessible solutions is likely to improve these issues.

Today, mobile VR is one of the most affordable ways to immerse in virtual environments (VE) (Gutiérrez-Maldonado, Wiederhold, & Riva, 2016); there are many supported mobile devices and VR Head-Mounted displays (HMD) available at a low cost such as Samsung Gear VR and Google Cardboard. These systems do not require any complicated set up compared to the PC-based versions, but can potentially have some other disadvantages despite their price, which will be investigated during this chapter. Their wide distribution allows more people to have access to immersive VR technology. In addition, the current generation of mobile phones provides more than just devices for talking: the broadly available smartphones are capable of supporting 3D graphics, images, sounds and software. With mobile VR, patients would be able to use their own HMD's, which could provide a more convenient approach, reducing the time and costs of the equipment maintenance.

This chapter describes the co-design process used to develop mobile VR systems for psychological interventions and its technical implementation. The developed systems were used to conduct experiments for two case studies: pain management and anxiety disorders. Table 3.2 summarises the tasks and goals set for the design of the mobile VR application for pain management and anxiety disorder studies. The results from the anxiety disorder treatment are described in Chapter 4; whilst for the pain management case study, I was involved in a co-design phase as a designer/developer of the VR application, but the experiment results are part of another PhD research and are reported in two published papers co-authored by myself (Matsangidou, Ang, Mauger, Otkhmezuri, & Tabbaa, 2017; Matsangidou et al., 2019).

This chapter is broken down into four sections: Section 3.1 describes the co-design and development processes of the mobile VR application for the first case study (e.g. on pain management); Section 3.2 describes the co-design and development processes of the mobile VR application for the anxiety disorders study; Section 3.3 provides outcomes from these studies; and Section 3.4 provides a conclusion.

<table>
<tr><th></th><th>Pain Management</th><th>Anxiety disorders</th></tr>
<tr><td>Determination of the psychological intervention base treatment</td><td>Pain management enhanced with the psychological intervention strategies</td><td>Cognitive Bias Modification of Interpretations training (CBM-I) (see Section 3.2.1)</td></tr>
<tr><td>The goal of the treatment</td><td>To reduce exercise pain</td><td>To reduce performance anxiety and increase positive interpretations</td></tr>
<tr><td>Identification of key aspects of the treatment therapy that need to be transferred into VR</td><td colspan="2">1. The participants profile data (e.g. age, physical and cognitive abilities)
2. The role of the therapist in the VR system e.g. whether the therapist is a passive observer and facilitator or being actively involved
3. The design of the user interface(UI) for both therapists and participants
4. The design of the virtual environment needed for the psychological intervention
5. The activities that the participants need to perform
6. The ease of use of the VR platform</td></tr>
<tr><td>Set of tools needed to develop the application</td><td colspan="2">1. Game Engine: Unity
2. 3D modelling tools: Autodesk Maya
3. VR equipment: Samsung S6 smartphone and Samsung Gear VR HMD
4. External devices and tools: Microsoft Band (for pain management), voice recognition tool (for anxiety disorders)</td></tr>
</table>

Table 3.1: Tasks and goals for the design of the mobile VR applications for pain management and anxiety disorders

3.1 Case study 1: Co-Design of the Mobile VR Application for Pain Management

In the first case study, we looked at the co-design process and the technical implementation of the mobile VR application for the pain management intervention. The goal for this case study was to co-design and explore the issues and possibilities of applying mobile VR applications for pain management intervention. During the first case study, I was involved in the co-design process as a technical researcher (the developer and designer of the VR application).

3.1.1 Background on pain management

Pain has an essential role in protecting the body from harm through the mechanism of avoidance behaviour. This means that pain experienced during exercising may affect decision making, which either results in the individual reducing the intensity of the exercise (so that pain is reduced) or withdrawing from the exercise entirely (Mauger, 2014). In any case, this may have negative consequences for the person's level of physical activity and/or their motivation for training. To increase the length and intensity of the exercise, it would be beneficial to find a way to alter/decrease the perception of pain during the exercise. This could potentially result in increased levels of physical activity and lead to a healthier lifestyle.

In the last decade, the studies related to pain management have suggested that, whilst analgesics and psychological methods have been effectively used for treating pain in patients, VR technology can also provide an alternative solution to pain management (Riva, 2005; Rothbaum et al., 1997; Morris, Louw, & Grimmer-Somers, 2009; Li et al., 2011). For example, VR can allow the patients to focus on the virtual experience, thus distracting them from the perception of pain (Hoffman et al., 2006).

Moreover, it has been found that the visual properties of an object, such as size, can affect the force that will be applied by a person towards that object (Adelson, 2001; Johansson & Westling, 1988). This means that by changing the visual properties of the object during the exercise, it would be possible to affect the subsequent perception of pain caused by the exercise.

Therefore, the need for the application that will allow to examine how the visual properties of objects in VR can influence an approach to pain management was established.

3.1.2 Research team and design process

The research team involved in the design process consisted of two psychologists with expertise in pain management and sport and exercise science; a technical researcher specialising in game development; and a 3D artist. The literature review carried out in Chapter 2 demonstrated variety of stages that could be considered during the co-design process (see Section 2.4). Taking into consideration that the psychological intervention already exists in the physical world (there was no need to create a new intervention), the research team adopted those stages (Bratteteig et al., 2012) for this case study. The designed prototype of the VR application for pain management went through five co-design iterations over a period of five months and was used in the two experiments (Matsangidou, 2018).

Table 2 summarises the co-design process of the mobile VR application for pain management.

Stages	Design Process
1	**Initiation session and tech demo with the research team** The psychologists introduced the Altered Visual Feedback Strategy (AVFS), which is used for manipulating the visual feedback in order to affect the pain levels (see Section 3.1.3). Mobile VR technological possibilities were demonstrated to the psychologists through the standard Gear VR applications.
2	**First brainstorming session with the research team** Specific aspects of the intervention and how it can be translated into mobile VR application were discussed (see Section 3.1.4).
3	**First evaluation session with the technical researcher and the psychologist** During this evaluation session, the interaction mechanism, which involved the synchronisation of the virtual hand with the real hand, was tested (see Section 3.1.5). Several connectivity tests were run to ensure stable and reliable interactions. Based on the outcome of the tests, the interaction mechanism was revised. Afterwards, a virtual 3D generated environment and a User Interface (UI) for the psychologists were developed (see Section 3.1.8). Decisions on the visual representation of the bodies in VR (both male and female), were made (see Section 3.1.5).
4	**Second evaluation session with the technical researcher, psychologist and a volunteer test user** Further testing on the mobile VR interaction and the UI elements for the psychologists were conducted (e.g. the control panel for the setup of the session). The UI element was then updated to provide more features for the therapy customisation and the first experiment was conducted (see Section 3.1.6).
5	**Second brainstorming session with the research team** The results from the first study were discussed. Another developer joined the research team. It was decided to further investigate other elements that could influence the mobile VR intervention for pain management. The application was further updated (see Section 3.1.7) and the second experiment conducted.

Table 3.2: Tasks and goals for the design of the mobile VR applications for pain management and anxiety disorders

3.1.3 Initiation session and tech demo with the research team

During the Initiation session, the technical researcher introduced VR to the psychologists and explained the various capabilities of the technology. Various types of VR technologies (Oculus Rift, Gear VR and Google Cardboard) were demonstrated and provided to psychologists for tests. The purpose of this familiarisation was to introduce several modalities of VR (wired/wireless, HMD/handheld, PC-based/Mobile) with various interaction techniques (head rotation only, using the control pad, using handheld controllers).

After that, the psychologists demonstrated the Altered Visual Feedback Strategy (AVFS). AVFS is a strategy which uses visual feedback manipulation in order to reduce chronic pain and improve physical activity for the participants (Bolte, de Lussanet, & Lappe, 2014; Chen, Ponto, Sesto, & Radwin, 2014; Harvie et al., 2015). Psychologists have explained the strategy by presenting the video of the "The Rubber Hand Illusion" [1] as well as demonstrated similar technique, applied in the video, using mirrors (see Figure 3.1) for the technical researcher to try it. The research team decided to take AVFS as a core intervention reference for the design of mobile VR application.

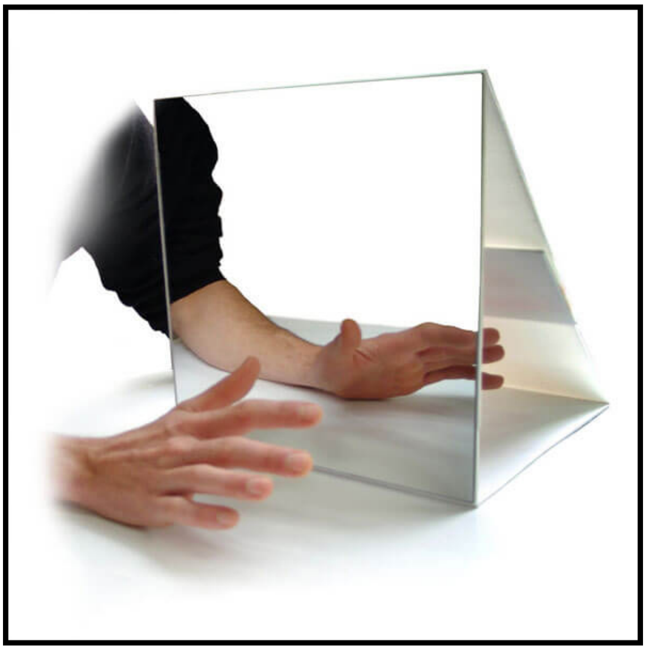

Figure 3.1: Mirror illusion (retrieved from Moseley, 2012)

The information knowledge sharing facilitated the researcher's understanding of theoretical notions. After this demonstration and watching the video, the technical researcher had a sense of how a person's visual perception can be affected by their feelings. During this session, psychologists elaborated that research has shown that the level of pain could also depend on other factors such as Private Body Consciousness (PBC) (Ahles, Cassens, & Stalling, 1987), besides the visual information influence. PBC describes how well one is aware of internal and physical body sensations (Ferguson & Ahles, 1998). In addition, it has also been found

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[1] The Rubber Hand Illusion video (https://www.youtube.com/watch?v=sxwn1w7MJvk)

that expectations about a painful stimulus can seriously influence the brain and pain perception (Atlas & Wager, 2012).

The research team discussed two studies in detail (Bolte et al., 2014; Harvie et al., 2015) that were found in the literature. Both studies showed the effectiveness of PC based VR systems and AVFS on fear of movement and chronic pain. The results from these studies demonstrated the effects of visual manipulation on improving participants' movement amplitudes (e.g. head, neck and hip rotation) that increased the engagement of participants in physical activities. However, it did not affect the length of the exercise time or the ability of the participants to engage in extended training. Also, in both experiments, the visual feedback manipulation did not exceed 20%, which is relatively low. As a result, the psychologists were interested in conducting an experiment to address the effect of VR AVFS on how well a participant could tolerate a given level of exercise intensity.

In order to address the limitations of the previous studies (Bolte et al., 2014; Harvie et al., 2015), the research team decided to conduct an experiment with a more substantial manipulation (for example up to 50%) which would allow a clearer identification of the effect of AVFS. Although the use of PC based VR systems and AVFS showed positive results, the use of such systems in real life environments may not be very convenient due to the complexity of the system setup. Given that the study was planned to be conducted outside the lab, a mobile VR system was suggested by the technical researcher as a more suitable option than traditional PC-based systems. This VR system could be more appropriate to use within the exercise (gym, sports centre) or the home environment due to its portability. Having a PC-based VR that is more expensive in cost and unfeasible in terms of space requirement, will be unreasonable. Generally, gym equipment takes a lot of space, and it's hard to dedicate a special unit for PC-based VR training, even if it is proven effective.

Furthermore, a PC-based VR requires a certain computer that can run VR applications, which could be comparable to buying considerably expensive sports equipment. Considering that the target users may or may not have extensive familiarity with the equipment, a system that is easy to set up and use would be required. Two mobile VR headsets were taken into consideration: Samsung Gear VR and Google Cardboard. The research team agreed that the VR system that consisted of Samsung Gear VR[2] and Samsung S6 smartphone[3] could be suitable devices for this case study. Compare to another mobile headset (Google Cardboard and similar), Samsung Gear VR provide the ability for users to interact with the application via the touch input system. In addition, it comes with the head strips, meaning that the users hands will be free from holding the headset.

The introductory session allowed the research team to set the goals for the the experiment: 1) to investigate the impact of VR technologies and AVFS on the perception of pain caused by physical exercise among a healthy group of participants; 2) to test and identify the opportunities and limitations of using the mobile VR system in pain management research. At the end of the session, it was decided that the design solutions and their transformation into the mobile VR application, would be discussed during the next session.

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[2] https://www.samsung.com/global/galaxy/gear-vr/

[3] https://www.samsung.com/uk/smartphones/galaxy-s6-g920f/SM-G920FZKABTU/

3.1.4 First brainstorming session with the research team

Following the Initiation session, the research team discussed the experiment design.

Participants. Considering the goals that have been defined during the previous session, it was agreed to recruit participants without chronic muscle pains or other conditions that could affect their performance in the experiment. This would allow to accurately measure the effect of AVFS.

Design of an exercise activity for participants. To induce muscle pain, in order to measure the effect of visual feedback manipulation on participants' perception, a bicep curl exercise whilst sitting was suggested by one of the members of the research team, a psychologist with expertise in Sport and Exercise Science. The exercise was chosen for the following reasons: firstly, the equipment for this task would be available in any gym or at home. Secondly, both male and female participants could perform it, potentially increasing the number of participants. Finally, considering that the user would be completely isolated from the real world when using VR, this exercise is safe in the sense that participant can wear the VR headset without the need to walk or move which may be a safety risk.

The exercise required the participants to hold the weight with their elbow at a right angle and with their wrist joint 20cm above the surface of the table, for as long as possible (see Figure 3.2). During the exercise task, the participants were supposed to sit at a table in the allocated room with their elbow resting on the table. To ensure a comfortable position for the elbow, a yoga mat was placed beneath it.

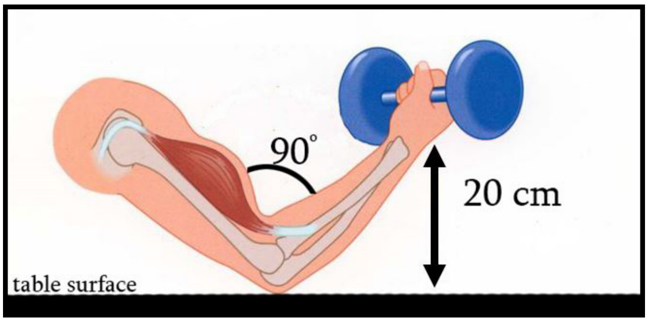

Figure 3.2: Bicep Curl Isometric Position

Due to the various physical abilities of the participants, it was required to calculate the baseline weight that each participant could hold. In order to do that, 20% of the heaviest weight that each participant could lift in one repetition (1RM), whilst performing a standing bicep curl exercise, was taken as the baseline weight using the following formula 3.1.

$$Weight(kg) = \frac{lRM * 20}{100} \tag{3.1}$$

The psychologist with expertise in Sport and Exercise Science suggested to perform standing bicep curl, in order to accurately calculate the baseline weight (see Figure 3.3). In this sense, calculations must be taken in a separate session from the actual experiment session as the bicep curl weight determination exercise is an effort on its own and could affect the results of the experiment.

Figure 3.3: Bicep curl 180º lift exercise to calculate the heaviest weigh that participants can lift (retrieved from Bissaillion, 2019)

Experiment design. To examine how the mobile VR AVFS influences the perception of task difficulty and exercise performance, it was decided to visually modify the weight in VR in comparison to the real weight held by the participants, either decreasing or increasing it. In order to have clear results, it was decided to split this session into two days of intervention sessions (session (1) - increased weight by 50% of the real weight and session (2) - decreased weight by 50% of the real weight). The actual weight, which participants were held during both sessions, remained unchanged.

In order to compare the results, a control session was required. It was decided to perform the same task without the alteration of the weights in VR. This session was to be performed on a different day; in our case, it took place before sessions (1) and (2). During the control session, the participants were given the VR headset with the hand tracking device and asked to lift and hold their baseline weight for as long as possible with the same weight shown on the HMD display.

At the end of the experiment, it was decided to ask the participants if they could tell the difference between the three sessions, and if so, what the difference was. Moreover, a questionnaire was produced for participants to rate:

1. The sense of presence in the mobile VR (e.g. "I had a sense of being in VE").
2. The sense of virtual hand ownership (e.g. "I had the feeling that the hand in the VR HMD was mine"; "It felt as if I was looking directly at my hand").
3. The comfort of the study setup (e.g. how comfortable it was to lift the weight with the VR HMD on).
4. Motivation (e.g. could you imagine using the VR HMD to exercise daily for 10 minutes).

Mobile VR design. The research team discussed the possibilities of transforming the bicep curl exercise into a VR activity. First, in order to help participants perceive themselves in the real-life environment, it was required to develop a virtual representation of the experimental environment and the equipment. In order to increase the level of presence, it was decided to recreate the experimental room in VR without adding any elements that do not exist in that the real room.

Secondly, the participant should see a virtual version of themselves holding the dumbbell so that the visual connection between the physical hand and the virtual hand is established (see Figure 3.4). Self-identification within the VR representation plays an important part in recognising the existence of a virtual self and embodiment (K. M. Lee, 2004). The embodiment relates to a combination of sensations that appear in conjunction with being in, having, and controlling a virtual body (Kilteni, Groten, & Slater, 2012). In order for participants to experience the self in a virtual environment, it was decided to create a 3D virtual human body.

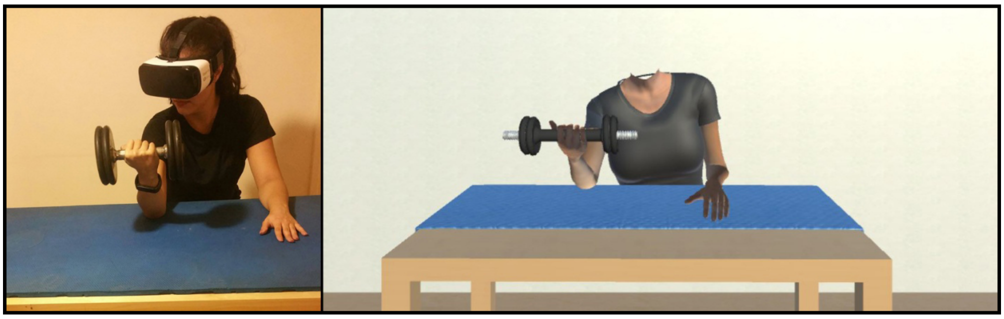

Figure 3.4: On the left: Example of the user performing the static exercise while immersed in VR. On the right: a screenshot of 3D generated human body in VE made in the Unity game engine

Considering that the upper body will be the only visible part in the VR, as participant will be sitting at a table, it is crucial to examine how we can increase the sense of body ownership in the virtual world. One of the goals is to avoid an unrealistic setup, where the hand of the participants is completely static over the duration of the bicep curl exercise. This could not match a real-world situation where participants performing this activity demonstrate minimal hand movement. The sense of connection to the hand is very important for engaging the participants' body. Therefore, the research team needed to find a way to synchronise the real and virtual hand movement to increase the sense of embodiment and ownership.

This resulted to be challenging for mobile VR where generally only the movement of the head is tracked. Various options for hand tracking were considered. One of the options discussed was the use of the Leap Motion sensor[4]. Leap Motion is a new technology which provides tracking of the movement of hands and fingers. However, this option was not suitable for the experiment for the following reasons: first, it required a connection to a laptop as there are no USB ports in the Gear VR HMD. The use of large equipment, such as a laptop, would ultimately compromise the advantages of a mobile VR system. Secondly, the use of a laptop and the Leap Motion sensors, in addition to the phone and the headset, would add on to the cost and feasibility of the system as well as complicate the setup and therefore, the system usability. In addition, having a wire connected from the headset to the laptop would restrict portability and thus compromise the advantages of using a mobile VR system. Moreover, during the testing of the sensor, a limitation was found within its 'working area'. In order for the sensor to detect the movement of the hands, the hands needed to be exactly in front of

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[4] https://www.leapmotion.com/

the sensor. Any rotation of the head, as well as positioning of the hands too close to the sensor, would interfere with the hand tracking process.

As an alternative to Leap Motion, the research team considered employing smartwatches, which are widely used nowadays in monitoring health and exercising (Mortazavi et al., 2014). Microsoft Band[5] was suggested by the technical researcher as a simple and straightforward device which could be used for tracking purposes for this experiment (see details about synchronisation in Section 3.1.8.3). This was done to increase the sense of self in a virtual environment for participants.

During this session, the research team also concluded that the presence of a therapist was required in order to set up the application and choose the correct weights for the participants. To aid the therapists with the setup, it was decided to develop a weight customisation tool which would allow the therapist to adjust the weights for the intervention sessions (see Section 3.1.6).

3.1.5 First evaluation session with the technical researcher and the psychologist

Based on the two sessions (Initiation and Brainstorming), the first prototype of the mobile VR application was developed, and an evaluation session conducted with the technical researcher and the psychologist. A 3D model of the human body was developed (see Section 3.1.8.1 and Figure 3.5), and Microsoft Band used to synchronise the position between the real and the virtual hands. The aim of the testing session was to check the hand tracking device connectivity to ensure a stable and reliable connection. Moreover, this session was used to provide the instructions for the psychologist on how to use the application. The guidelines regarding how to connect the tracking device via Bluetooth and system setup were provided.

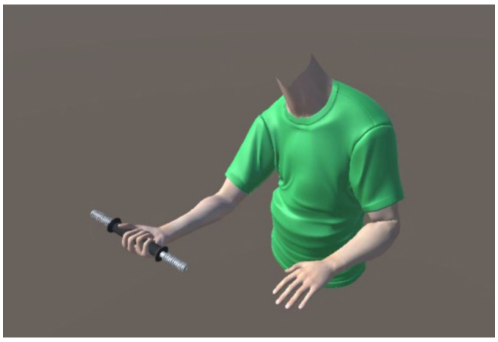

Figure 3.5: The 3D generated male human body developed by 3D artist

A list of technical issues and future development tasks was compiled after the testing. Firstly, the unstable connectivity issue was identified during the testing. The evaluation session revealed that, even though the tracking device remained connected to the smartphone via Bluetooth, the connection would drop after a couple of VR sessions. In addition, the psychologist was not able to easily check the connectivity status. To resolve this issue, a UI was required to display the connectivity status in the application. Therefore, when the design of the

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[5] https://support.microsoft.com/en-us/help/4000323/band-hardware-sensors

application was considered, it was noted that it should not be limited to the design of the VR therapy activities but should also include a way of troubleshooting technical problems ensuring that the technology would work as intended.

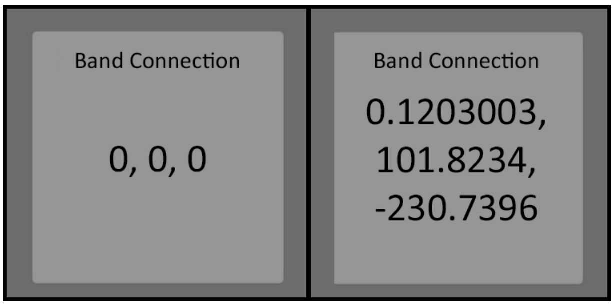
Secondly, it was noted during the evaluation session that the participants would require a certain amount of time to get used to the VR technology. Considering that a typical user has never experienced VR before (Carrozzino & Bergamasco, 2010), it was decided to add an introductory session for the participants to familiarise themselves with the VR devices after the calculation of the baseline weight. This was done in order to let the participants adapt to the VR HMD and the task that they would need to perform during the experiment. It should be noted that there was no specific order design of the conducted sessions. It could potentially influence the results and could refer to the limitation of the first experiment. Further experiment will take into consideration the order effect to minimise the chances of influencing the results. The agreed-upon first experiment consisted of four separate sessions:

1. Day one: familiarisation with the equipment and the calculation of the baseline weight for each participant.
2. Day two: control session where the participants were performing the static task with the same visual feedback (virtual weight) in HMD as the baseline weight.
3. Day three: the virtual weight was increased by 50% with the baseline weight remaining the same.
4. Day four: the virtual weight was decreased by 50% with the baseline weight remaining the same.

In addition to this, a decision was made regarding the visual representation of the body in VR, e.g. skin and shirt colours. It was decided to create both left and right-handed male and female characters to increase the sense of embodiment with the virtual avatar. At the end of the session, the psychologist gave a detailed account of the potential location for the experiment in order for the developers to re-create it in a 3D generated environment.

3.1.6 Second evaluation session with the technical researcher, psychologist and a volunteer test user

Taking into consideration the results from the previous test session, the second version of the application was developed. The psychologist was provided with an integrated UI element to check the connection status of the hand tracking device. This information would appear on the main screen of the application (see Figure 3.6). This element allowed the psychologist to check whether or not the Bluetooth connection would need to be restarted prior to the experiment.



Band Connection

0, 0, 0

Band Connection

0.1203003,
101.8234,
-230.7396

Figure 3.6: The band tracking device connection information provided to the psychologist on the VR headset screen. On the left the screenshot with no connection. On the right the screenshot with Band connected

During the first brainstorming session, it was decided that the psychologist should take part in the setting up of the VR system. The developed UI control panel allowed the psychologist to set up the application, i.e. choose the weights and change the skin and shirt colours (see Figure 3.7).

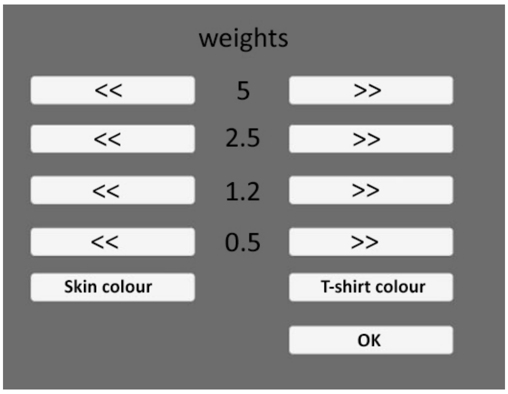


Figure 3.7: The control panel for the psychologist to set up the VR application

In this study, four weight variations were used (0.5 kg, 1.25kg, 2.5kg, 5kg). In order to change the weights according to the requirements of the experiment design, a weight selection menu was created. The adding and removing of the weights via the menu would be reflected in the appearance of the virtual dumbbell. All weights were presented as different size 3D models that were designed based on the provided gym equipment that was used in the study (see Figure 3.8).

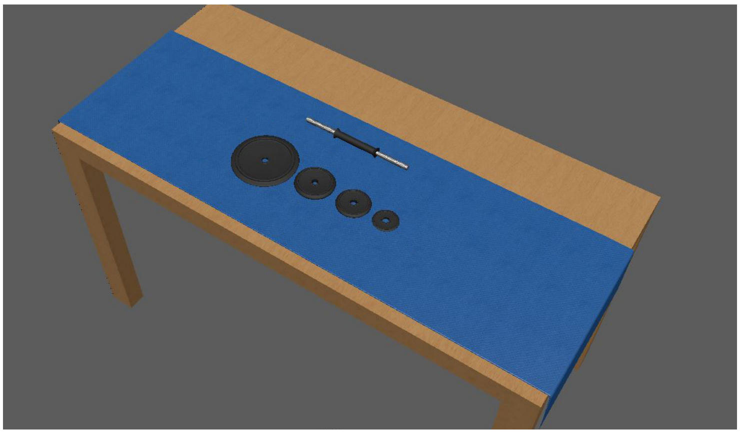


Figure 3.8: The developed virtual weights, dumbell, table and a yoga mat in Autodesk Maya

In order to increase the sense of presence, an option to adjust the appearance of the avatar to the participants' look by changing the colour of the shirt was added. For these purposes, eight preset colours that the psychologist could adjust via the control panel were included (see Figure 3.9).

Additionally, it was required to include an option to change the skin tone of the 3D generated human body to further match the participants' look. A set of four skin tones (see Figure 3.10) was developed and a skin-tone setup button added to the control panel.

Finally, four different scenarios of the application were added to cater for both right-handed and left-handed males and females (see Figure 3.11).

Figure 3.9: The shirt colour presets developed for the application on a right-handed female avatar in the Unity game engine

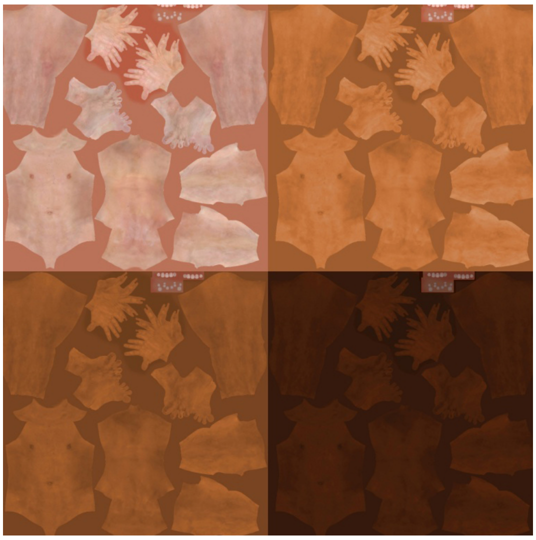


Figure 3.10: Skin colour variations for 3D characters

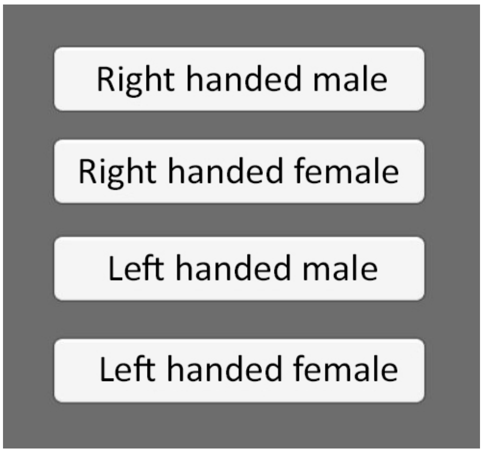


Figure 3.11: The menu where the psychologist can select the scenarios

Overall, an application customisation system was developed for the therapist that allowed to: 1) select the version of the 3D model based on the gender and dominant hand of the participant; 2) adjust the skin and shirt colour according to the participants look to increase the level of presence and self-identification in VE; and 3) set up the application providing different visual properties of the weights to the participants according to the the experiment design, thus having a more substantial manipulation to clearly identify the effect of AVFS.

During the second evaluation session, the updated application was tested with the psychologist and a volunteer test user with no major issues found. Using this version of the VR application, the experiment was conducted. The results of this experiment are part of another PhD research (Matsangidou, 2018).

3.1.7 Second brainstorming session with the research team

The results from the experiment confirmed that the created application for the mobile VR HMD, combined with AVFS, has the potential for reducing levels of pain when used in exercising. However, a certain limitation of the mobile VR system was identified. It was found that the cooling system of the Samsung S6 was not designed for continued use in VR, resulting in overheating[6]. Although the device was capable of working properly for two continuous VR sessions lasting approximately 20 minutes each, after that, it was no longer possible to continue using it without cooling down period. To minimise the overheating problem, the method of connecting Microsoft Band to the smartphone was revised.

The initial design assumed immediate and continuous hand tracking data synchronisation with the application upon its launch. To limit the overheating issue, it was decided to initiate the band connection only after the psychologist had set up the application. Moreover, the band should be disconnected when not in use and reconnected when resuming the experiment. It should also be noted that the evaluation sessions conducted prior to the first study revealed that no overheating problems were apparent when the system was tested by a solo volunteer during evaluation sessions. This means that the system could still

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[6] https://forums.androidcentral.com/vr-headsets/613563-gear-s6-edge-overheating-how-can-i-fix.html
https://www.vrbound.com/guides/how-to-deal-with-samsung-gear-vr-overheating
https://www.reddit.com/r/GearVR/comments/8np6ll/major_overheating_on_s7_and_s6_edge/

be suitable for personal and/or infrequent use. A way around the overheating issue within a clinical environment would be to have more than one smartphone at hand so that devices could be used interchangeably when multiple sessions are required.

To explore further the effect of mobile VR intervention on pain management, the research team decided to further update the application and create two versions of the system to conduct another experiment:

1. **An application with a relaxing environment**

   To decrease the perception of pain and levels of stress, the research team decided to improve the positive impact of AVFS by including images of nature and pleasant natural sounds into the 3D environment. Studies have shown that viewing scenes of nature for a few minutes assist in the lowering of stress and blood pressure levels (Altman & Wohlwill, 2012; Maller, Townsend, Pryor, Brown, & Leger, 2006; Pretty, Peacock, Sellens, & Griffin, 2005; Ulrich, 1991; Ulrich et al., 1991). Taking into consideration the above, the VE created for the second experiment was developed to present a 360-degree media environment of a forest park with background sounds of singing birds (see Figure 3.12).

Figure 3.12: The flat image representation of the 360-degree media environment used in the study

2. **An application with a distraction** Another strategy to minimise pain could be through distracting the participant in VR. Based on the observations from the literature (Markus et al., 2009; Sil et al., 2014; Dahlquist et al., 2008; Dahlquist, Herbert, Weiss, & Jimeno, 2010; Ulrich et al., 1991), it was decided to enhance the mobile VR AVFS with a simple distraction game element. For the decreased weight session, a bouncing ball was added to the existing virtual room, and the participant was required to count the number of times that the ball hits the surface of the table. Based on selective attention theory (Lavie, Hirst, De Fockert, & Viding, 2004) and distraction techniques, the research team hypothesised that this approach might enhance pain relief (see Figure 3.13).

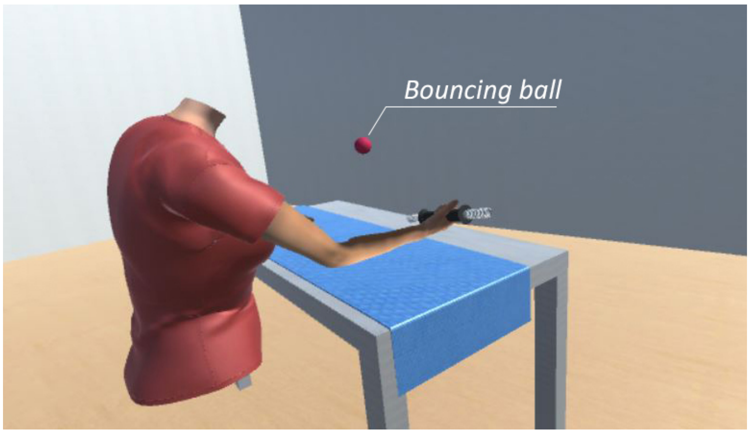

Figure 3.13: The distracting object (bouncing ball) session from the Unity game engine

Implementation of these two versions of the system was done in order for the research team to explore other elements and features that might enhance and further improve the effectiveness of the mobile VR pain management intervention (Matsangidou, 2018). In addition, to address the limitation of the first experiment, the sessions order effect was taken into account, and a counterbalanced design was used to minimise the impact on the experiment results.

3.1.8 Implementation

Mobile VR headset Samsung Gear VR designed for immersive mobile VR environments and Samsung S6 Smartphone were used for these experiments. The smartphone displayed a VE through Samsung Gear VR headset. To synchronise the head movements in the VE, visual feedback was created by tracking the real movement of the participant's head, using the internal gyroscope and accelerometer sensors of the smartphone.

3.1.8.1 Development of the VE

1. **3D Generated Environment and 3D Bodies**
   Autodesk Maya[7] was used to create 3D models of the virtual environments and human bodies. Autodesk Maya is a 3D computer graphics software which is widely used to develop 3D applications, including video game development, animated films and visual effects. The equipment for the experiment and the room where the experiment would take place were recreated using virtual 3D generated representations. This was done in order for the participants to experience the same degree of immersion during each stage of the experiment. 3D models of human bodies (both male and female) were developed to represent participants in the VE (see Figure 3.14).

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[7] https://www.autodesk.co.uk/products/maya/overview

Figure 3.14: The 3D generated human bodies in the Unity game engine

To be able to animate hand movement, the 3D bodies were rigged in Autodesk Maya (see Figure 3.15). Rigging is a process of creating a skeleton for a 3D mesh in animation. This was done to provide a high level of presence and body awareness for the participants during the experiment through embodiment.

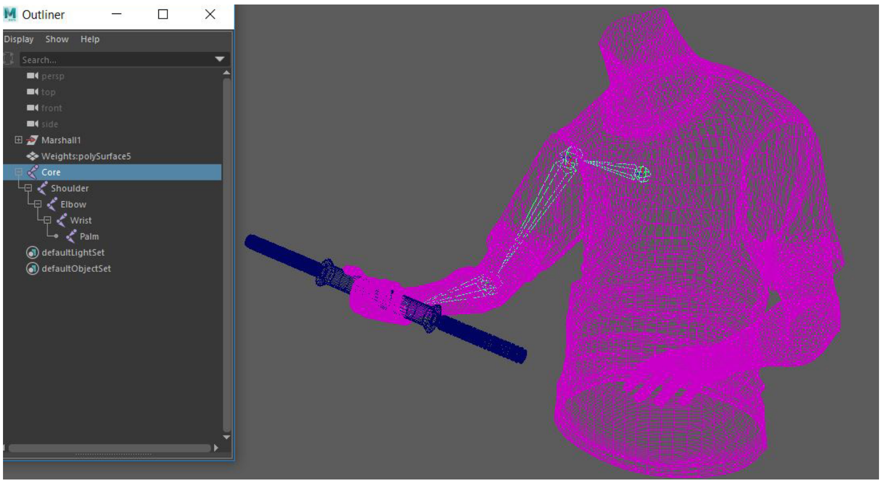

Figure 3.15: The rigged 3D body made in Autodesk Maya. A green skeleton was created for the right hand of the male 3D model

2. **360-degree media Environment**

An additional way of creating a virtual environment for mobile VR is based on the use of 360-degree videos or images. The content can be produced by using 360-degree cameras, for example, the Samsung Gear 360[8] or the Insta 360[9], which can both record high-resolution videos; or by using Internet resources such as YouTube 360-degree videos. During the design and development of the virtual environments for the second experiment, a number

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[8] https://www.samsung.com/global/galaxy/gear-360/

[9] https://www.insta360.com/

of 360-degree nature-related videos and images were considered, as well as natural sounds.

However, it became apparent that due to the limitations of the hardware used in the experiment, it was hard to achieve a video quality higher than HD in mobile VR. The tested 360-degree video environment appeared pixelated despite the high quality of the video itself. The display quality of the Samsung Gear VR headset depends on the choice of a smartphone being used. Although the screen resolution of the Samsung S6 smartphone[10] is 2560 x 1440 pixels (2K), when the display of the smartphone is placed directly in front of the lenses of the headset, the resolution of the display drops down significantly. This occurs due to the magnification of the smartphone display by the lenses of the headset. In addition, it was found that the Unity game engine version 5.6.0f3 (the latest version on that time) was downgrading the quality of the video due to its software limitations[11]. Whether it will be the same in the later versions, need to be checked. Therefore, it was decided to use 360-degree image-based forest environment instead of the video-based one. At the time of the experiment, the latest model of the Samsung S series smartphones was the Samsung S7. With the new generation of software as well as smartphones and affordable 360-degree cameras capable of recording 6K and higher quality videos, it will be possible to achieve better video quality for the mobile VR systems.

Unlike a regular video or image that has a rectangular frame, a 360-degree video or image has a spherical shape. As a result, there is a significant difference in the design approach between a 3D generated environment and a 360-degree media environment. One of the key differences is the limitation resulting from the position of the virtual camera. In comparison with 3D generated environments, where the virtual camera can be placed anywhere, and its position can be changed, this cannot be done in the 360-degree media environment.

In order to create this kind of media environment for the experiment, a sphere with the radius of 1 unit was used. It was placed at the centre of the world coordinates in the Unity game engine scene. The position of the virtual camera should also be set to the exact same location as the centre of the sphere in order to act as the viewer's eye. Placing it elsewhere would make the image look distorted.

By default, the texture applied to any 3D object is positioned on the outside of the object. Due to the positioning of the camera, the content needs to be visible from the inside. In order to achieve this, the faces of the 3D object would need to be flipped. To flip the faces inwards, C# script was used (see Appendix A). This allowed for the content to be visible from the inside of the sphere (see Figure 3.16).

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[10] https://www.samsung.com/global/galaxy/galaxys6/galaxy-s6/

[11] https://docs.unity3d.com/560/Documentation/Manual/VideoPlayer.html

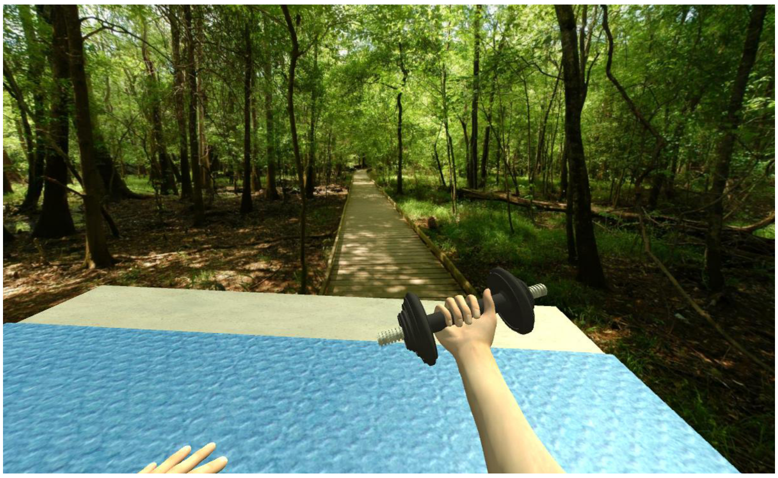


Figure 3.16: Participants' point of view in a 360-degree media environment developed for the second experiment for pain management

3.1.8.2 Development of the User Interface (UI) interaction mechanism

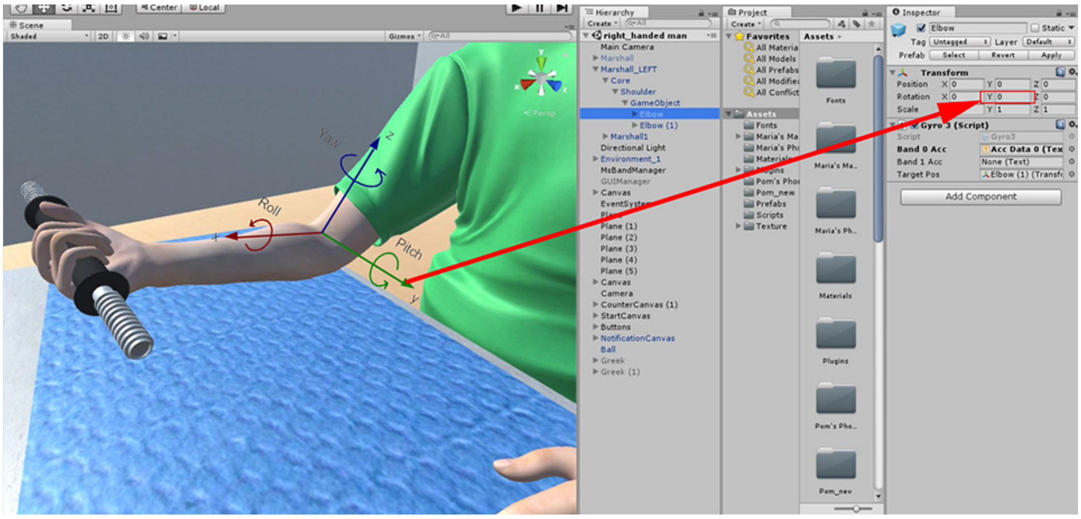
The design of the interaction mechanism for the mobile VR UI was adapted based on the design principles of a 2-dimensional interface, such as the use of a cursor and buttons on the PC. In order to use the UI control panel and navigate through the virtual space, an interactive cursor point was created. The cursor point was placed at the centre of the screen and its movement synchronised with the movement of the user's head. To simplify the use of the cursor and provide visual feedback to the user, the colour of the interactive objects would change when the cursor point hovered over them. To execute an action, the user needed to tap the touch panel on the side of the VR headset which would simulate the left mouse button click on the computer (see Figure 3.17). This design provided users with a simple, intuitive and comprehensive UI mechanism (Chu, 2014).

Figure 3.17: On the left a screenshot showing the process of setting up the application by the psychologist; On the right the Gear VR touch panel that the psychologist uses to simulate the mouse button click

3.1.8.3 Hand tracking

One of the key limitations of the most mobile VR systems and especially the first generation of mobile VR, compared with the PC-based VR systems is the absence of hand tracking devices. Thus for this case study, one of the most serious technical difficulties was the provision of the hand tracking device. Due to the fact that the participants of the experiment were holding weights in their hands, it was not possible to use a hand-held controller. Therefore, a simple, light-weight controller that could be attached to the wrist was required, such as, for example, Microsoft Band which suited the needs of the experiment (see Figure 3.18). By using the Microsoft Band Software Development Kit (SDK) for the Unity game engine, the gyroscope data from the band was taken and synchronised with the rotation parameters of the virtual hand, i.e. the elbow joint of the 3D model. A script in C# (see Appendix B) was developed to map the gyroscope rotation values along the Y-axis to the rotation transform attribute of the elbow joint in the Unity game engine (see Figure 3.19).

Figure 3.18: Microsoft Band 2 used in the case study



Elbow
Tag Untagged Layer Default
Prefab Select Revert Apply
Transform
Position X 0 Y 0 Z 0
Rotation X 0 Y 0 Z 0
Scale Y 1 Z 1
Gyro 3 (Script)
Script Gyro3
Band 0 Acc Acc Data 0 (Tex
Band 1 Acc None (Text)
Target Pos Elbow (1) (Transf

Figure 3.19: The rotation transform attribute of the elbow joint in Unity

3.2 Case Study 2: Co-Design of Mobile VR Application for Anxiety Disorder

In the second case study, we looked at the design of the mobile VR application with the aim of reducing anxiety levels for participants, as well as exploring the impact of the VR technology on the cognitive bias modification (CBM) training intervention. This study was published in JMIR Mental Health (Otkhmezuri et al., 2019). During the second case study, I was involved in the co-design process as the developer and designer of the VR application as well as created all 3D environments. In addition, I conducted the data collection for the study described in Chapter 4 for which this application was developed and took part in the data analysis.

3.2.1 Background of Cognitive Bias Modification of Interpretations for anxiety disorders

Research has demonstrated that people with anxiety problems generally tend to interpret ambiguous contextual information automatically in a negative or threatening way (Mathews & MacLeod, 1994). This leads to a worsening of their anxiety symptoms. Interpretation bias (IB) training interventions have been designed to train individuals to deal with such situations in a more positive way. These interventions have demonstrated the ability to reduce emotional activity towards stress, trait and state anxiety, as well as the symptoms of general anxiety disorders (MacLeod & Mathews, 2012).

Mathews and Mackintosh (Mathews & Mackintosh, 2000) developed a programme designed to modify IB: cognitive bias modification of interpretations (CBM-I). In order to modify biases, a series of ambiguous social stories was presented to the participants, each story ending with a fragmented word. The completion of the word would change the interpretation of the story either positively or negatively. Some studies have demonstrated that anxious individuals tend to think negatively when presented with questionable information (Salemink, van den Hout, & Kindt, 2007).

In the research of Mathews and Mackintosh (Mathews & Mackintosh, 2000), it was discovered that the interpretations would change depending on the direction of training. Participants who were trained to interpret the information negatively demonstrated negative interpretation of the ambiguous information. On the other hand, participants who were trained to interpret the information in a positive way showed positive results with the ambiguous information. Both cases lead to a change in the participants' level of anxiety. The results demonstrated a causal relationship between IB and anxiety (MacLeod & Mathews, 2012; Mackintosh, Mathews, Yiend, Ridgeway, & Cook, 2006).

With the increase in distribution of affordable mobile VR headsets, there is a new opportunity to apply these portable devices to existing psychological treatments, such as exposure therapy and cognitive training. In this case study, we translated CBM-I into a mobile VR environment (mobile VR CBM-I).

3.2.2 Research team and design process

A research team consisting of two human-computer interaction (HCI) researchers, three psychologists with expertise in CBM-I and a technical researcher specialising in game development, were involved in the design process for this application. The VR application prototype went through five design iterations over a period of four months (see Table 3.3).

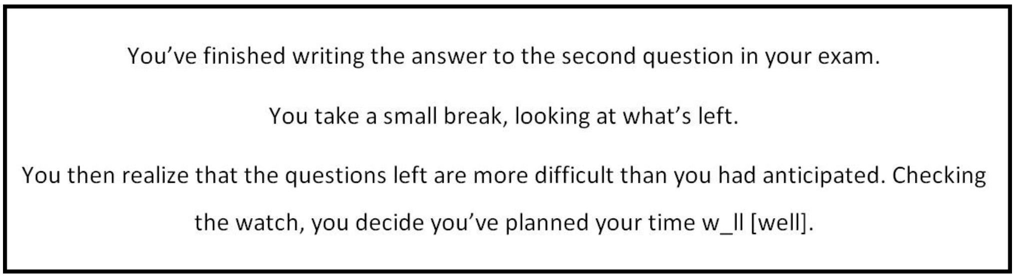
Stages	Design Process
1	**Initiation session and tech demo with the research team** Psychologists introduced the CBM-I programme. The technological possibilities of the Mobile VR were demonstrated to the psychologists.
2	**Brainstorming session with the research team** Specifications of the psychotherapy protocols and how they can be translated into a mobile VR application were discussed. Virtual environment locations for the study and list of scenarios were established.
3	**First evaluation session with the technical researcher and the psychologist** The virtual 3D generated environment was developed and the scenarios implemented in VR. The performance of the application and the position of the virtual camera were tested.
4	**Second evaluation session with the technical researcher and two volunteers** Virtual keyboard and voice recognition tools were tested to explore the best possible way for the users to interact with the scenarios.
5	**Third evaluation session with a volunteer and the technical researcher** The final version of the application was tested.

Table 3.3: Design stages for the anxiety disorders case study

3.2.3 Initiation session and tech demo with the research team

During the initiation session, the technical researcher introduced the PC-based and mobile VR systems to the psychologists and explained the various capabilities of these technologies; the procedure was similar to the first case study. Then, the psychologists introduced the PC-based at-screen CBM-I training (standard CBM-I) which was the core design reference for development of the VR application.

In this training paradigm, the participants repeatedly read short text scenarios presented on a PC screen line by line. These scenarios described ambiguous situations relevant to their type of anxiety, and each of them ended with a fragmented word. The task of the participant was to read the text and complete the last word in a meaningful way. Figure 3.20 shows an example of a training scenario.



You've finished writing the answer to the second question in your exam.

You take a small break, looking at what's left.

You then realize that the questions left are more difficult than you had anticipated. Checking the watch, you decide you've planned your time w_ll [well].

Figure 3.20: An example of a training scenario used in CBM-I training

Upon completion of the initial scenario, the participant was presented with a subsequent question related to the interpretation (e.g. Will you have time to complete the exam?). The correct answer (Yes or No) was then positively reinforced. Then the next trial started with a new scenario, and so on.

CBM-I training tasks often feature a very basic and unattractive layout (i.e. a few lines of text against a neutral background), which can make training sessions rather dull. Previous research shows that the participants who took part in the training reported it to be repetitive and monotonous (de Voogd et al., 2017; Beard, Weisberg, & Primack, 2012). The risk here is that the participants can be distracted easily and, as a result, become disengaged with the training. This could result in sessions being less effective and/or productive (de Voogd et al., 2017). It would therefore be beneficial to modify the visual features of the standard CBM-I training tasks to improve engagement with the programme and its results.

To enhance the effect of CBM-I training it was decided to use affordable mobile VR tools and provide the participants with the interactive VEs during the training session. This could transform the participants' engagement with the task and make the process more appealing. The choice in favour of the mobile VR was that this technology could potentially be used anywhere and at any time when anxiety-provoking situations occur, as the system does not require the use of a PC/laptop and it is wireless.

It is important to note that VR-based interventions, and more generally eHealth and mHealth interventions, refer to the implementation of therapeutic principles in a digital environment rather than the design of an entirely novel intervention paradigm (Khadjesari, Murray, Hewitt, Hartley, & Godfrey, 2011; Kraft & Yardley, 2009). In so doing, a mobile VR-based CBM-I training would harness the potential for simulating complex, real-life environments where individuals can fully immerse themselves and explore, whilst keeping the effective principles which underlie the training paradigm as intact as possible. In VR, users are no longer simply external observers of images or text on a computer screen, but they are active participants immersed in a computer-generated 3D virtual world.

The latter feature of VR is of special interest for the optimisation of CBM-I training interventions. The use of imagery instructions in CBM-I training has been found to boost the effects of intervention (Menne-Lothmann et al., 2014). The ability of VR to "physically" immerse users within ambiguous scenarios and to provide the proprioceptive perception of being an active agent in the virtual world has the potential to activate relevant memory schemas and evoke the typical interpretational and emotional response. Given recent insights into the importance of (a strong) discrepancy between expectations and the actual situation (Vincelli, 1999), VR may activate the dysfunctional schema and thus enhance the discrepancy with the positive interpretation provided in the CBM-I training, boosting prediction-error learning.

As such, VR has the potential to enhance the therapeutic mechanisms underlying the training intervention. In fact, the activation of (anxiety-relevant) ambiguity and the related individual's habitual pattern of biased information processing are necessary ingredients to successfully retrain toward a more benign resolution (Mathews & Mackintosh, 2000; de Voogd et al., 2017). Furthermore, the interactive and immersive properties of VEs may lead to an improvement of motivation to engage with the training application and the overall training user experience, compared to other media (e.g. desktop computers).

Despite VR technology being widely used as part of exposure therapy for anxiety disorders, the use of this technological platform in other forms of psychological intervention such as CBM training has received far less attention. To the best of our knowledge, only one proof-of-concept study has explored the feasibility of a VR-based CBM training for social anxiety targeting attentional bias for threatening stimuli (Urech, Krieger, Chesham, Mast, & Berger, 2015). Although this study (Urech et al., 2015) did not include a control group and was not designed, or powered, to test the effectiveness of the intervention, the VR-based attentional bias training was associated with higher scores in enjoyment, flow, presence, and motivation than the standard training. This is a good indication of acceptance and feasibility of the VR training intervention.

During this initiation session the target users and type of anxiety were also identified. To explore the effect of mobile VR CBM-I training on test anxiety, the research team decided to recruit students. The research team concluded that the training must resemble the stressful situations being targeted in order to successfully induce change in the interpretations. Based on the type of anxiety selected and participant population, 40 scenarios were selected from a list of 70 previously used in the domain of performance anxiety (Mackintosh, Mathews, Eckstein, & Hoppitt, 2013). The selected scenarios included test/examination sessions, job interviews and other similar activities where students might experience problems.

3.2.4 Brainstorming session with the research team

Based on the information from the initiation session, the research team discussed technical solutions for translation of the standard CBM-I training into mobile VR. The research team grouped 40 scenarios, selected in the previous session, into several virtual locations. These included the exam hall, classroom, computer laboratory, student accommodation rooms and a bookshop (see Figure 3.21). The research team believed that the use of VEs can have an effect on user engagement and experience, which in turn will boost the effect of CBM-I interventions.

Figure 3.21: Examples of virtual locations: exam hall, bookshop, classroom and computer lab made in the Unity game engine

Participants. Based on the initiation session, it was decided to recruit students with high-level anxiety to participate in the study. To aid with the anxiety pre-screening process, the research team created an online form for the students to complete. Only those with anxiety levels higher than the median level of the general population were recruited. In order to measure the anxiety levels, the psychologists suggested using standardised questionnaires such as the State-Trait Anxiety Questionnaire, STAI (Spielberger, 1989; Julian, 2011) (see Chapter 4 section 4.1.3 for more details).

Standard CBM-I procedure. When the standard CBM-I training was performed using the PC (see Figure 3.22), a keyboard was used to interact with the scenario. In order to interact with each scenario presented to the participant, the spacebar on the keyboard was used to go from one line to another. The last sentence of the scenario contained a word with missing letters. The participants needed to complete this word as quickly and accurately as possible by pressing the spacebar again and typing in the missing letters. The correct answer was then shown in green, whereas the incorrect or no answer was shown in red. In the case of a no answer or after 10 seconds of inactivity, the correct answer was shown on the screen. After that, the comprehensive question appeared and the participants had to reply yes or no by pressing the Y or N buttons. The accuracy of the response and the relevant feedback was then shown to the participants to reinforce the positive interpretation.

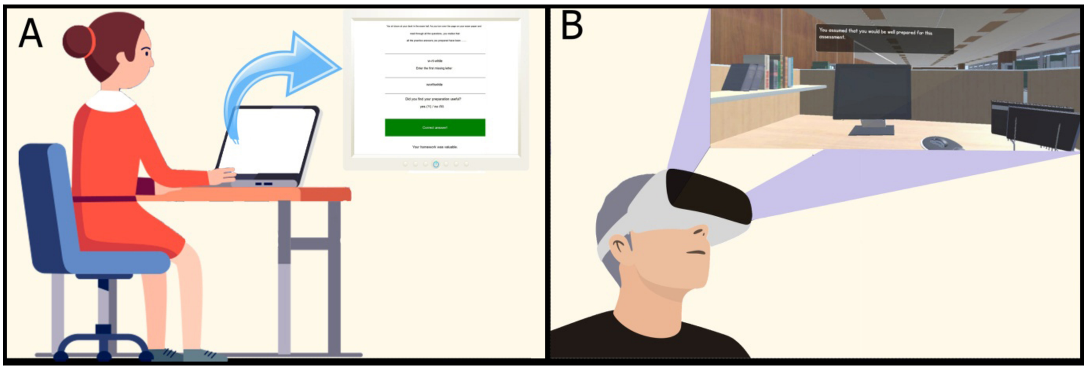


Figure 3.22: Representation of the standard CBM-I and VR-CBM-I training: (A) Standard CBM-I training; (B) VR-CBM-I training (participant's point of view on the computer room virtual environment in the top right corner)

Mobile VR design. The mobile VR systems do not have any input devices such as keyboards. Therefore, interaction with the scenarios in the VE needed to be addressed. Two suggestions were made by the technical researcher and HCI experts regarding this matter. Virtual keyboard and voice recognition tools were discussed. The virtual keyboard option was ruled out, as it revealed two significant drawbacks: it was both time-consuming and inconvenient to use. According to the HCI experts, using a virtual UI keyboard in mobile VR could potentially cause physical discomfort, since the user has to move his or her head to navigate the keyboard which, in turn, can lead to a strain in the neck. When designing UIs, factors like range of motion, vision and ergonomics should be considered, as participants will not have any desire to utilise a technology that is physically uncomfortable (Fox, Park, Borcar, Brewer, & Yang, 2018). Thus, interaction using voice recognition was chosen.

In order for the users to go through the scenario line by line, the touch pad and later the "Back Key" on the side of the VR headset were used (see Figure 3.23). The contents of the scenario would appear in a pop-up text box. Similar to the standard CBM-I training, the correct and incorrect answers were highlighted in green and red correspondingly with the interpretation feedback following afterwards.

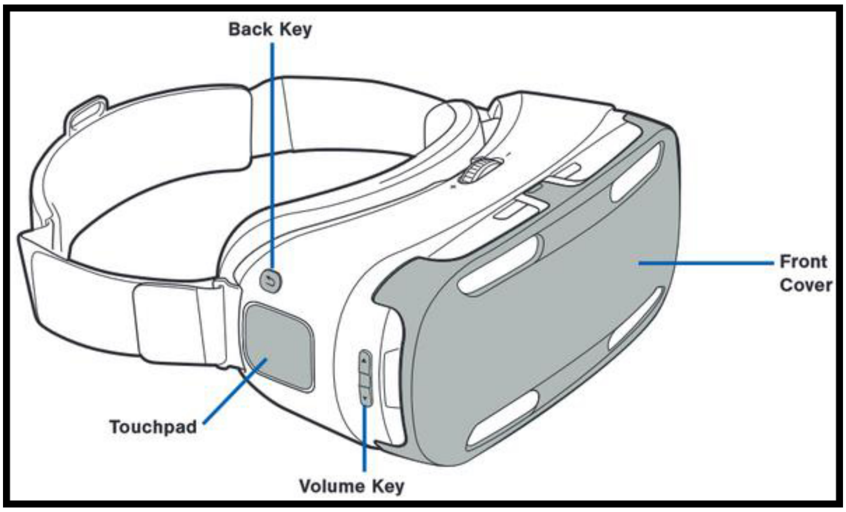


Figure 3.23: Samsung Gear VR headset with a "Back key" button on the side used to display the scenarios and activate voice recognition

As a result of the brainstorming sessions, the research team created a procedure for the experiment consisting of three stages:

1. A baseline assessment for the participants measuring the levels of stated anxiety (how you feel "right now") and IB should be conducted with the use of the questionnaires (see Section 4.1.3).
2. Training sessions to be organised: the PC-based version of CBM-I (standard CBM-I) and the mobile VR version of CBM-I (VR-CBM-I). The standard CBM-I session would act as a control condition.
3. Post-training assessment for stated anxiety, IB, perceived immersion and presence during the training should be conducted.

3.2.5 First evaluation session with the technical researcher and the psychologist

Based on the information from the two sessions (Initiation and Brainstorming), the first version of the application was developed. Two members of the research team, one of the psychologists and the technical researcher, took part in the testing. The aims of the first evaluation session were: 1) to demonstrate the developed VE to the psychologist and 2) to test the application performance and interaction with the scenario using mobile VR tools (displaying and switching between the lines of the text).

After the evaluation, a list of technical issues was compiled and the presentation of the scenarios in the VE's was discussed. The first technical issue that was identified during the testing was the slow performance of the smartphone. A delay in rendering appeared when the user started rotating his or her head. Rendering delay is the time elapsed between new data entering the graphics pipeline and the production of a new frame with that data (Jerald, 2015). Rendering delay is dependent upon the complexity of the VE, quality of the resulting image, number of rendering passes and the graphics performance (software/hardware). To make the environment look more realistic, a significant number of 3D generated objects, lights and textures were added. Since the graphics card of the smartphone is less powerful than that of a PC, the performance of the smartphone was considerably slower. To improve the performance of the mobile VR, we applied optimisation techniques presented in the Section 3.3.2.

The way users see the scenarios was also discussed during this evaluation session. The first prototype version of the application presented the scenarios in the form of a pop-up UI text box, which followed the rotation of the camera. This was done in order for the participants to face the scenario while exploring the environment. However, the psychologists noted that it was hard to read the text and explore the environment simultaneously due to the overlaying of the text and textures in some of the VEs (see Figure 3.24).

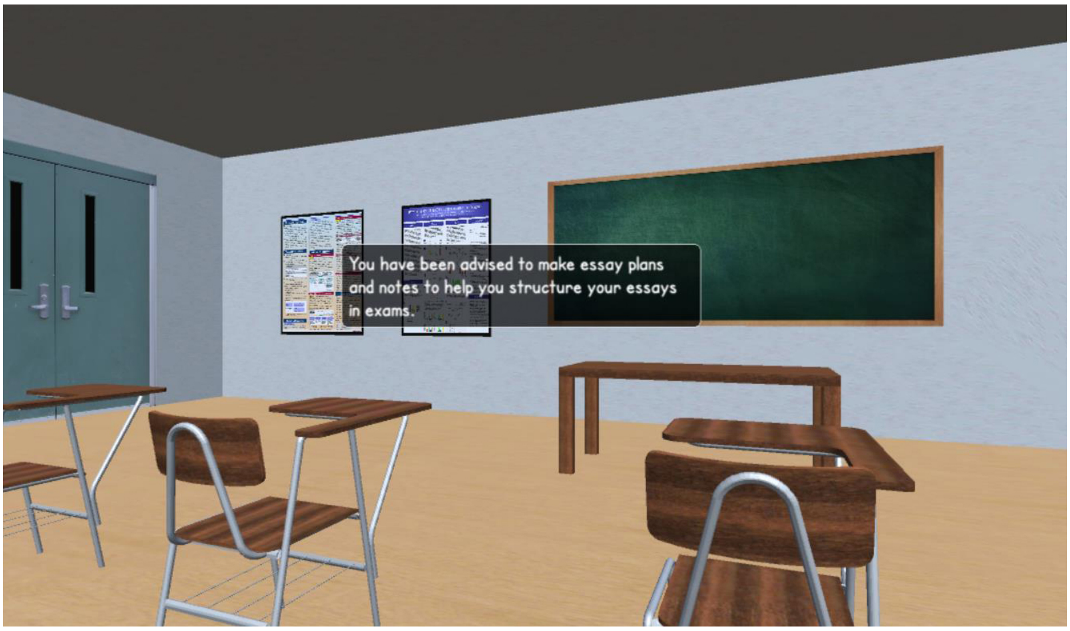


Figure 3.24: Example of the overlaying pop-up text box in the VE

The initial design of the pop-up text box utilised a black, non-transparent background which was blocking a large part of the VE, as the text should be quite large in order to be able to read it. To target this issue, the research team decided to reduce the opacity of the text box background to let the participants see through it. This decision affected the readability of the text. The visual properties of the background affecting the readability of text have been previously studied. However, only little research has considered content incorporated with video and 3D illustrations (Jankowski, Samp, Irzynska, Jozwowicz, & Decker, 2010). The contrast and spatial frequency of the background texture were identified as being factors affecting the legibility of text (Scharff, Hill, & Ahumada, 2000). Nonetheless, it is difficult to control the texture characteristics of the 3D background in VR. A solution to this issue was proposed by the technical researcher. It was suggested to use a 'fixed UI' in order to anchor the position of the text and place it against a suitable background. The fixed UI would allow the participants to see the text box in front of them, but the position of the box would not change regardless of the rotation of the head. This means that the participants would be able to explore the VE and read the scenario uninhibited.

For the second evaluation session, the application was updated and the second version of the prototype was developed and tested.

3.2.5.1 Second evaluation session with the technical researcher and two volunteers

To improve the performance of the 3D generated environment, a number of issues had to be addressed, for example, reducing the number of polygons and the resolution of the textures of the 3D objects. Resolved the performance issue, the second version of the application was developed and tested. This version included the new voice recognition tool. The aim of this session was to test the optimised performance and the voice recognition functionality, as well as to make a pilot session of the VR-CBM-I therapy.

Two volunteers were recruited to test the anxiety VR application. Both testers raised the same concerns regarding the over-complicated features of the voice recognition function and the scenario interaction in the VE. Users commented that it was difficult to understand when they needed to start and stop speaking, as well as which button was supposed to be used for which option. A tone was therefore added to indicate the beginning and end of the voice recording process to make it simpler for the participants to interact with the procedure. In case of an incorrect answer, participants were able to repeat their answer twice or skip the step entirely. To skip a step and see a correct answer, the participants needed to press the "Back Key" button twice; a comprehension question would then appear. This design was chosen due to the different input approach of the mobile VR application in comparison to the standard training where the correct answer is shown automatically after 10 seconds.

The initial design of the application utilised the touch panel located on the side of the VR headset to display each line of the scenario and the "Back Key" button (see Figure 3.23) to initiate the voice recognition process. The participants needed to tap the touch panel for the new line of the scenario to appear on the display. This was done in order to mimic the standard CBM-I training. Many mobile devices are moving towards touch-based interaction rather than physical buttons. The research in non-visual feedback for mobile devices showed that haptic feedback on touch-sensitive displays provides significant benefits in terms of reducing errors and increasing the speed of interaction (Hall, Hoggan, & Brewster, 2008; Leung, MacLean, Bertelsen, & Saubhasik, 2007).

However, this was not feasible in our experiment. The touch panel on the side of the Gear VR does not provide any haptic feedback, which makes it difficult to use in the application. In addition to this, the participants tended to hold the headset with their hands and accidentally make contact with the touch panel, which then led to undesired effects (e.g. skipping a line of text). To minimise any accidental erroneous actions, it was decided to just use the "Back Key" button on the VR HMD for both scenario interaction and voice recognition activities. The "Back Key" button is a physical button that requires users to apply pressure in order to activate it.

In order for the research team to assess the data during the analysis, all user actions, such as switching between the lines of the scenarios, voice recognition inputs etc., were recorded as a text file and stored on the smartphone. The purpose of this was to verify the results of the voice recognition process. The application was fully automated, but differences in pronunciation would sometimes lead to the voice recognition system rejecting the correct answer. In such cases, an intervention was required from an assistant in order the experiment could continue. Therefore, whilst certain aspects of the assessment were automated, there were still some areas requiring human involvement.

The participants also expressed concerns regarding spending too much time in a VE. During the test session, the participants would typically spend around 40 minutes in VR. To address this, a short break between activities was introduced. Overall, the system showed a good level of graphical (GPU) and processor (CPU) optimisation and did not cause any visual discomfort for the participants. Having incorporated all the changes, the final version of the application was tested and no other usability issues were found.

3.2.6 Implementation

The same principles as those used in the pain management research were applied in this study; i.e. head tracking and displaying 3D generated environments. Seven VE's (exam hall, classroom, computer room, etc.; see Figure 3.25) were created in Autodesk Maya and 3ds Max[12] to represent the 40 training scenarios used in the standard CBM-I. Each environment included between 2 and 7 scenarios. The stereoscopic 3D virtual environments were then textured and rendered in the Unity game engine[13] version 5.6.0f.3, and the text of the training scenarios added to the UI. The participants could then freely interact and explore the environment by moving their head.

You are sitting in a small room and have just started doing a test that seems very difficult.

Together with a friend, you are preparing for a physics test.

While shopping, you are asked to take part in a market research.

Figure 3.25: Examples of virtual environments: classroom on the left side, living room in the middle and bookshop on the right side made in the Unity Game Engine

3.2.6.1 Development of the voice recognition tool

The main obstacle in creating a mobile VR application based on CBM-I training for anxiety disorders was the lack of usual input devices such as a keyboard, which would normally be used for the PC version of the intervention. Figure 3.26 demonstrates the hardware and software configuration for the standard CBM-I intervention.

As a result, a voice recognition tool was developed for participants to interact with the application using their voice. The "Android SpeakNow" plugin[14] for the Unity game engine was used. This allowed the participants to complete the fragmented word by saying it out loud and answer the subsequent comprehension question by saying yes or no. Figure 3.27 summarises the hardware and software configuration for the voice recognition tool. The participant pressed the "Back Key" button on the VR headset to activate voice recognition. The application recorded the participant's voice using the inbuilt smartphone microphone. Using the "Android SpeakNow" plugin, the recorded audio file was sent to the Google "Speech-to-text" server where it was converted into text. The result of the conversion appeared on the smartphone screen as text in either green for correct or red for incorrect answers.

The application cannot work offline since the voice conversion requires a connection to Google services. However, the advantage of using Google services is the ability to support a variety of languages. If the VR-CBM-I training needs to be

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[12] https://www.autodesk.co.uk/products/3ds-max/overview

[13] https://unity.com/

[14] https://assetstore.unity.com/packages/tools/integration/android-speaknow-16781

carried out in a language other than English, it could be easily done by switching the language option of the voice recognition tool in the application code.

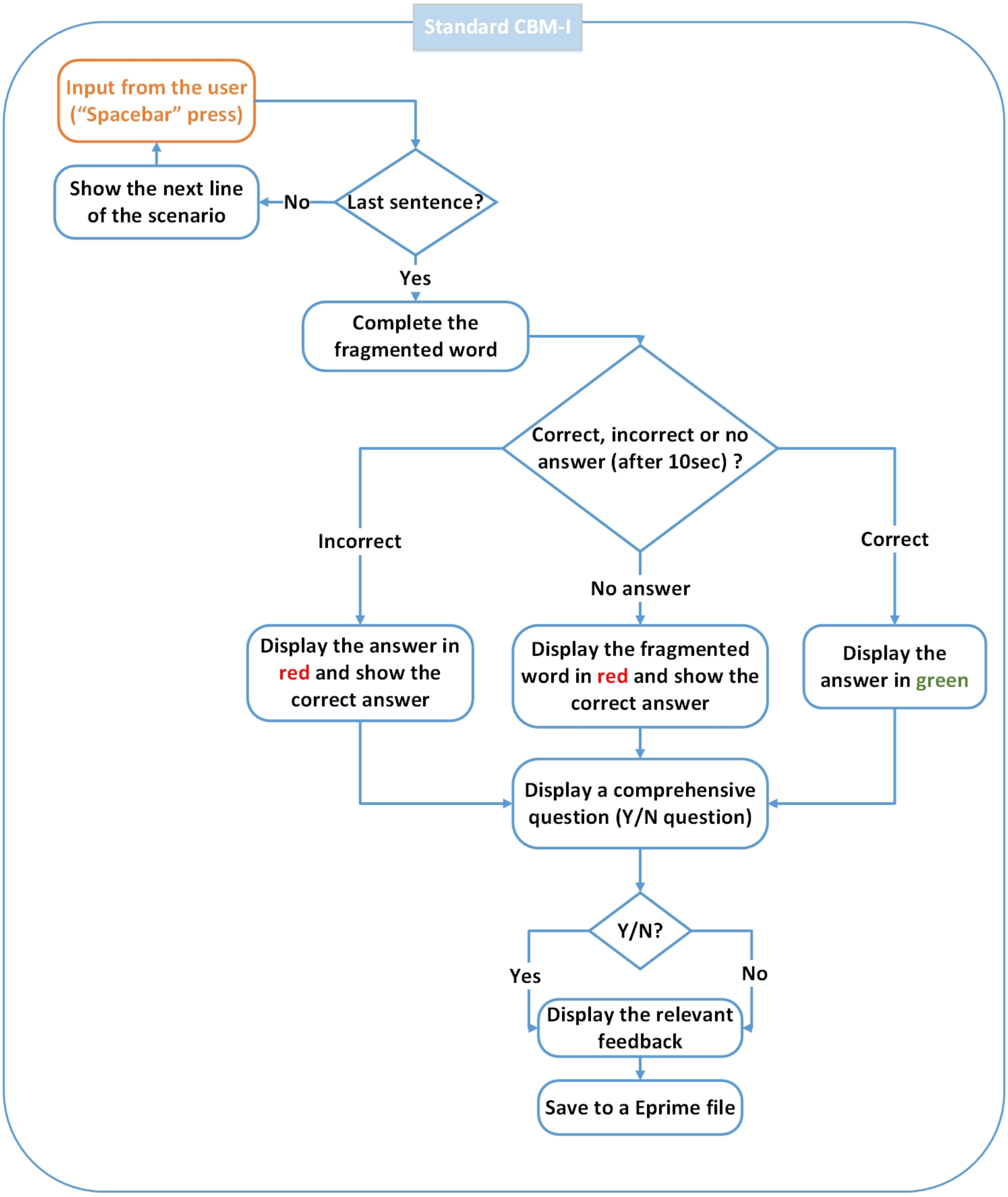

Figure 3.26: Diagram summarising the process for standard CBM-I

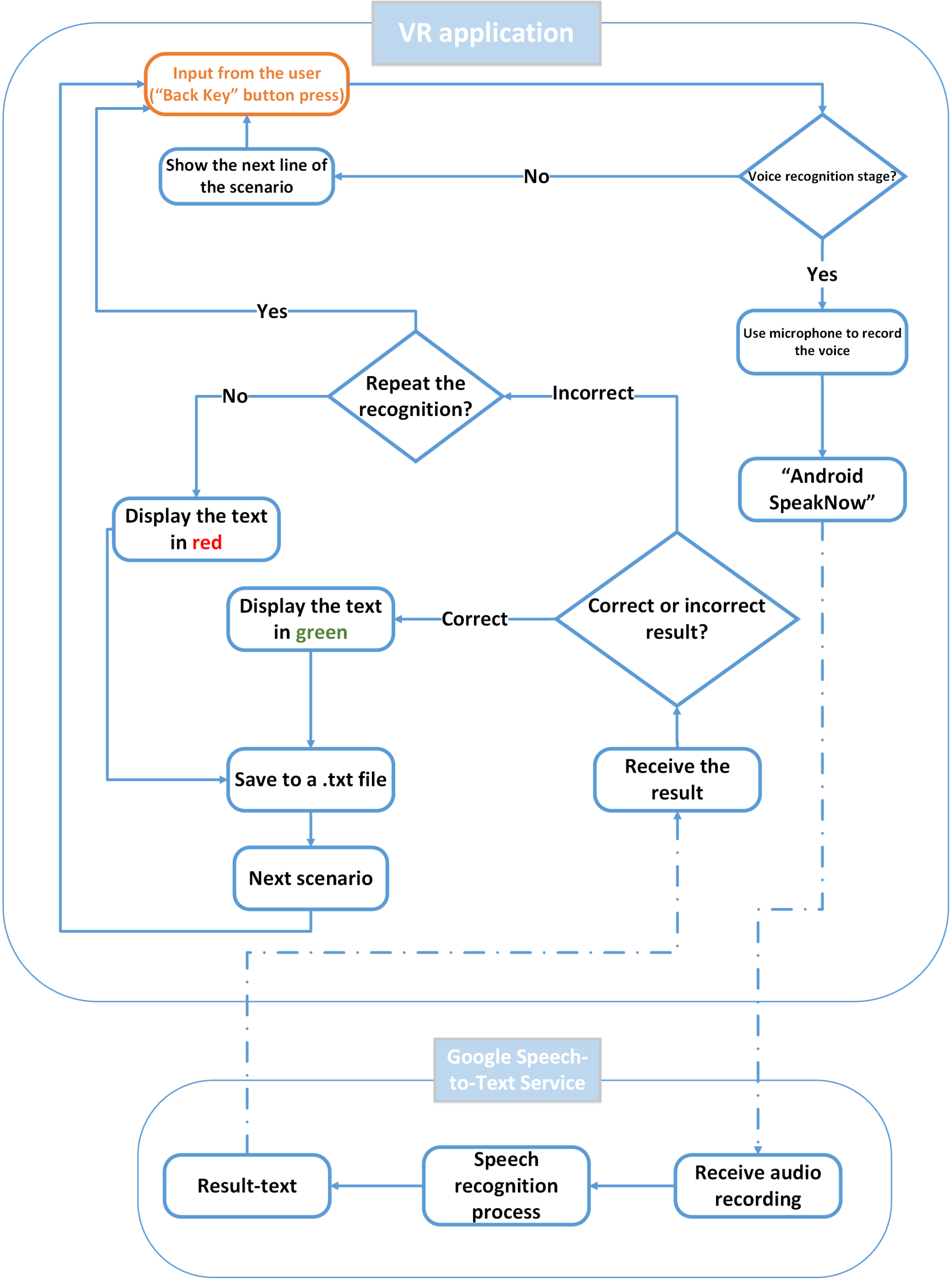

Figure 3.27: Diagram summarising the voice recognition process used in the experiment

3.3 Outcomes of the two case studies

A number of lessons were learnt from the co-design and development process described in this chapter. Firstly, sections 3.1.3 and 3.2.3 (initiation sessions for both studies), demonstrated that all design should begin with an understanding of the main aims and purposes of the psychotherapy which need be discussed with the psychologists. Moreover, it was noted that most psychologists have never experienced VR before. This means that the first session should be also used by the technical and HCI researchers to demonstrate the possibilities of targeted VR systems to stakeholders. A good example of an introduction application for Gear VR was found to be the free Samsung application, Introduction to Virtual Reality[15].

Sections 3.1.4 and 3.2.4 (brainstorming sessions) demonstrated the co-design process for the VR psychotherapy interventions. During this stage, the psychologists established the number of goals and distinctive features of each treatment and its transformation into the VR application. Moreover, in drawing up the VR therapy design, the profile data of the target users, i.e. age, gender and physical and cognitive abilities, should be considered. This could influence the technical approach and development; for instance, people with disabilities would potentially require a different set of tools to perform the VR therapy.

All aspects of the design, such as the interaction mechanisms, environment requirements and presence of a therapist during the VR intervention, should be agreed upon before the development commences. This should allow the technical researcher to work out the required hardware, software and the design of the application, as well as provide suggestions for the psychologists as to what can be potentially achieved.

In many cases, the interaction between users and the VE in mobile VR is complicated by the lack of external controls. Depending on the psychotherapy application, different solutions were offered for any interaction problems, for example, the use of Microsoft Band for hand tracking.

Certain design considerations were taken into account during the development stage, such as providing technical support within the application for the psychologists to ensure the correct and continuous run of the application. For example, an additional UI was provided to display the band connection status for Case Study 1.

During the period of iterative development and evaluation, it was found that performance testing should be carried out before the beginning of the evaluation sessions with the test users. It was also found during the evaluation session for the anxiety disorders application, that testing on the PC using Unity tools may not provide a correct representation due to the different hardware specifications. This issue was identified in the second case study (see Section 3.2.5). Therefore, performance testing should be executed on the selected mobile device.

However, the developers can still use Unity tools for the initial testing and detection of code errors. Performance optimisation will ensure that the application works sufficiently prior to the evaluation sessions so that the test users can focus on interaction and functionality rather than the performance-related issues of the application.

The co-design approach allowed for the psychologists, HCI experts and developers to mutually benefit from the experience of all team members. The HCI experts and developers learned about the psychological treatments and related terminology, whilst the therapists and psychologists had an opportunity to build up and develop a technical vocabulary which could potentially help them in their future research. Overall, based on the conducted case studies, the co-design process of VR-based psychological treatments could be divided into 5 steps:

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[15] https://www.oculus.com/experiences/go/1016573058409292/?locale=en_GB

1. The “Initiation” session with psychologists of differing areas of expertise (e.g. sport and exercise science, pain management and anxiety), should be carried out to identify the concepts of designing a relevant VR system.
2. The “Brainstorming” session/s should be conducted to identify the ways to translate the current “offline” practice into VR therapy activities.
3. The “Brainstorming” session/s should be conducted to design the experimental procedure which include the tasks for the participants to carry out (e.g measuring of the baseline weight for the pain management study).
4. Based on the concepts from the “Brainstorming” sessions, a number of software and external hardware devices should be evaluated for consequent use in the development of the appropriate VR system.
5. The experimental procedure and the VR system should be tested iteratively with the psychologists and volunteer testers in order to refine the procedure and address any usability issues within the system.

It should be also noted that there is quite a lot of research going on nowadays in pain management and anxiety. Therefore, in order to expand the knowledge in the application of mobile VR tools in this area, it was decided to choose these two interventions. However, the techniques and methods described in this Chapter could be applied to any other treatments with the use of mobile VR tools.

3.3.1 Outcomes of the evaluation sessions

For a successful implementation of the VR application, regular testing was required. Between evaluation sessions, the updates to the interface and changes to the interaction mechanism were applied. This way, the developers of the application constantly made small changes - less time-consuming than if they were to discover a potentially major design flaw.

Evaluation sessions with the test users, starting from the beginning of the development and continuing throughout, were found to be useful; the purpose of which was to highlight potential problems with the system interaction or the UI that are sometimes not obvious to the developer. For instance, the problem with the overlaying of text in the anxiety disorder study (see Section 3.2.5).

The usability assessment played a crucial role in the evaluation sessions. This consisted of examining: 1) how easy it was for the test users to understand what they needed to do; and 2) whether or not they experienced any difficulties when using the VR application in terms of performance and/or interaction. Some limitations in the testing of the mobile VR were discovered. For example, during the test session, the developer was not able to see what the test user saw as the image shown in the mobile VR is difficult to show on a separate screen. Therefore, if there was an issue and the test user wanted to point it out, it would not be easy for the developer to know exactly where the issue lay. Preparing a set of printouts of the important screens and application menus would be useful as it would help the users give feedback after the end of the test session.

3.3.2 Outcomes of the performance optimisation

During the development process of the mobile VR applications for anxiety disorders and pain management, some areas for improvement were identified: the overall performance of the application, the optimisation of the 3D objects and the prevention of overheating in the smartphone. All these issues played an essential role for the users to engage in VR psychotherapy comfortably over a period of time.

This research has led to the proposal of the following sets of recommendations:

1. Try to ensure that the application operates on a ratio of 60 frames per second (fps). Any deficiency in this parameter is very obvious to the user, as losing frames leads to “lagging”, which means the extremely slow rendering of the image.

2. Do not fully rely on the Unity game engine frame rate counter when building mobile VR applications. Although it provides feedback on the performance level, it was found through research that it is more accurate to test the application on the selected hardware.

3. Remove all invisible faces from the 3D geometry to reduce the polycount (the term used to describe the number of polygons of a 3D model) in order to improve the performance of the application.

4. Use occlusion culling to avoid rendering of the geometry which cannot yet be seen in the scene, for instance, furniture behind a wall; or remove invisible geometry for the virtual camera if it is set to be static.

5. Where relevant, use “light baking” tools to “bake” the shadows and lights for the static objects (saving shadows and lights as a texture), instead of using the dynamic or real-time light, which is a resource-costly process.

6. When rendering 3D objects that are far away from the user, use a model with fewer details and a lower number of polygons (LOD- the level of details) and change it to a more detailed model when the user approaches it.

Better optimisation of the application will lead to a reduction in both GPU and CPU processes. This, in turn, will provide not only better performance but also extend battery life, especially when several external devices are connected to the mobile device, which can generally cause greater battery consumption and overheating.

3.4 Conclusion

This chapter presents the process of co-design and software development of mobile VR applications for psychological interventions. Firstly, the co-design of the VR applications for pain management and anxiety disorders was presented. Secondly, the results from the testing of the applications, together with actions taken to address the identified problems, were provided. Then the development of various types of VE for mobile VR and the design of different interaction techniques were explained. Finally, the theoretical design guidelines for the technical implementation and testing processes were presented.

The co-design approach, together with the guidelines and technical recommendations developed here, would enable the preparation of a robust mobile VR application for psychological interventions. The use of the mobile VR application for anxiety disorders will be examined in Chapter 4.

Chapter 4

The Use and Effect of Mobile Virtual Reality on Anxiety Level of Young Adults

Using the VR application for anxiety disorders co-designed in the previous chapter, the study was carried out to investigate whether using mobile VR technology improves the experience and effectiveness of CBM-I training (VR-CBM-I). This chapter will provide the results from this study.

The main goal of the current study was to examine the feasibility of using mobile-based stereoscopic-3D VR technology in a CBM-I training paradigm (VR-CBM-I) for performance anxiety to improve the users' experience with the training program (i.e. feelings of immersion and presence). An additional objective was the enhancement of training effects on state anxiety, emotional reactivity, and interpretation bias, compared to the standard training paradigm (standard CBM-I). The research team hypothesised that, compared with participants receiving the standard CBM-I training, participants completing the VR-CBM-I training would show 1) higher self-reported rates of immersion and presence in the training scenarios; 2) a greater endorsement of positive interpretations and fewer negative interpretations after the training; 3) a reduction in state anxiety after the training; and 4) lower emotional reactivity to stressors.

This chapter is broken down into five sections: Section 4.1 provides details for the study design and procedures; Section 4.2 provides the results from the study; Section 4.3 discusses of the findings; Section 4.4 describes the limitations revealed; and Section 4.5 provides a conclusion.

4.1 Study design and procedure

4.1.1 Procedure

Upon arrival at the experimental laboratory, participants were briefly given an explanation of the goal and the procedure for the study. Participants were informed that the study was focused on how CBM-I training can help support people with anxiety and that we were interested in exploring how different technologies, including VR, can facilitate the training of interpretation bias. The participants did not know the specific hypotheses of the study, nor that they would receive a stressor task. Several things were explained to the participants: how a general scenario-based CBM-I training task works; that they would be divided into two groups of equal size; and that afterwards, they would have to complete an assessment of stress, immersion and system usability. After giving their informed consent, they were assigned to either the standard CBM-I (n = 21) or the VR-CBM-I (n = 21) training condition in a counterbalanced fashion, stratified by gender.

The experiment started with a baseline assessment of participants' state anxiety (State-Trait Anxiety Questionnaire (STAI, (Spielberger, 1989; Julian, 2011)), A-State subscale) and interpretation bias (Recognition Task). STAI is a standardised measure of a sub-clinical and clinical trait (A-Trait subscale) and state (A-state subscale) anxiety with very robust psychometric properties (Julian, 2011). This was followed by the training session, completed on either the computer (standard CBM-I) or a head-mounted display system (VR-CBM-I), according to the allocated condition. At the end of the training and after an optional short pause, participants completed a post-training assessment of state anxiety (STAI A-State subscale), interpretation bias (Recognition Task), and perceived immersion (Immersion Experience Questionnaire, IEQ) (Jennett et al., 2008) and presence during the training (Slater-Usoh-Steed questionnaire, SUS) (Slater, Usoh, & Steed, 1995). The IEQ was originally designed for the serious games field and has shown acceptable psychometric properties (Slater & Steed, 2000). SUS Questionare was originally designed in the VR field, has been tested in multiple empirical studies and has been shown to correlate with behavioural measures of presence (Slater et al., 1995; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002).

The post-assessment phase ended with a stress induction manipulation, where participants rated their mood before and after performing the Anagram Stress Task (MacLeod et al., 2002). The purpose of this task is to asses emotional response to an actual failure. Macleod and colleagues (MacLeod et al., 2002) concluded that the key issue is not whether biases lead to increased anxiety as such, but how such biases can contribute to vulnerability in responding anxiously to subsequent stressors. This task should allow the psychologists to see if there are any potential benefits of using VR to protect users from stress. This task is designed to appear easy but is in fact very difficult and almost impossible to complete. Finally, participants were fully debriefed about the study and the stressor procedure and compensated with a £10 voucher. The study was approved by the Research Ethics and Advisory Group of the Department of Engineering and Digital Arts of the University of Kent (ref. N. 0631516).

4.1.2 Participants

Participants were recruited through convenience sampling from the undergraduate student population of the University of Kent. Candidate students were invited by email to participate in a study on the use of VR in the reduction of anxiety levels. Sixty-seven interested students aged 18+ were screened online for moderate to high trait anxiety (a score >40 on the A-Trait subscale of the STAI, which is a standardised clinical measure of trait and state anxiety) and, when meeting this criterion, further invited to schedule a lab session. Forty-two students (23 females and 19 males) aged between 18 to 35 years (M = 21.60, SD = 2.96) and with a mean trait anxiety score of 51.0 (SD = 8.7) took part in the study.

4.1.3 Outcome measures

Immersion and Presence experience
Participants' subjective experience of being immersed in the training scenarios was assessed with the IEQ (Jennett et al., 2008). IEQ consists of 31 items scored on a five-point Likert scale covering five aspects underlying the immersive experience with a digital environment.

These were:

1. Emotional (6 items; e.g. "To what extent did you feel that the scenario was something you were experiencing, rather than something you were just doing?") and Cognitive (9 items; e.g. "To what extent did you feel you were focused on the scenario?")
2. Involvement, which refers to the feelings and the amount of focus experienced whilst interacting with the digital environment.
3. Real world dissociation (7 items; e.g. "To what extent did you feel as though you were separated from your real-world environment?"), referring to the sense of detaching from the outside world and increasing awareness of the digital environment.
4. Challenge (4 items; e.g. "To what extent did you find the training scenario easy?"), which is the experience of being challenged by the digital environment.
5. Control (5 items; e.g. "At any point did you find yourself become so involved that you were unaware you were even using controls?"). This refers to the extent to which the user feels in control whilst interacting with the training.

To adapt it to the context of this study, all game-related instances in the items were replaced with "involvement with the training scenarios".

The experience of presence within the training scenarios was assessed with the SUS (Slater et al., 1995), a six-item questionnaire rated on a seven-point Likert scale, evaluating:

1. The sense of "being there" in the scenarios as compared to being in a place in the real world (e.g. "Please rate your sense of being in the scenario, on the following scale from 1 to 7, where 7 represents your normal experience of being in a place. I had a sense of "being there" in the scenario.").
2. How much the scenarios became the dominant reality (e.g. "To what extent were there times during the experience when the scenario was the reality for you? There were times during the experience when the scenario was the reality for me...").
3. The extent to which a participant remembered the scenarios as a place visited, rather than as a computer-generated text or image (e.g. "When you think back about your experience, do you think of the scenario more as "images" that you saw, or more as somewhere that you visited ? The scenario seems to me to be more like…").

For the purpose of this study, all VR instances in the questionnaire were carefully replaced with "scenarios".

Interpretation Bias

Positive and negative interpretations were assessed with the Recognition Task before and after the training, a validated computerised task that has shown great sensitivity in capturing CBM-I training effects across both sub-clinical and clinical samples (Mathews & Mackintosh, 2000; Salemink et al., 2007; Salemink, van den Hout, & Kindt, 2009; Salemink & van den Hout, 2010). The task is similar in structure to the scenario-based standard CBM-I training (only with an added title), yet both the solution of the fragmented word and the comprehension question do not disambiguate the scenario, which remained ambiguous. The task presented ten new, unique, ambiguous scenarios related to performance anxiety at each assessment time point.

An example of a test scenario is the following:

Facts and Logic
You are working through a set of examples in your exam and concentrating very hard to try and remember the facts and logic you studied earlier.
When it comes to recalling what you have learnt you feel you know how effectively the test measures your true ……
m–ory ability [memory ability]
Was your memory for facts and logic being tested in an exam?

After presenting the ten scenarios in a random order, the titles of the scenarios with four interpretations were presented again, one at a time in random order. Participants were asked to rate the four interpretations on a 1 (very different) to 4 (very similar) scale, regarding how similar each was in meaning, to the original (Salemink et al., 2007; Salemink & van den Hout, 2010). The sentences represented a) a possible positive interpretation, b) a possible negative interpretation, c) a positive foil sentence, and d) a negative foil sentence. The four corresponding sentences of the "Facts-and-logic" scenario are presented here:

Facts and logic

(a) *You think you did not do well in the test because you cannot apply your good memory ability.*

(b) *You think you will do well in the test because good memory is not important for it.*

(c) *You think you will not do well in the test revealing your poor memory ability.*

(d) *You think you will do well in the test because of your good memory ability*

Emotional outcomes

State anxiety was assessed with the A-state subscale of the STAI questionnaire Form Y (Spielberger, 1989), including 20 items rated on a four-point Likert scale. Stress reactivity to failure was measured by assessing participants' emotional responses to a cognitive stressor, the Anagram Stress Task (MacLeod et al., 2002).

Participants were presented with 13 anagrams of different levels of difficulty that had to be solved within 28 seconds by typing the correct word. A new anagram was presented after responding or when the 28 seconds were expired. Participants were told that the task was a test of their language skills, which were found to be a reliable predictor of success in many domains, and that students normally perform well in such a task. Although the test appeared relatively easy, it was in fact extremely difficult, so that all participants failed most items. Before and after the task, participants rated how anxious and how sad they felt on two visual analogue scales ranging from 1 (happy or relaxed) to 100 (sad or anxious).

4.2 Results

4.2.1 Sample descriptives

Table 4.1 shows baseline sample descriptives. Comparison between the groups revealed no significant baseline differences in age, gender, trait and state anxiety, previous experience with VR, or accuracy in the solution of both the word fragments and the comprehension questions in the pre-training Recognition Task.

Variables		**VR-CBM-I**	**Standard CBM-I**	**Statistics**	***P***	**Effect size**
Gender						
	Males	7(16.7%)	12(28.6%)	$\chi^2(1)$=0.24	0.12	V=0.24
	Female	14(33.3%)	9 (21.4%)			
Age		21.05(1.91)	22.14(3.7)	t(40)=-1.20	0.24	d=0.37
Trait anxiety		50.43(8.63)	51.57(8.93)	t(40)=-0.42	0.68	d=0.13
State anxiety		45.76(6.30)	44.48(4.66)	t(40)=0.75	0.46	d=0.23
Baseline accuracy Recognition Task						
	Word fragments	0.76(0.77)	1.10(0.77)	t(40)=-1.41	0.17	d=0.39
	Comprehension questions	1.86(1.46)	1.96(1.28)	t(40)=-0.23	0.82	d=0.07
Previous experience with VR						
	Yes	4(9.5%)	3(7.1%)	$\chi^2(1)$=0.17	0.68	V=0.06
	No	17(40.5%)	18(42.9%)			

Table 4.1: Mean scores for the IEQ subscales (SD in parentheses), F statistics, p-value and effect size $\eta_p{}^2$ for the VR-CBM-I and standard CBM-I groups

4.2.2 Presence and immersion

An independent sample t-test was carried out to examine whether participants completing the VR-CBM-I experienced more intense feelings of presence during training than participants completing the standard CBM-I training, as measured by the mean rating on the SUS items. Results showed that the VR-CBM-I group experienced significantly higher levels of presence (M = 4.97, SD = 0.90) than the standard CBM-I group (M = 3.33, SD = 1.30; t(40) = 4.75, $P < 0.001, d = 1.47$).

To test whether the VR-CBM-I condition was associated with a more immersive experience than the standard CBM-I condition, a MANOVA was carried out using the five IEQ subscales. A significant main effect of Group was observed

(F(5,36)=20.9, P< 0.001, $\eta_p{}^2$ = 0.74), indicating that the VR-CBM-I group experiences a greater degree of immersion in the training scenarios than the standard CBM-I group. Univariate analyses indicated that the VR-CBM-I and standard CBM-I groups differed significantly on the following four subscales: Control, Real World Dislocation, Emotional Involvement, and Cognitive Involvement, and not on the Challenge subscale (see Table 4.2).

IEQ subscale	**VR-CBM-I**	**Standard CBM-I**	***F* Statistics**	***P***	$\eta_p{}^2$
Challenge	4.18(0.79)	3.96(0.80)	*F*(1,40)=0.77	0.39	0.02
Control	4.85(0.86)	3.32(0.84)	*F*(1,40)=33.73	< 0.001	0.46
Real World Dislocation	5.14(0.52)	3.03(0.81)	*F*(1,40)=100.33	< 0.001	0.72
Emotional Involvement	4.49(0.95)	3.10(0.77)	*F*(1,40)=26.86	< 0.001	0.40
Cognitive Involvement	5.34(0.57)	4.26(0.70)	*F*(1,40)=30.26	< 0.001	0.43

Table 4.2: Mean scores for the IEQ subscales (SD in parentheses), F statistics, p-value and effect size $\eta_p{}^2$ for the VR-CBM-I and standard CBM-I groups

4.2.3 Interpretation bias

To test whether the VR-CBM-I training was more effective in changing interpretations than the standard CBM-I training, the RT data were subjected to a 2 x 2 x 2 x 2 mixed ANOVA with Group (VR-CBM-I vs. standard CBM-I) as between-subjects factor and Time (Pre- vs. Post-training), Valence (Positive vs. Negative), and Interpretation type (Target vs. Foil) as within-subject factors. A significant main effect of Interpretation type was revealed (F(1, 40) = 71.0, P < 0.001, $\eta_p{}^2$= 0.64), as well as two significant two-way interaction effects (Time x Valence, F(1, 40) = 36.3, P < 0.001, $\eta_p{}^2$= 0.48; and Time x Interpretation Type, F(1, 40) = 7.3, P = 0.01,$\eta_p{}^2$= 0.15). These effects were subsumed within a significant higher order three-way interaction effect of Time x Valence x Interpretation Type (F(1, 40) = 8.2, P = 0.007, $\eta_p{}^2$= 0.17).

To decompose the three-way interaction effect, separate analyses were carried out for target and foil sentences (Interpretation Type) separately. Both analyses revealed significant Time x Valence interaction effects (Targets: F(1, 40) = 36.0, P < 0.001, $\eta_p{}^2$= 0.47 and Foils: F(1, 40) = 10.0, P < 0.001, $\eta_p{}^2$= 0.20). The effects sizes for these interaction effects are larger for the targets compared to the foils, suggesting stronger training effects on interpretations than on foil statements. Subsequently, separate pairwise t-tests were conducted to decompose the Time x Valence effects for Targets and Foils separately, consistent with the goal of the positive interpretation training conditions, there was a significant increase in positive target interpretations (t(41) = -5.1, P < 0.001, $drepeatedmeasures(drm)$ = 0.79, pre-training: M = 2.16,SD = 0.40; post-training: M = 2.50, SD = 0.44) and a significant decrease in negative target interpretations (t(41) = 4.7, P < 0.001, drm = 0.72, pre-training: M = 2.44, SD = 0.44; post-training: M = 2.07, SD = 0.50). The effects were less pronounced for the foils and only the increase in the endorsement of positive foil sentences was significant (t(41) = -5.2, P < 0.001, drm = 0.81, pre-training: M = 1.95, SD = 0.40; post-training: M = 2.24, SD = 0.44; negative foil sentences, t(41)= 0.3, P = 0.76, drm =

0.04, pre-training: M = 1.95, SD = 0.48; post-training: M = 1.93, SD = 0.48). Collectively, this suggests that the stronger training effects on targets versus foil sentences is driven by the specificity effects in the negative interpretations. The four-way interaction effect of Group x Time x Valence x Interpretation type was not significant (F(1, 40) = 0.9, P = 0.35, $\eta_p{}^2$= 0.02), indicating that the VR-CBM-I training did not result in stronger effects on interpretations than the standard CBM-I training.

4.2.4 State anxiety

To test whether the VR-CBM-I training resulted in a stronger reduction in state anxiety than the standard CBM-I training, the STAI A-state scores were subjected to a 2 (Group: VR-CBM-I vs. standard CBM-I training) x 2 (Time: Pre vs. Post-training assessment) mixed ANOVA. There was a significant main effect of Time (F(1, 40) = 120.9, P < 0.001, $\eta_p{}^2$= 0.75) and a significant Group x Time interaction effect F(1, 40) = 22.0, P < 0.001, $\eta_p{}^2$ = 0.35, confirming the stronger effects of the VR-CBM-I on anxiety. That is, while state anxiety did not differ significantly between the two groups before training t(40) = 0.8, P = 0.46, d = 0.23 participants who completed the VR-CBM-I training reported significantly less anxiety symptoms after training than participants in the standard CBM-I group (t(40) = -3.1, P = 0.003, d = 0.97) (see Panel A in Figure 4.1).

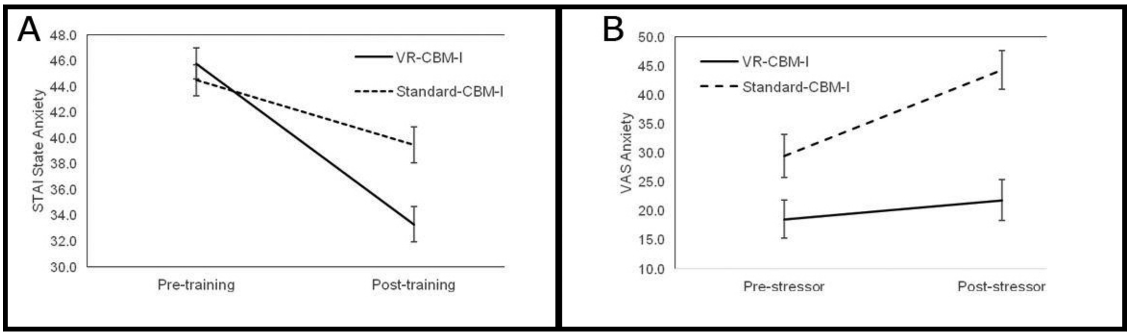

Figure 4.1: (A) Mean (and standard error, SE) state anxiety scores from pre- to post-training for the VR-CBM-I and standard CBM-I groups. (B) Mean (and SE) VAS anxiety scores from pre- to post-stressor for the VR-CBM-I condition and Standard CBM-I condition

4.2.5 Stress reactivity

To test whether the VR-CBM-I training resulted in a reduced emotional response to the stressor, the VAS anxiety was subjected to a 2 (Group: VR-CBM-I vs. standard CBM-I training) x 2 (Time: Pre- vs. Post-stressor) mixed ANOVA. In addition to significant main effects of Time (F(1, 40) = 12.9, P = 0.001, $\eta_p{}^2$= 0.24; increase in anxiety from pre- to post-stressor) and Group (F(1, 40) = 15.4, P < 0.001, $\eta_p{}^2$= 0.28; lower anxiety in the VR-CBM-I group), the predicted Group x Time interaction effect was significant (F(1, 40) = 5.2, P = 0.027, $\eta_p{}^2$= 0.12), consistent with our predictions, while the stress task resulted in a significant increase in anxiety in the standard CBM-I group (t(20) = -3.3, P = 0.003, d = 0.72). This was not the case for the participants who followed the VR-CBM-I training (t(20) = -1.4, P = 0.18, d = 0.31) (Panel B in Figure 4.1).

Exploratively, we examined whether the effects of training on emotional reactivity generalised to depressive feelings by subjecting the VAS Sadness to the same 2x2 mixed ANOVA. Again, significant main effects of Time (F(1, 40) = 41.8, P < 0.001, $\eta_p{}^2$= 0.51; significant increase in sadness from pre- to post-stressor) and Group (F(1, 40) = 12.2, P = 0.001, $\eta_p{}^2$= 0.23; lower sadness scores in the VR-CBM-I group) were observed. However, the Group x Time interaction effect was not significant (F(1, 40) = 2.7, P = 0.09, $\eta_p{}^2$= 0.07).

4.2.6 Post-hoc analyses

In addition to already performed analysis, the member of the research team (psychologist) suggested and conducted the additional post-hoc analysis in order to examine further whether the observed changes in state anxiety and emotional reactivity to the stressor were associated with perceived immersion and presence. This would allow identifying what potential aspects of the co-designed mobile VR application have more influence on therapy and participants and in the future research concentrate on them. Pearson correlations were computed between the IEQ and SUS scores, and changes in state anxiety over the course of the training and changes in anxiety reactivity due to the stressor (see Table 4.3). Change indices were calculated by subtracting pre-training from post-training scores (i.e. negative values indicate greater decrease). Stronger reduction in state anxiety across the training was significantly correlated with higher Control, Real World Dislocation, Emotional Involvement, and Cognitive Involvement. Furthermore, less anxiety reactivity was significantly correlated with greater perceptions of Real World Dislocation and Cognitive Involvement.

	IEQ Challenge	**IEQ Control**	**IEQ Dislocation**	**IEQ Emotional Involvement**	**IEQ Cognitive Involvement**	**SUS**
State anxiety change	-0.10	-0.49^b	-0.51^b	-0.33^a	-0.52^c	-0.18
Anxiety reactivity to stressor	-0.16	-0.26	-0.36^a	-0.17	-0.31^a	-0.12

$^a p < 0.05$; $^b p < 0.01$; $^c p < 0.001$

Table 4.3: Pearson's correlation coefficients between IEQ and SUS scores and changes in state anxiety and in anxiety reactivity due to the stressor

Psychologist further computed the correlation between changes in interpretation bias scores (amount of positive target interpretations, amount of negative target interpretations) as a result of the training intervention (difference in interpretation bias score between post-training and baseline) with changes in state anxiety and anxiety reactivity, and with the IEQ and SUS scores. None of the correlations were significant (Pearson's r range = [-0.13, 0.20], p's > 0.05).

4.3 Discussion

In this proof-of-principle study, the use of stereoscopic-3D VR technology to enrich the training experience and ultimately enhance the effects of CBM-I training for performance anxiety was examined. The main idea behind the study was to investigate whether the embedding of the training scenarios in a virtual environment, where participants could immerse themselves and explore, would improve the participants' engagement with the training and amplify the activation of (anxiety-relevant) schemas and the related individual's habitual pattern of biased information processing (i.e. negative interpretation bias). All of which are necessary ingredients for this type of intervention to succeed.

Consistent with previous studies, where standard CBM-I interventions have been shown to reduce state anxiety levels (Mackintosh et al., 2006; Salemink et al., 2007, 2009; Salemink & van den Hout, 2010), all participants showed an overall decline in state anxiety after the training. As hypothesised, these reductions were significantly more pronounced in the VR-CBM-I group, compared to the standard CBM-I. In addition, lower anxiety reactivity to a stressor was observed in the VR-CBM-I compared to the standard CBM-I group. Perhaps one explanation for this is the difference in participants mental imagery which plays an important role in anxiety (Holmes & Mathews, 2010). Previous research has shown that disturbing mental images (such as memories of traumatic events (Krans, Näring, Becker, & Holmes, 2009), mental images of embarrassment in social anxiety (Hackmann, Clark, & McManus, 2000), and so on) were associated with difficulties in mentally imagining (future) positive events (Holmes, Blackwell, Heyes, Renner, & Raes, 2016). It was also shown that an active stimulus based on images has a stronger effect on interpretation bias and emotional vulnerability (Holmes, Mathews, Dalgleish, & Mackintosh, 2006). In our case, VR-CBM-I combined not only visual input, which potentially facilitated and developed positive mental images but also was accompanied by a verbal stimulus (pronunciation of the scenarios word fragments and answers to the comprehensive questions). The combination of these two factors could have a greater impact on participants, allowing them to demonstrate better results on the stressor. However, this needs to be further investigated. Nevertheless, contrary to our expectations, there was no significant difference between the two training versions in the impact of the training on the target information-processing mechanisms, as both versions resulted in a comparable increase in positive interpretations and a decrease in negative ones.

When examining participants' experience with the training, the VR-CBM-I group experienced a higher degree of immersion and presence during the training than the standard CBM-I group. In particular, the results showed that there was a significantly higher level of perceived control, real-world dissociation, and emotional and cognitive involvement for participants in the VR-CBM-I group, while there was no significant group difference in the level of perceived challenge. Post-hoc analyses showed that a higher degree of cognitive involvement in the training scenarios and a greater perception of dissociation from the real world outside were related to both a greater reduction in state anxiety and lower anxiety reactivity to the stressor. Further, a greater feeling of emotional involvement and being in control within the scenarios were also positively associated with reductions in state anxiety. Conversely, greater feelings of presence were not associated with any change in state anxiety or emotional reactivity.

Altogether, the results of the study seem to suggest a combination of specific and non-specific effects of the VR-based CBM-I training on anxiety. The two versions of the training did not differ in the successful manipulation of the targeted interpretation bias for threatening information: all participants showed a decrease in the tendency to interpret ambiguous information negatively, in favour of more benign interpretations. Furthermore, although both groups showed a decrease in state anxiety, VR-CBM-I training induced a steeper reduction in state anxiety and a blunted emotional response to the stressor. The combination of the CBM-I training mechanisms and other VR-specific factors may have enhanced these effects. Although to be taken cautiously, the positive correlations between changes in state anxiety and anxiety stress reactivity and the control, cognitive and emotional involvement, and the real-world dissociation components of the immersive experience in the VE, seem to support this hypothesis. By experiencing the scenarios in a “deeper” fashion, thus activating the biased threat-related interpretive schemata more effectively, the training effects on basic information cognitive processing would more easily generalise to stronger emotional effects, as observed in the VR-CBM-I group.

4.4 Limitation

Despite the very promising results, no definite conclusion on the (clinical) effectiveness of VR-CBM-I can currently be drawn. Being the very first combining of VR and CBM-I, this study was primarily concerned with examining the feasibility and potential of VR-CBM-I training, by focusing, as a first step, on comparing the delivery modes of the training within a semi-experimental design. Therefore, the lack of a full control condition (i.e. placebo or neutral CBM-I training group) prevents the research team from claiming that VR-CBM-I is more effective than the standard CBM-I. The next step in the evaluation of VR-CBM-I would consequentially involve a full factorial experimental design, combining the two delivery modalities (VR yes vs no) and the two intervention components (active vs neutral CBM-I), in order to: 1) experimentally compare the effects of both interventions against a neutral condition with no active training ingredients, and 2) disentangle the active effects of the VR environment from the CBM-I training-specific effects.

In relation, according to the preliminary phase of the study, participants completed only one session of training in the lab. Although the VR-based-CBM-I successfully impacted on emotional outcomes in the immediate term and in response to a stressor, the duration of the effects over time is yet to be tested against a full control condition, as well as the exposure to multiple sessions of training over time. These latter aspects are particularly crucial in the view of effectively deploying (mobile) VR-based CBM interventions. The present findings are also encouraging regarding the boredom participants experience with multiple sessions of standard CBM-I (Holmes & Mathews, 2010; Beard et al., 2012).

The results of our study are restricted to the type of anxiety considered (i.e. performance anxiety) and the self-selected group of undergraduate university students based on convenience sampling. Although students actively responded to emails, which advertised the training as a tool to be used for the reduction of test stress and anxiety, they were all compensated for participation, and this may have inspired an exaggeration of their initial levels of trait anxiety, in order to be included in the study. Whether the results of this study could be generalised to other forms of (more severe) anxiety and groups of patients would need to be further investigated in a larger study with a self-motivated target population (e.g. patients with anxiety problems).

4.5 Conclusion

To conclude, this proof-of-principle study is the first to investigate the feasibility and potential of using mobile VR technology to deliver CBM-I training for anxiety problems. When compared to the standard CBM-I training, a mobile VR-based CBM-I training improved the users' experience with the training program and produced greater beneficial effects on anxiety-related emotional outcomes, while similarly changing the targeted cognitive processes. This study provided the first evidence that 1) the putative working principles underlying CBM-I training can be translated into a virtual environment, and 2) stereoscopic-3D mobile VR technology appears to be a promising technological affordance with which to boost the effects of such classes of intervention, whilst increasing users' experience with the training application.

Chapter 5

Design and Development of a Remote Multi-User VR System for Eating Disorders

In the previous chapters, the design of mobile VR applications and their implementation in pain management and the treatment of anxiety disorders were discussed (Chapters 3 and 4). This chapter focuses on the co-design process of a more advanced PC-based VR application.

With the advent of new VR PC-based headsets, such as the Oculus Rift or HTC Vive, there is a new opportunity for applying "telemedicine" to already existing treatments such as cognitive behavioural and exposure therapy. The term, telemedicine, is used to describe the use of telecommunications to support healthcare (Perednia & Allen, 1995). Over the past four decades, telemedicine has become a more cost-effective alternative to face-to-face care and was integrated into a variety of healthcare settings, for instance, hospitals, doctors' offices and patient homes (Kvedar, Coye, & Everett, 2014). Most descriptions of remote psychological therapy consider a hybrid form of delivery, with a face-to-face assessment followed by interactive video conference treatment. Simpson and colleagues (Simpson, Deans, & Brebner, 2001) reported that the majority of patients indicated high levels of satisfaction with this type of therapy delivery.

Due to increasing Internet bandwidth and the lower cost of VR hardware, it is not too hard to imagine a future scenario where patients can enrol in a VR therapy session from their own physical space at any time that is suitable to them, and which is supported by a therapist at a remote location. In such a scenario, both the patient and the therapist would virtually join a simulated environment specifically designed and personalised to optimise the therapeutic benefits. In most VR therapy sessions reported in the literature, the therapist was present in the same physical space as the patient. Although VR has been widely researched and is increasingly used in psychotherapy, little has been done to investigate remote Multi-User Virtual Reality (MUVR) systems in which the patient and therapist are simultaneously immersed in a VE which has been designed according to specific therapeutic requirements.

The combination of VR and telemedicine can potentially offer a personal private platform for psychotherapy, which can improve engagement in therapy. Furthermore, MUVR could reach a greater number of patients, which in turn will enhance the quality of life for people as it removes the restrictions of a physical geographical location. This new, affordable technology is expected to result in an improvement in healthcare provision.

This chapter presents the co-design process of an online remote MUVR system which was used for eating disorder (ED) therapy in collaboration with clinical psychologists at the University of Cyprus. I was involved in the co-design process as the developer, designer and 3D artist of the MUVR application. The research team explored the possibility of using remote VR treatment through the example of ED therapy and further explored how to design and integrate the MUVR system to be suitable for psychotherapy treatment.

The application developed in this chapter was then implemented for the study described in Chapter 6, which took place in Cyprus. Together with the psychologist from the University of Cyprus, I conducted data collection as well as took part in the data analysis for this study. The findings from this chapter and results from the study conducted (Chapter 6) have been submitted to the Human-Computer Interaction journal and the article is under review.

The chapter is broken down into five sections: Section 5.1 describes the co-design and development processes of the MUVR system; Section 5.2 provides details on remote VR interaction, navigation and communication mechanisms; Section 5.3 provides final description of the remote intervention; Section 5.4 provides a summary of the design features of the system and challenges as well as describes the key lessons learnt from the co-design and development process; and Section 5.5 draws the conclusions.

5.1 Co-design process of the MUVR system

Taking into consideration the previous mobile VR design approach, we decided to apply a similar co-design method when developing the remote MUVR system. The team consisted of a research group which included four clinical psychologists, two human-computer interaction (HCI) experts and a developer with expertise in graphic design and VR application development. In this way, all the relevant areas for the application (clinical content, system usability and technical development) were covered by experts in each of the subjects.

The MUVR system evolved through eight design iterations over six months, each involving focus groups or interviews as well as evaluation sessions with therapists and a pilot evaluation with a total of four representative users. Observational notes were taken and in-depth discussions were recorded for analysis to improve the design. Table 5.1 shows a summary of the iterative co-design process.

Phases	Stages	Design Process
Focus Group Sessions Phase 1	1	**Initiation session and tech demo with the research team** A PC-based VR system was demonstrated to psychologists to show its technological possibilities. Psychologists introduced the general idea of ED therapy (see Section 5.1.1.1).
	2	**First brainstorming session with the research team** Discussed the specifics of the psychotherapy protocol suggested and how it could be built into MUVR. The first prototype of the MUVR was then developed.
Evaluation Sessions and Iterative Development Phase 1	3	**Evaluation session with 1 therapist and 1 developer** Two VE navigation mechanisms were tested i.e. i) "Point and Click Teleportation", ii) "Navigation by Hand" movement (see Section 5.2.7.1 for details). Remote connectivity was evaluated to ensure stable and reliable user synchronisation. "Navigation by Hand" movement was removed due to it causing motion sickness. The prototype version of the MUVR system was revised based on the outcome of the evaluation. The second prototype was then developed.
	4	**Evaluation session with 1 psychologist, 1 therapist, 2 HCI experts and developer** Testing on the social interaction synchronisation and the user interface (UI) elements for the therapist (e.g. a control panel for the therapist to facilitate the remote session) was conducted (see Section 5.2.5 for details). The UI element was updated to de-synchronise the control panel, as the participants could be confused by the UI. It was decided that this UI would only be visible to the therapist. Decisions on visual representations of the virtual objects, icons, etc. for the VR activities were made.
	5	**Evaluation with 2 psychologists, 1 therapist and developer** Testing was carried out on the avatar customisation system for the exposure part of the intervention (see Section 5.2.4 for the details about avatar customisation system development). It was decided that the avatar body should be further exaggerated to represent the extremes of body type. New virtual hairstyles as well as colours were added to represent more closely the hairstyles of potential patients.
Focus Group Session Phase 2	6	**Second brainstorming session with the research team** From the evaluation sessions it was decided that the therapy activities should be gamified to improve participants' engagement. After further brainstorming, a decision was taken to create two versions of MUVR: a) an ACT MUVR and b) a Play Therapy (PT) MUVR in order to test the effects of gamification on remote therapy more systematically.
Evaluation Session Phase 2	7	**Evaluation with 1 therapist and 2 representative users** The evaluation provided by the participants and the therapist was positive overall, with only minor issues noted. Two "object grabbing" mechanisms (see Section 5.2.6 for details) were tested for intractable objects, i.e. i) a "Button Hold" tool (imitating natural activity) and ii) an "Automatic Hold" tool. Option ii) was rejected due to patient confusion. In addition, virtual controller buttons were coloured for visual identification of the activity (e.g., red to grab, blue to move, etc.).
MUVR Therapy Pilot Session	8	**Pilot with 2 therapists and 2 representative users** Two pilot sessions were carried out to address further issues with the MUVR and the protocol. No further usability issues were reported.

Table 5.1: Co-design of the MUVR prototype

5.1.1 Focus group sessions phase 1

5.1.1.1 Initiation session and tech demo with the research team

A focus group was conducted between four experts in the field of psychotherapy, two experts in HCI healthcare and the developer of the MUVR system. In the focus group, the HCI experts and the developer demonstrated the general possibilities of VR systems via a standard Oculus Rift VR application[1]. This application was used to demonstrate to clinical psychologists the basic VR user interaction (grabbing objects, navigation). Then, psychologists introduced us to The Acceptance and Commitment Therapy (ACT) for eating disorders (Hayes, Strosahl, & Wilson, 2011).

According to ACT, experiential avoidance increases the impact and often the frequency of avoided thoughts, feelings, and sensations. Via ACT, the individual learns to accept their inner feelings about troubling situations and commit to behaviour change, regardless of unwanted internal thoughts and feelings (Hayes et al., 2011; Juarascio et al., 2013; Merwin & Wilson, 2009). In general, ACT emphasises on altering the individual's behaviours rather than shifting attention away from troubling thoughts and feelings (Juarascio et al., 2013).

Clinical psychologists demonstrated the AcceptMe (Nikolaou, 2017) web-based programme, that was based on the ACT, used in their previous research. This programme is a digital programme used for young people at risk of developing an ED. It is a six-session programme that aims to treat young people via gamified tasks to control their thoughts regarding their bodies so as to combat body and shape-related concerns. Users communicate with the web-based programme via an avatar. The avatar assists users during the performance of tasks. AcceptMe also offers a version of exposure therapy (ET) where participants are encouraged to carry out ET after it has been demonstrated by the avatar. Thus exposure is not even carried out in the traditional sense as in face-to-face interventions. A distinctive feature of this program is the absence of a real therapist. Patients communicate with the real therapist only after all conducted six web sessions with a pre-programmed avatar.

However, I believe that compared to the web-based program, MUVR may have the advantage of providing the patients with an anonymous medium to communicate their inner thoughts, without removing the availability of a real therapist. Research has shown that a close relationship can be developed between users within a virtual world, especially when they could communicate verbally during a virtual game (Utz, 2000; Henderson & Gilding, 2004). This is particularly important as positive outcomes from the therapeutic process are strongly related to the therapeutic relationship or alliance between the therapist and the patient (Horvath & Symonds, 1991; Martin, Garske, & Davis, 2000; Norcross, 2002). The MUVR could increase the level of presence in order to potentially improve engagement and effect of the ET as well as add the aspect of social presence (see section 2.2) that could potentially build a close relationship between participant and therapist that would lead to a better outcome of the therapy.

The results from this session were that:

1. It was decided that the ACT for EDs was to be used for MUVR.

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[1] https://www.oculus.com/experiences/rift/1217155751659625/?locale=en_GB

2. The tasks for the remote therapy and the protocol would be determined during a subsequent brainstorming session.

5.1.1.2 First brainstorming session with the research team

Based on the information from the initiation session, psychologists created a one-session protocol that was adapted from their previous research and was based on the AcceptMe programme. This protocol consisted of four parts: 1) The therapist introduces the intervention to the patient; 2) The first therapy task is presented to the participant; 3) The second therapy task is presented to the participant; and 4) The tasks of the virtual intervention are followed by ET.

Design of the introduction part for therapists/participants. One of the differences between the web-based platform and MUVR system was that real therapists were involved in the remote intervention. This means that some sort of communication between therapists and patients was needed. Two options were considered: text-based chat and voice chat communication systems. Text chats are quite a popular means of communication and are used at work (Nardi, Whittaker, & Bradner, 2000) and in other fields, such as education (Cunliffe, 2005), leisure (Grinter & Palen, 2002) and massive multiplayer online (MMO) games (Ducheneaut, Yee, Nickell, & Moore, 2006). One variety of text communication is instant messaging, which is an almost synchronous one-on-one communication (e.g. Messenger[2]) (Nardi et al., 2000). The time taken for message transmission is just a fraction of a second and so communication happens almost simultaneously. However, this type of communication would be inconvenient in VR as it would require users to type their messages using a virtual keyboard which could be time consuming. The research team decided to implement a voice communication system in order to provide therapists and patients with real-time, natural communication and potentially increase the level of social presence (see Section 5.2.2 for details on the voice chat system).

Moreover, it was suggested by the developer that the participant and the therapist should be presented as cartoon avatars in the VR environment (see Figure 5.1). This decision was made based on previous research findings that suggested the use of animated cartoons could help reduce the stress and anxiety of participants in therapy (Cohen, Blount, & Panopoulos, 1997; Lee et al., 2012). In addition, it was decided that the remote session would be started in a neutral VE in order to gradually immerse participants (see Section 5.2.3).

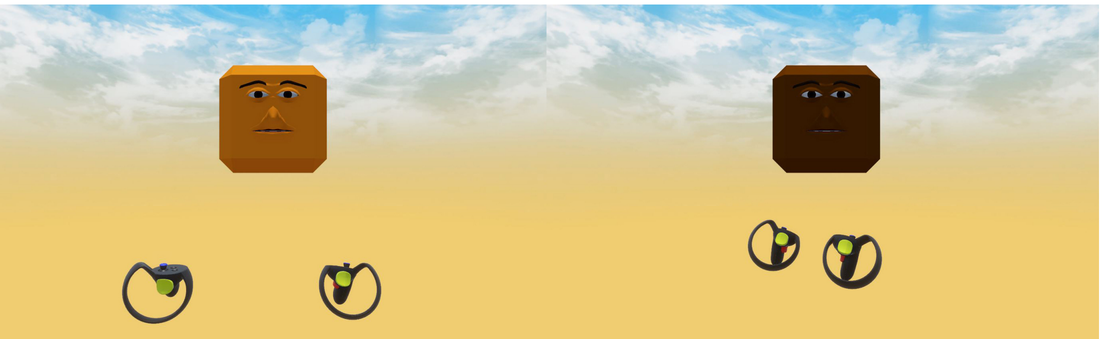

Figure 5.1: The screenshot shows two virtual cartoon avatar representations for therapists (on the left) and patients (on the right)

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[2] https://www.messenger.com/

Based on the protocol suggested, the research team generated ideas for the tasks to be included in the MUVR system, whilst considering ACT and proposals for the exposure part. Specifically, two virtual tasks: 1) The "Value task" and 2) "Life Map task" were suggested by psychologists for the MUVR system. Through these tasks the individual makes contact with valued life domains and recognises how actions related to concerns about body shape and weight can interfere with living a valued life (Nikolaou, 2017).

Design of the "Value task". First, the design of the value task was discussed. It was agreed that the design of this task would be transferred from the web-based platform into VR (see Figure 5.2). During this task, as part of the web platform, users select values from a list using the mouse. It was decided that a similar experience for participants in VR would be recreated. In the VE, participants were presented with a table from which the therapist asked them to choose six numbers (see Figure 5.3). Each number represented a value of life (e.g. success, ambition, addiction etc.). At first, participants could only see the numbers and not the significance of each number. After selecting six numbers, the values, which were represented by these numbers, were shown to the participant. The therapist discussed these values and asked the participants to decide what their lives would be like. Via this activity, the therapist explained to the participant how important it was not to allow worrying thoughts to take over, but to do things that were important for the participant. After the explanation, the therapist asked the participant to repeat the same task, but differently. This time, the participant was able to see from the beginning the meaning of each number and was asked again to select six numbers. The therapist explained that living based on personal values meant recognising what was important in life and choosing to act in accordance with that.

Δες τον πίνακα και διάλεξε τα 6 πράγματα που οπωσδήποτε θες στην ζωή σου και σημείωσε τους αριθμούς ώστε να βοηθήσεις την....

Figure 5.2: Web-based version of the "Value task" of the AcceptMe programme

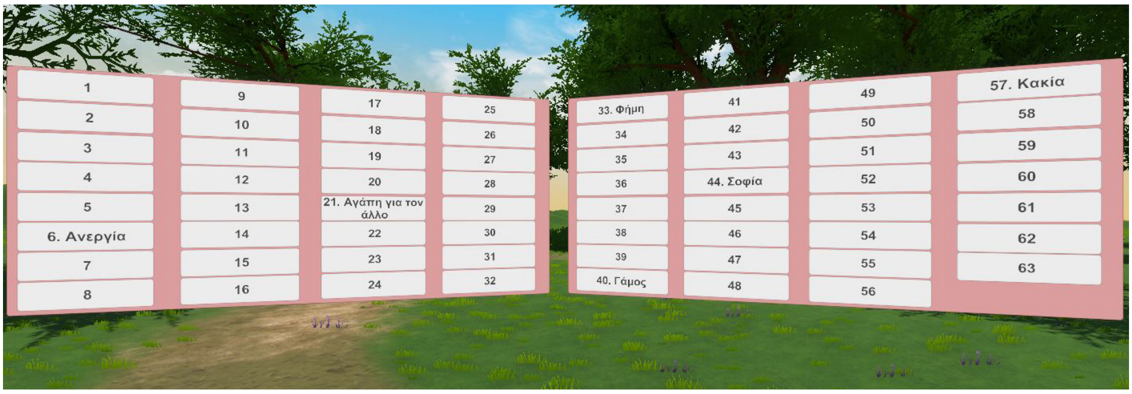

Figure 5.3: Screenshot showing six selected numbers by participant during the virtual "Value task"

Design of the "Life Map task". Second, the design of the virtual life map task, which aims to help the participant identify personal values and beliefs, was discussed. The initial idea of psychologists was to recreate the solution they proposed in the web-based platform and, specifically, provide participants with a pre-designed map of important life values that they would be able to select and discuss with therapists (see Figure 5.4). However, one of the problems that was noted by the HCI experts and developer is that it would be difficult for the therapist to see what values the participant selected. As the web-based platform did not have any interaction between the avatar and participants, due to the fact that all content was shown on the screen just for the users, this issue did not arise. An alternative solution was suggested which would not affect the psychological aspects of the task but would use the advantages of VR interaction and make the process more interesting for participants. A menu of choices regarding the values and beliefs, represented as virtual animated objects placed on pillars (e.g. family, health etc.), was given to the participants instead.


Κάνε κλικ σε κάθε γειτονιά ώστε να μπορέσεις να απαντήσεις τα ερωτήματα που θα σε καθοδηγήσουν προς τις αξίες σου

Figure 5.4: Web-based version of the "Life Map" task of the AcceptMe programme

After completing the value task, the therapist and the participant were "teleported" into the virtual location for the life map task. The participant was asked by the therapist to select up to five of the most important personal values and beliefs of their life by "grabbing" the value and "placing" it inside the blue rings (see Figure 5.5). By doing this, participants were able not just to discuss the values with the therapists but to create their own life map. The participant was also asked to verbally explain each value/belief they had selected. During this activity, the therapist asked appropriate questions to further support the participant. Via this process, the participant is able to develop a personal life map that allows them to outline their important life values through embodied interactions (i.e. grabbing and placing). This process provides the therapist with an understanding of what is important in the participant's life and at the same time it gives the participant an opportunity to understand and consider the central values and beliefs of their life.

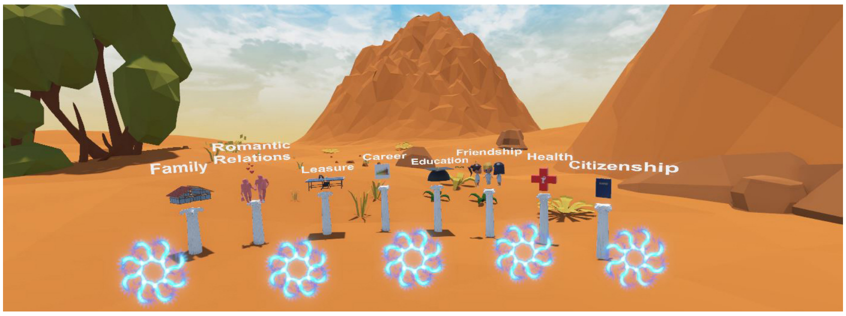

Figure 5.5: A screenshot showing eight values placed on the pillars for the MUVR "Life Map task"

Design of the Exposure Therapy part (ET part). Several ideas were discussed for the exposure stage. Psychologists suggested using mirror exposure (ME) therapy as a base for the virtual exposure part of the system. Research has shown that mirror confrontation is the most effective form of exposure because of the strong emotional response it elicits among people with ED (Key et al., 2002). ME has also proven to be efficacious in reducing negative body-related emotions (Vocks, Legenbauer, Wächter, Wucherer, & Kosfelder, 2007) and improving body image among individuals dealing with ED and significant concerns about the body schema (Hildebrandt, Loeb, Troupe, & Delinsky, 2012).

The web-based platform offered a rigid, non-customisable version of ME therapy which was demonstrated to the participants by the avatar (see Figure 5.6). During this stage, participants were asked to follow the avatar instruction and stand in front of the mirror. The virtual avatar did not have the ability to be customised (no changes in cloth and body size) as well as was not able to react on the participants' answers and thoughts due to the absence of the real therapist.

Figure 5.6: Web-based version of the ET part of the AcceptMe programme

To overcome all these limitations of the ET part in the web-based platform, the research team worked on a few ideas regarding how to improve the approach used in a AcceptMe program and use the advantages of MUVR. These ideas included:

1. The creation of a virtual 3D model of a mirror with real-time virtual reflection of the participants' virtual representation.

2. The use of the participants' own personal photos instead of a real-time reflection in the 3D mirror.

3. The development of a 3D representation of the participants based on the measurements of their body. Several presets of body types were provided (e.g. slim, normal, overweight) and shown to the participants.

4. The development of an avatar customisation system similar to the "Sims[3]" game customisation.

Based on suggestions from the developer of the system, the first idea was excluded due to the high level of resources which would be consumed in the creation of a real-time reflection in a VR mirror. More graphics card resources would be required to ensure that the application ran smoothly. Moreover, in order to produce a reflection, developers would need to create a full body representation of the participants and control the whole body with only the use of Oculus Rift hand controllers. This would not allow for the creation of a realistic animation of the body as the system does not support full body tracking.

The second idea was also excluded due to the unrealistic nature of the approach. Participants could move in the VE but the image would be static. Therefore, this approach would mean that either the research team would need to have the photos of the participants before the development of the MUVR system or the pictures would need to be uploaded during the experiment.

The third idea was also excluded as it did not represent real participants' body shapes and, as a result, the exposure stage would have been ineffective. After some discussion, the research team decided to pick the fourth option and develop an avatar customisation system (see Section 5.2.4). This system allows participants to create body shapes at the beginning of the therapy using virtual sliders. This avatar would then be used in the last exposure part of the MUVR therapy.

In the ET part, the participant faces a virtual mirror and is asked to customise an avatar body to match his or her own virtual self. The exposure progresses by gradually removing the avatar's clothing until the avatar is left only in underwear (see Figure 5.7). This process allows the participant to understand and accept the way their body really looks, as most individuals dealing with ED tend to overreact to their appearance (Bruch et al., 1974). Compared to a web-based programme, the MUVR allowed participants to change the clothing, hairstyle and skin colour as well as adjust the size of body parts (see Section 5.2.4)

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[3] https://www.ea.com/en-gb/games/the-sims

Figure 5.7: The images depicted represent the four stages of ET part

As a result of this brainstorming session, the tasks of the protocol were confirmed (see Figure 5.8), allowing development of the MUVR system to start.

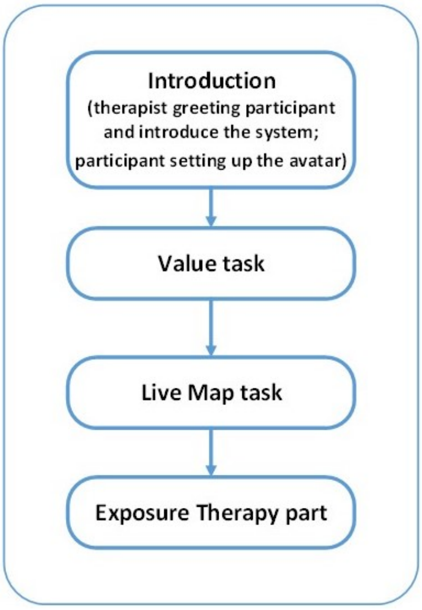

Figure 5.8: The protocol procedure for the MUVR intervention

5.1.2 Evaluation sessions and iterative development phase1

The prototype of the remote VR system was iteratively developed, tested and refined in collaboration with clinical psychologists, representative users and therapists who were taking part in the study. Independent testing of each part of the system (e.g. protocol tasks for ACT and ET part) was carried out remotely (UK-Cyprus). Changes were made in response to any problems that were identified after each testing session, and before the application was presented for testing in the next round.

5.1.2.1 Evaluation session with one therapist and one developer

Drawing from the two sessions (initiation and brainstorming), the first version of the MUVR system with “Value task” was developed. A therapist (acting as a participant) and a developer evaluated the MUVR system. The aim of the session was to test the network connectivity (see Section 5.2.1 for details), navigation mechanisms in the VE (“Point and Click teleportation” and “Navigation by Hand” tools) (see Section 5.2.7.1 for details) and the “Value task”. Table 5.2 contains a summary of the issues and improvements made during the first evaluation session.

Problem/issues found	**Improvement**
The ability to deselect the values in the table and not very obvious signs that the value was selected during the “Value task”	Firstly, the ability to deselect the values was added. Secondly, the user interface background colour for the values selected was changed (see Figure 2.5).
“Navigation by Hand” tool caused motion sickness	The tool that caused motion sickness issues was removed

Table 5.2: A summary of the key problems/issues encountered and improvements made to the system after the testing of the initial prototype

One of the concerns raised during testing was that of poor visual representation of the values selected. In the initial design, after the selection of a number in the table, the text font changed, but it apparently did not change enough for the values that had been selected to be recognised during the activity. To solve this issue, the background colour of the selected value was changed upon selection (see Figure 5.9). The therapist also noted that there was a need for participants to deselect the values. This option was added to the system in the second prototype version.

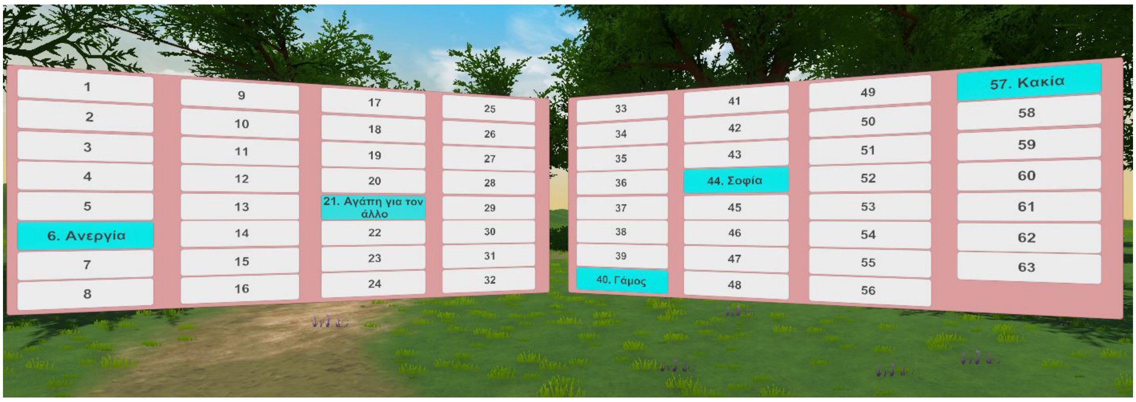

Figure 5.9: The revised representation of the selection process. The selected value has a turquoise background

One more concern raised during the testing was that of motion sickness suffered by the therapist, the cause of which was the navigation by hand movement tool. For the therapist, motion sickness appeared as soon as she started making movements using this tool. The navigation by Hand movement mechanism was designed to simulate real-life walking. The motion sickness occurred because of a sensory mismatch between the perception of the visual system and the vestibular apparatus. Moreover, new users are more vulnerable to motion sickness than people who have tried VR before (Jerald, 2015). Using a “Navigation by Hand” tool allowed users to remain static and just move their hands, while the position of the camera changed gradually, thereby giving the impression of movement. Based on the results of the evaluation session, it was decided to remove the navigation by hand mechanism and simply leave the “Point and Click teleportation”.

5.1.2.2 Evaluation session with one psychologist, one therapist, two HCI experts and one developer

The improvements suggested by the first evaluation session were made and the second version of the application was developed. This prototype version included two virtual locations where participants perform ACT tasks (“Value task” and “Life Map task”). Additionally, the VR voice communication system was developed so that users would be able to communicate in a shared VE (see Section 5.2.2). A second evaluation was carried out with one clinical psychologist, one therapist, two HCI experts and one developer. The focus of this evaluation was on:

1. The social interaction mechanism and its synchronisation.
2. The user interface (UI) elements designed for the therapist (see Section 5.2.5 for details).
3. The navigation/teleportation mechanism (teleportation through doors) allowing movement between task locations (see Section 5.2.7.2 for details).

Table 5.3 shows a summary of the key problems and improvements made to the application after the second evaluation session.

Problem/issues found	**Improvement**
Participants were distracted by the therapists’ UI elements	The UI elements were hidden from the participants’ view but the therapist was still able to see them.
Difficulty with navigation between locations	The navigation system between different locations was redesigned so that instead of doors, virtual portals were developed.

Table 5.3: A summary of the key problems encountered and improvements made to the system after the second evaluation session

The evaluation session did not reveal any synchronisation, connection or social interaction problems.

However, one of the concerns raised during testing was the distraction of the participants caused by the UI elements that allowed the therapist to control the application. The UI elements were attached to the therapist's virtual controller to ensure better interaction (see Figure 5.10). This meant that the participants were able to see all the therapist's hand movements, together with UI control panel movements. This distracted them from focusing on their own tasks. To solve this issue, the UI elements were hidden from the participants' view but the therapist was still able to see them and control the application.

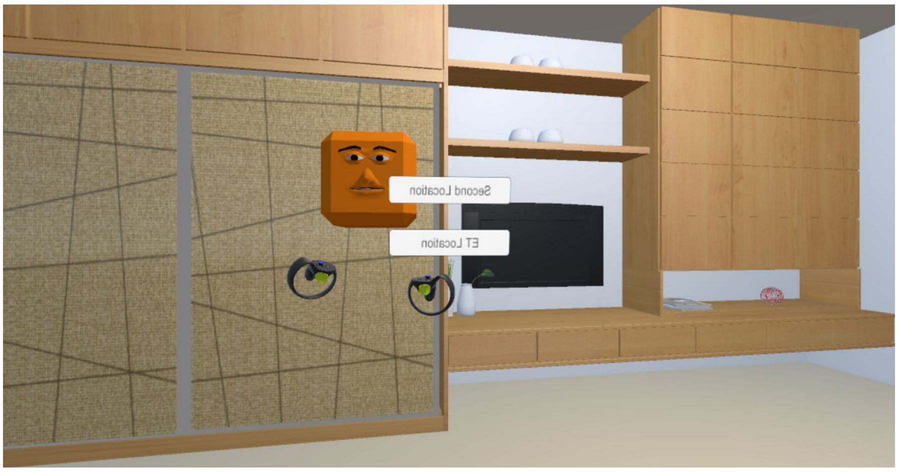

Figure 5.10: The UI therapist's control panel from the participants' perspective

Moreover, navigation/teleportation between different virtual locations needed to perform the ACT tasks was found to be difficult. It was confusing for the therapist to know when and how the virtual doors were working. The teleportation mechanism was redesigned to make the process simpler for participants (see Section 5.2.7.2 for details). Teleportation through virtual portals was developed to allow users to move more easily between virtual locations (see Figure 5.11).

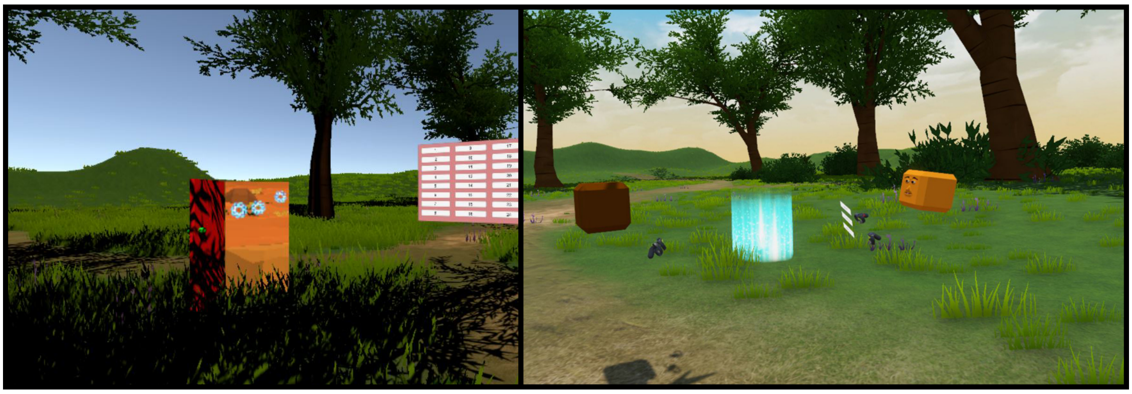

Figure 5.11: On the left, the teleportation through doors mechanism; On the Right, the updated teleportation mechanism using virtual portals

5.1.2.3 Evaluation with two psychologists, one therapist and one developer

Problem/issues found	**Improvement**
Inadequate contrast of the body shape between normal and overweight avatars	The size of the avatar body parts were enlarged to represent both extremes (anorexic and overweight)
The lack of skin colour variations	More variations of skin colour were added to correspond with the local (Cypriot) population
The ability to change hair colour	The ability to change hair colour and different variations were added
The language of the user interface	The language of the user interface was changed to Greek
The lack of understanding of basic controls for the application	A tutorial scene was created

Table 5.4: A summary of the key problems encountered and improvements made to the application after the third evaluation session

The improvements suggested by the second evaluation session were made and a third version of the application was developed. This prototype included the ET part with the avatar customisation system. A third system evaluation was conducted between two psychologists, one therapist and one developer. The aim of the session was to test the avatar customisation system for the ET part. Table 5.4 shows a summary of the key problems and improvements made to the application after the third evaluation session.

One concern raised during this evaluation session was the limited variation in the extremes of the body shapes. Psychologists wanted to create slimmer and more overweight versions of the avatar to accommodate more extreme body shapes. However, the system had size limitations for body parts. To solve this issue, the sizes of the avatar body parts were changed to represent both extremes (anorexic and obese).

Moreover, some limitations of customisation were found. The lack of variations in skin colour or ability to change hairstyle did not allow for the creation of a virtual representation of the local population. To solve this issue, hairstyles were created, and hair and skin colour variations were introduced, to match the Cypriot population. This was needed to increase the sense of the avatar self-identification for the participants.

Additionally, it was noted that English UIs caused some difficulties in understanding. It was decided to translate the UIs into Greek so that participants could enjoy a better application experience.

Finally, the lack of understanding and practice of the basic controls for the application caused difficulties in interaction. To allow participants and therapists to familiarise themselves with the buttons, it was decided that a tutorial should be developed (see Section 5.2.8 for details).

5.1.3 Focus group session phase 2

After testing all parts of the protocol, the research team decided that another version of the MUVR system should be designed. The second version was intended to act as a control condition in order to identify the effectiveness of the ACT tasks. It was agreed that in addition to designing ACT activities for the MUVR, a different therapy approach known as play therapy (PT) should also be explored.

PT has recently gained widespread acceptance and is used as a treatment modality for abused, developmentally delayed and behaviourally maladapted children (Leblanc & Ritchie, 2001). Specifically, PT has been used to treat issues faced by younger patients because of the holistic experience it provides (Schaefer, 2003). PT is a form of psychotherapy in which play is used as a means of helping the patients to express and communicate their feelings. It has been demonstrated that PT has an impact on patients' β-endorphins which are released in the human body to reduce stress (Schaefer, 2003).

Previous research has demonstrated a positive relationship between PT and the treatment of ED. This is because people who are suffering from ED face difficulties in resolving dysfunctional features that usually remain after the treatment. Some of these, such as alterations in executive functioning (e.g. impulsivity, planning, and decision-making) and emotional deregulation (e.g. self-control strategies, or tolerance to frustration) are particularly difficult to modify and are associated with an adverse outcome (Dahlgren, Lask, Landrø, & Rø, 2014). The research has demonstrated the usefulness of PT in reducing impulsivity and enhancing emotional regulation in people suffering from ED (Claes et al., 2012). The results suggest that PT is able to improve emotional regulation and enhance impulsivity control, which might lead to functional cerebral changes that ultimately translate into better cognitive and emotional performances. These results were documented by both physiological (decrease in average heart rate) and neural changes (reduction in reaction time) (Fagundo et al., 2013).

By analysing the activities in the two ACT tasks, it was decided that the experience for the PT condition should be made as similar as possible to the ACT (e.g. relatively equal duration of activities, equal time spent in the condition, an equal number and type of interaction, etc.). Accordingly, painting and basketball game activities were selected because of their capability to reduce the attention required to process worrying thoughts (e.g. mindfulness drawing activities and a target shooting task) (Curry & Kasser, 2005; Conn, 2010). These two games were found to be easy to follow and engaging for participants but, at the same time, could improve the participant/therapist relationship due to their collaborative nature. In addition, both games allowed the participant to concentrate on the virtual experience and, as a result, distract him/her from any troubling thoughts.

Figure 5.12: The virtual colouring activity for the PT condition from the participants' point of view

Figure 5.12 shows the virtual colouring game of the PT condition, where the participant was instructed to use a virtual palette and brush to colour in the inanimate objects. The palette contained a variety of colours and tones, which the participant could choose from based on his/her mood. The therapist also coloured in a separate inanimate object while talking with the participant. The research team believe that by engaging participant and therapist in the same activity, it will be possible to build friendly relationship, thus participants will be more open to share their thoughts.

During the co-design process, two versions of the MUVR application were developed. Figure 5.13 demonstrates the final procedure for this study.

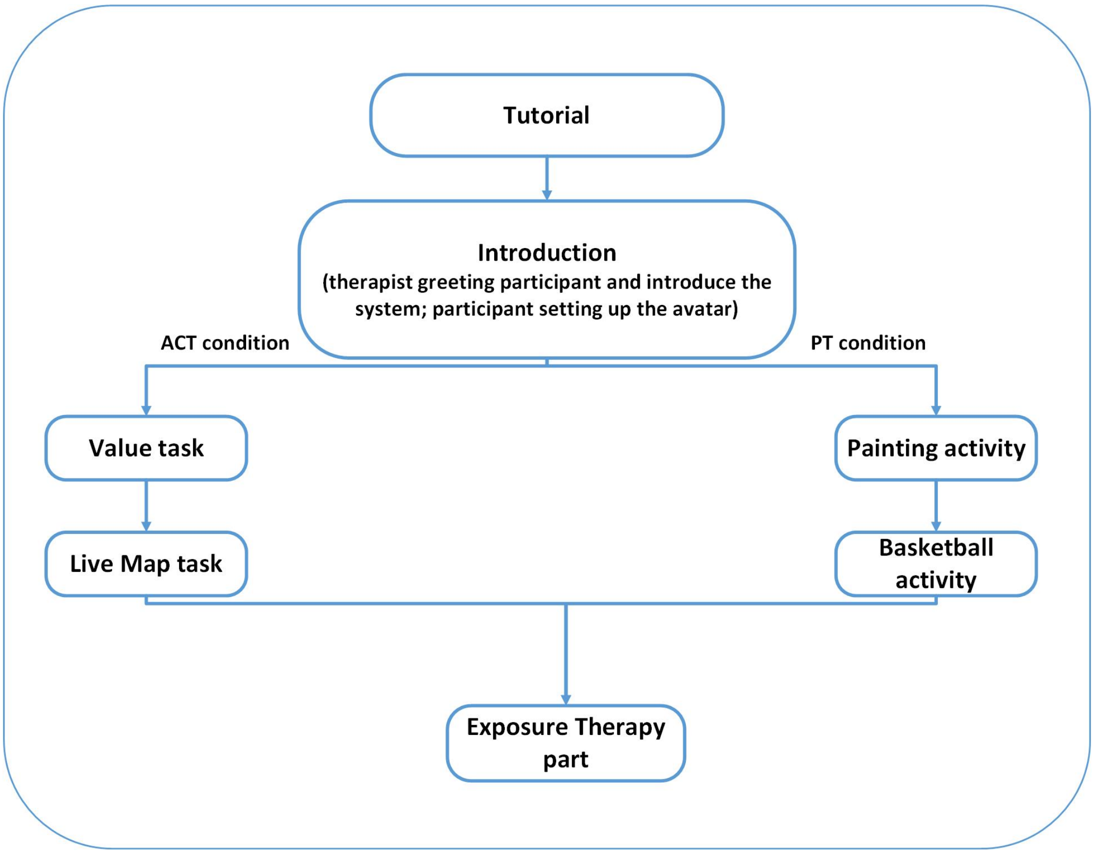

Figure 5.13: Two conditions co-designed for the remote ED intervention

5.1.4 Evaluation session phase 2

All the design suggestions from the previous evaluation sessions and the focus group session phase 2 were incorporated into the final MUVR system and a testing of the system carried out with two participants deemed at high risk of ED and one therapist. The aim of this session was to discover any further issues with the VR application. Table 5.5 shows a summary of the key problems and improvements made to the application after the fourth evaluation session.

Problem/issues found	Improvement
Complicated interaction with objects for participants	Removal of the confusing interaction tool
The buttons on the virtual controllers were confusing	To enhance the visual identification of each button, it was agreed to incorporate colours

Table 5.5: A summary of the key problems encountered and improvements made to the application after the last evaluation session

The evaluation session produced a positive response from participants and therapists towards the MUVR therapy. However, some minor usability issues were noted and fixed.

First, the participants reported difficulties in response to the grabbing activities of interactive objects (see Section 5.2.6 for details about grabbing mechanisms). Our initial design used an "automatic hold" mechanism which caused confusion for the user. Therefore, we decided to replace the "Automatic Hold" with a "Hold and Release" button which closely imitates natural movement.

Second, the initial design of the tutorial provided a detailed description for each tool in a neutral location (e.g. grabbing, teleportation and movement). Although this was useful, it was not fully effective, as the users had to make great efforts to understand and remember the instructions all at once. The feedback received during the evaluation session led us to redesign the tutorial, providing fewer but clearer instructions and to support it with gamified tasks. For instance, to introduce the navigation mechanism in the VE, participants and therapists needed to move in a neutral VE using "Point and Click teleportation" and collect virtual animated coins (see Figure 5.14). The coins were collected automatically when the user's avatar collided with them and a sound effect was used to confirm collection.

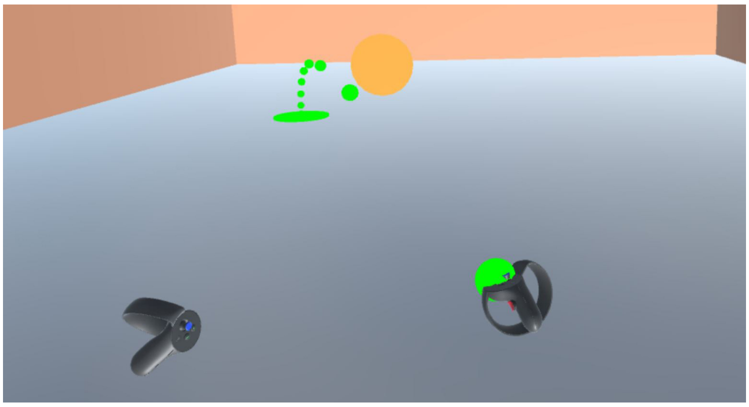

Figure 5.14: Two conditions co-designed for remote ED intervention

As the user progressed through the system, they received positive reinforcement (for example, “Good job! You have mastered your VR navigation.”). We also decided to mark the buttons on the VR controllers with different colours to improve identification of each corresponding task (e.g. we associated the red button with object grabbing) (see Figure 5.15).

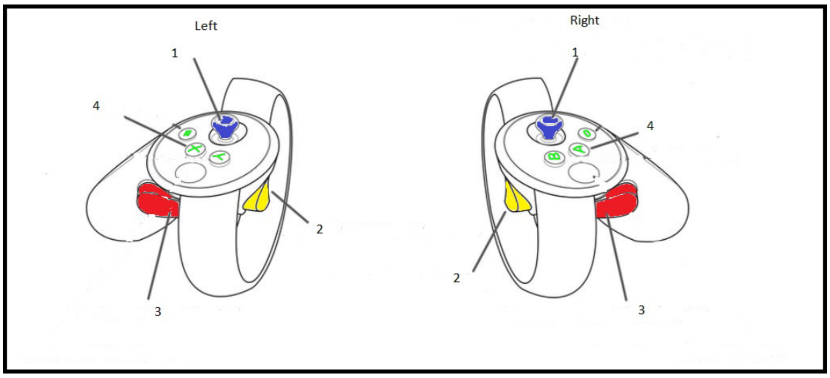

Figure 5.15: Image showing the updated design of the controllers. 1- navigation button; 2 - button to point to the UI elements such as virtual sliders and the virtual table; 3 - grab/release button; 4 - button to select the virtual UI elements

5.1.5 MUVR therapy pilot session

A final pilot therapy testing session was conducted to run the experiment’s procedure from beginning to end to identify any remaining issues. Two participants deemed as being at high risk from ED and two therapists performed a full therapeutic session (one based on ACT therapy and another based on PT). The aim of the pilot was to:

1. Make sure that the therapy procedure was appropriate.
2. Identify the approximate time needed to conduct the therapy.
3. Ensure that useful data (for instance system usability, MUVR experience, pre and post-cognitive fusion data to examine the effectiveness, etc.) could be obtained from the experiment.

The pilot evaluation session resulted in no further usability issues being reported. Representative users were recruited based on the inclusion criteria of the study (see Chapter 6). Each pilot test lasted approximately two hours. To guarantee the usefulness of the data collected, observational notes, questioners' results and other data were checked.

5.2 Implementation

The development of the MUVR system was divided into four stages as the initial prototype application consists of four main parts: ACT activities, PT activities, ET part and the tutorial. After each development stage was completed, evaluation testing was conducted (see Section 5.1.2, Section 5.1.4 and Section 5.1.5).

5.2.1 Hardware and software configuration

The VR system was developed using the Unity 3D Game Engine[4] version 5.6.0f3 and the Steam VR plugin[5]) to support both the Oculus Rift (used in the study) and HTC Vive VR platforms. The Steam VR plugin allows developers to target one application programming interface (API) which all the popular PC VR headsets can connect to. API[6] is a set of functions and procedures that allow for the creation of applications that can access the features or data of an operating system or other service. This means greater flexibility in the making of the VR application and allows it to be used with different VR platforms if required. Steam VR manages two main areas: the loading of 3D models for the VR controllers and headsets as well as handling input from those controllers. Moreover, this plugin provides an example of an interaction system which helps new developers to learn the interaction mechanism development process. In addition, the virtual reality tool kit[7] version 3.0 (VRTK) was used to speed up the development process. The VRTK provides a set of standard virtual interaction and navigation mechanisms that can boost the development process.

In order to implement multi-user capability, two platforms were taken into account: 1) the built-in Unity Multiplayer and Networking System (UNET) and 2) the external Photon Unity Networking Engine[8] (PUN). Both platforms support up to 20 users for free on the server. One of the biggest differences between UNET and PUN is the hosting process. UNET hosts applications in Unity instances (see Figure 5.16). This means that if the host (user who runs the server) is disconnected (network loss, crash, application closure), the entire session is terminated for all users (Unity, 2019).

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[4] https://unity.com/

[5] https://assetstore.unity.com/packages/tools/integration/steamvr-plugin-32647

[6] https://www.dictionary.com/browse/api

[7] https://vrtoolkit.readme.io/

[8] https://www.photonengine.com/

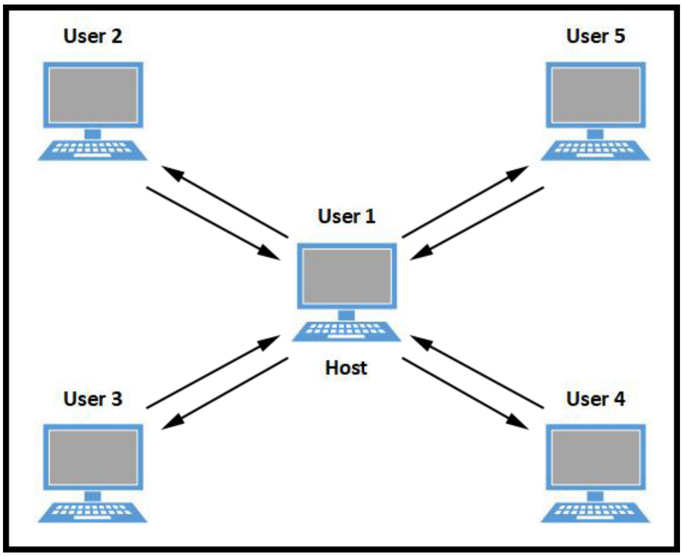

Figure 5.16: Diagram showing the UNET instance hosting process

On the other hand, PUN uses dedicated servers. This means that the session can continue no matter who drops out and the user can reconnect at any stage of the session. In order to connect users, developers need to create an application room on the Photon Engine Networking Server[9]. The application room created on PUN holds all the necessary information, such as the 3D VE, information from connected users and their position and activity. For example, when the user decides to pick up a 3D object, the information regarding the position of this object is passed to a server which allows the other users to see the changes in the object's position. All the tasks and activities between participant and therapist were synchronised in this manner. Therefore, PUN supports single and multi-user modes without the need to alter the code of the application, whether the application is being used offline (without an internet connection for a single-user mode) or online. This was helpful during the self-testing (testing by the developer, as opposed to the testing with clinicians and representative users) of the mechanisms developed for the application.

5.2.2 VR voice communication system

During the brainstorming session (see Section 5.1.1.2), it was suggested that a voice chat and not a text-based system should be implemented. The main reason for this was to provide a real-time communication experience, which is crucial for this type of psychological VR intervention. For these purposes, Salsa Lip-Sync with RandomEyes[10] version 1.5.5 and Photon Voice[11] version 1.16 were integrated allowing synchronous verbal communication between the therapist and the patient. Audio dialogue files were processed in real-time to automate the lip synchronisation process and animate the cartoon avatar faces. The louder the users speak, the more exaggerated the animation of the lips. In order for the users to be able to hear each other, a separate room (voice communication room) was created on the PUN server. The voice communication room was separate

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[9] https://www.photonengine.com/en/server

[10] https://crazyminnowstudio.com/unity-3d/lip-sync-salsa/

[11] https://assetstore.unity.com/packages/tools/audio/photon-voice-45848

from the application room, as the Photon Networking Engine requires audio data to be located in different rooms on the PUN server. Figure 5.17 summarises the hardware configuration of the MUVR system.

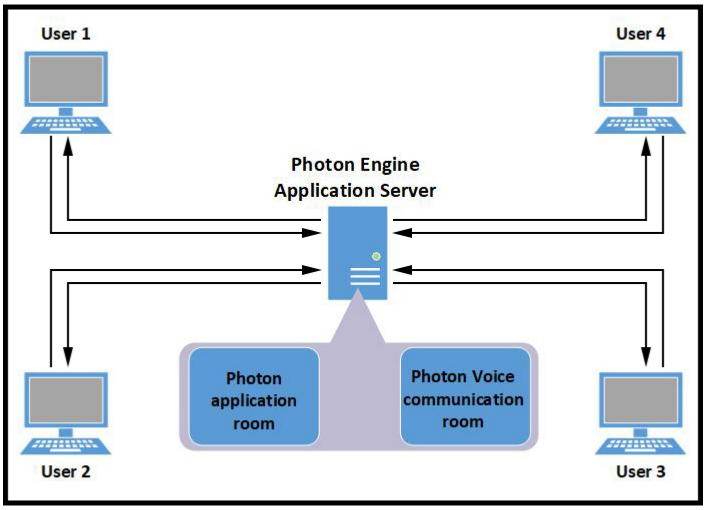

Figure 5.17: Diagram summarising the hardware configurations for the online system used in the experiment. The example shows the connection of four users

5.2.3 Development of the VE

To create the VE and 3D objects, the same software was used as for the mobile VR development - Autodesk Maya (see Chapter 3). In addition, free Unity Asset Store packages such as the LowPoly Enviroment pack[12] and Nature Starter Kit 2[13] were used and modified to speed up the development process. At first, five locations were developed, according to the protocol of the therapy:

1. A neutral starting location where participants can create their virtual avatar
2. A therapist room where the therapist introduces the therapy
3. A first natural environment for the first tasks under ACT and PT conditions
4. A second natural environment for the second tasks under ACT and PT conditions
5. A bedroom for the ET part

The decision to use two different natural environments for the ACT and PT tasks was taken because: 1) VR provides the opportunity to create different types of immersive location, which may add interest to repeated engagement with the therapy in the long term; and 2) based on previous mobile VR for pain management experiments (see Chapter 3), natural environments have demonstrated that they can create positive emotional responses. It was also decided that the bedroom location would be used for the ET task as the research team thought that the bedroom was the first place where most of the concerns regarding body image originated.

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[12] https://assetstore.unity.com/packages/3d/environments/landscapes/lowpoly-environment-pack-99479

[13] https://assetstore.unity.com/packages/3d/environments/nature-starter-kit-2-52977

After the second evaluation session, the therapist room was removed as it might seem intimidating and it was decided that meeting in a neutral location and provide gradual exposure could potentially reduce anxiety for the participants. Research also showed that office design could impact the psychotherapy intervention (Devlin et al., 2009). In addition, the therapist could introduce therapy during the participants' avatar creation process. Figure 5.18 demonstrates the final version of the VEs used in the study.

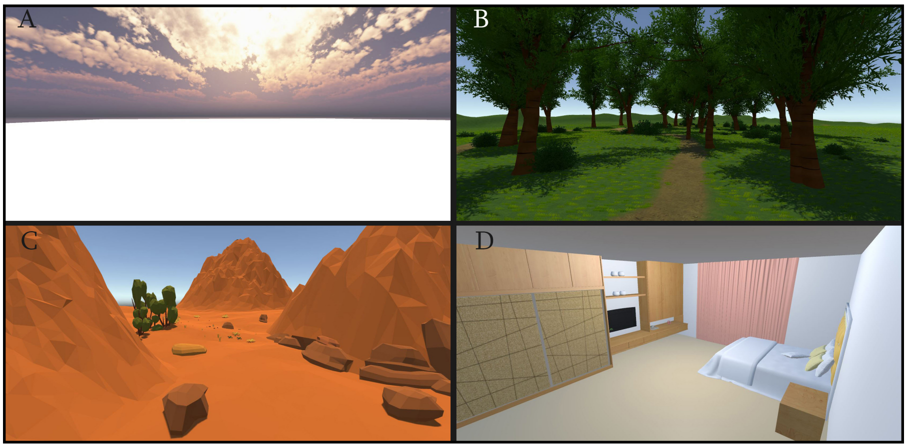

Figure 5.18: The final four virtual locations used in the study. A- the neutral starting location; B- the first natural environment for ACT and PT; C- the second natural environment for ACT and PT; D- the bedroom location for ET part

5.2.4 Development of the avatar customisation system

During the brainstorming session (section 5.1.1.2) with the psychologists, suggestions regarding the design of the ET part were discussed. It was decided that a virtual avatar customisation system would be developed to provide users with the facility to adjust the avatars to represent themselves. 3D models (human body, hair and clothing) were created in Adobe Fuse CC[14] and Autodesk Maya[15] version 2016. Adobe Fuse CC is free software that allows for easy assemblage of virtual human characters and their customisation using a wide selection of body parts, hair choices, clothing items and clothing textures, such as leather, cotton, metal and plastic (see Figure 5.19).

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[14] https://www.adobe.com/uk/products/fuse.html

[15] https://www.autodesk.com/products/maya/overview

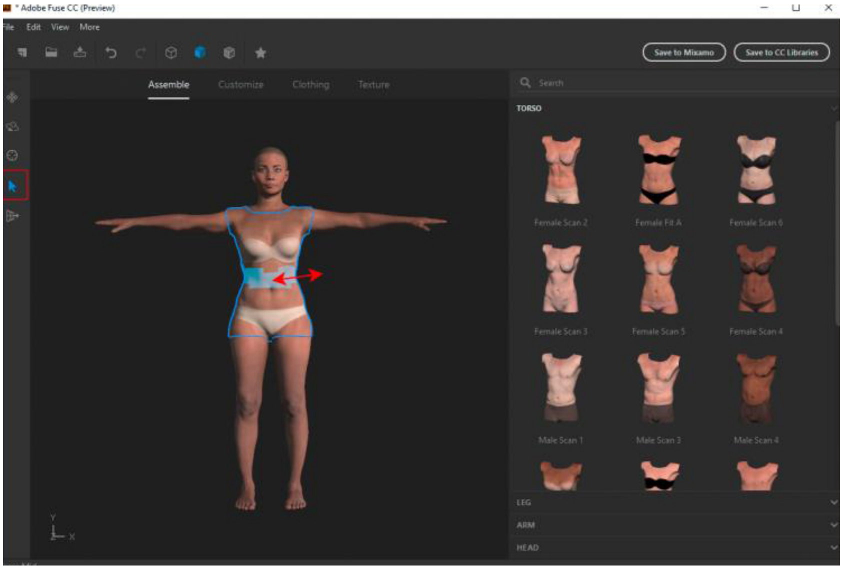
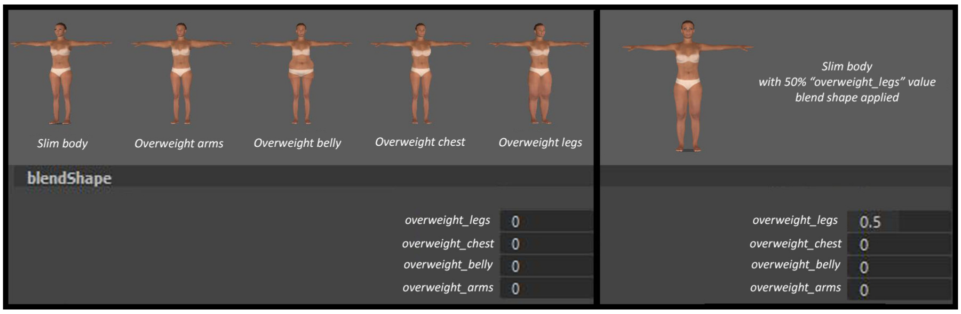


Figure 5.19: A screenshot of the avatar body development for MUVR in Adobe Fuse CC

The 3D meshes of the body, hair and clothing were created in two sizes (slim and overweight) in Adobe Fuse and were then exported to Autodesk Maya for further development. In order for the avatar to change its shape, blend shapes were created. Blend shape is a morphing technique that stores changes in vertex positions of the object, resulting in interpolation between starting and targeting a 3D mesh (Lewis & Anjyo, 2010). Consequently, having the different versions of the body shape (from slim to overweight), allowed for the creation of blend shapes that control the size of the body parts. Figure 5.20 demonstrates the four blend shapes (overweight legs, overweight chest, overweight body, overweight arms) that were applied to a starting slim body mesh. As such, it allows each part of the body to be controlled separately. The values of each blend shape range between 0% - 100%, where 0% equals the original slim body shape; 100% equals the target overweight body shape and the in-between values are interpolated accordingly.



overweight_legs 0
overweight_chest 0
overweight_belly 0
overweight_arms 0

overweight_legs 0.5
overweight_chest 0
overweight_belly 0
overweight_arms 0

Figure 5.20: The body blend shapes developed for the avatar used in the study. Image on the right demonstrates the applied 50% value of a blend shape for a slim body shape

After the blend shapes for the avatar's body and every item of clothing had been created, the virtual avatar was rigged and the animation was applied using Adobe Mixamo[16] software. Mixamo is an online software program which allows for the rigging (the process of creation of the skeleton for the 3D object in order

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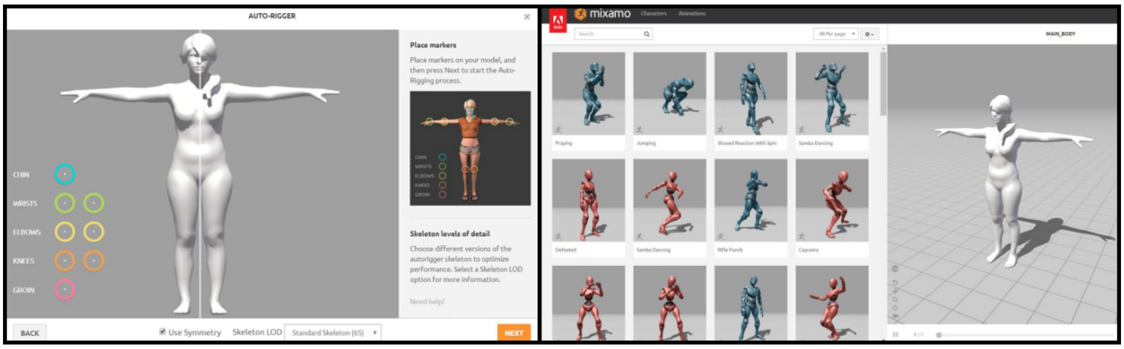
[16] https://www.mixamo.com/#/

to animate different parts of it) of humanoid models. Moreover, it contains a range of animation presets that can be applied to each individual character. In order to use Mixamo, developers need to upload their character (either in fbx or obj format) onto the Mixamo website and follow the instructions to position the body part joints (see Figure 5.21). Afterwards, a list of animations is presented which developers can choose from and they can download the rigged version of their 3D model with the selected animation.



Place markers

Place markers on your model, and then press Next to start the Auto-Rigging process.

Skeleton levels of detail

Choose different versions of the autorigger skeleton to optimize performance. Select a Skeleton LOD option for more information.

☑ Use Symmetry

Skeleton LOD: Standard Skeleton (65)

Figure 5.21: The rigging and animation process of the Avatar in Adobe Mixamo

Finally, the animated 3D model of the avatar with all its customisation features (e.g. blend shapes, different types of clothing and hairstyle) is imported to Unity 3D where it is synchronised with PUN. The model was presented to the participants in a neutral location where the study and first meeting with the therapist was due to take place (see Figure 5.22). Participants were given a choice between different hairstyles and colours as well as skin colour, while the clothing was the same for every participant. Each participant was provided with four virtual sliders that represented different parts of the body (arms, chest, belly area and legs) to customise the body shape. These sliders, that were previously created in Autodesk Maya, were connected to the blend shapes, by the C# script [see Appendix C], thus allowing for the model's shape to be changed.

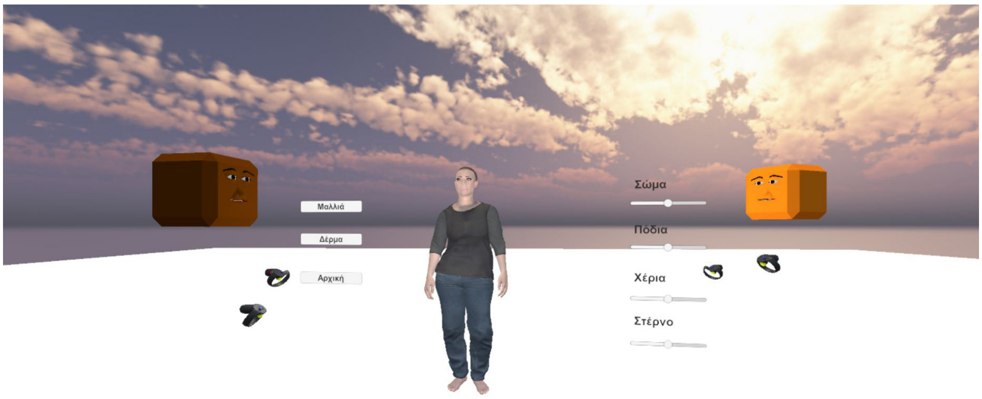


Figure 5.22: The virtual starting location where participants create avatars to represent their body schema

5.2.5 Development of the therapist control panel

In order for the therapist to control the therapy tasks, a special control panel was developed. This panel incorporates all the tools necessary for controlling the therapeutic activities and actions contained in the application. The panel consists of two parts. The starting control menu contains three buttons for activating the virtual locations (see Figure 5.23). At the beginning of the therapy session, only the starting location is loaded. As the therapy progresses, the therapist activates the rest of the locations chronologically, starting with the first therapy task location. When all users have moved to a new location, the previous location is deactivated. In order to return to the previous location, if required the therapist can reactivate it using the control panel. This was set up to optimise the graphics and processor resources of the computer.

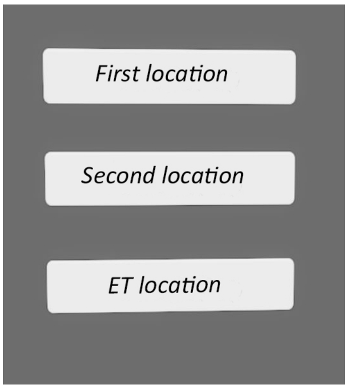


Figure 5.23: A screenshot of the control menu for the therapist to activate virtual locations

Secondly, the first ACT activity (the “Value task”) required some actions from the therapist to let participants repeat this activity. For this purpose, the second menu was created (see Figure 5.24), and it was activated when the therapist pressed the first location virtual button. This menu contains two control buttons, one to reset the task when needed and another to return to the location selection menu.

Figure 5.24: A screenshot of the controls for the therapist for the “Value task”

5.2.6 Development of the object interaction tools for the MUVR system

3D interaction mechanisms are fundamental parts of VR frameworks. The literature (Mine, 1995; Bowman & Hodges, 1999) highlights several categories of these mechanisms: selection, manipulation, navigation and application control. Due to the fact that new applications sometimes have unusual requirements, a variety of interaction mechanisms have been developed and designed for VR. The following factors have been identified that could affect the design of interaction techniques: task characteristics (travel distance or object size), environment characteristics (complexity and difficulty of the VE), user characteristics (cognitive and physical abilities) and system characteristics (frame rate) (Bowman & Hodges, 1999).

1. **"Automatic Hold" tool**
   Firstly, an "Automatic Hold" tool was designed to simplify the participants' interaction with 3D objects. The users had to press and release the grab button on the controller in order to pick up and hold the object automatically. To release the object, the users had to press the same button again. This meant the users would not need to hold down multiple buttons (one for navigation and another for holding the object) and could focus on the controllers while moving with the 3D objects in their hands. For example, this tool was used during the live map task ACT activity where participants needed to take a 3D object from a post, move with it and place it on a virtual life map. However, during the evaluation session phase 2, this tool was found to be confusing as the users continued to hold the grab button, which did not allow them to release the object upon releasing the button. As a result of this confusion the "Automatic Hold" tool was removed from the MUVR system.

2. **"Hold and Release" tool**
   Secondly, a more natural object interaction system was designed to replicate real hand movements when objects are picked up (see Figure 5.25). Users had to press the grab button on the controller (which is located under the middle finger) in order to grab the 3D virtual object and continue pressing it to keep hold of the virtual object. In order to release the virtual object, users simply needed to release the grab button. This tool was created for the PT condition where participants needed to perform some painting and basketball activities. However, it was also decided that this tool would be used as the main 3D object interaction tool for the MUVR system.

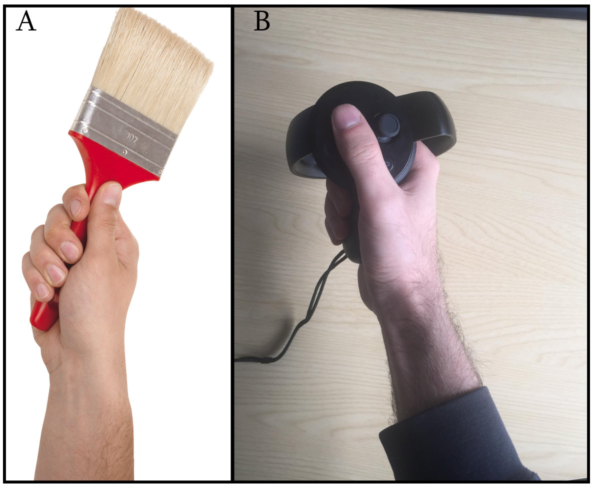


Figure 5.25: An example of real object hand holding (A) vs. its representation using the "Hold and Release" tool in the MUVR system (B)

5.2.7 Navigation in VE

Another important part of the immersive VR experience is the navigation in the VE. With the technological development of VR systems, different locomotion techniques were developed (Boletsis, 2017; Hale & Stanney, 2014). Development of the navigation tools was divided into two stages:

1. Development of the mechanisms for movement in the VE while performing the tasks.
2. Development of the mechanisms used to move between different locations of the application.

5.2.7.1 Users' movement in VE

1. **"Point and Click teleportation"**

   One of the most common ways of introducing navigation for the avatar to move around in the VE is by using a "Point and Click teleportation" tool. This technique is now one of the most widespread methods that is fully supported by commercial HMDs (Bozgeyikli, Raij, Katkoori, & Dubey, 2016). This mechanism is similar to using a laser pointer. Users specify a point on the virtual floor by using a button on the controller and the avatar will "jump" to that point (see Figure 5.26). The red pointer notifies the user if it is not possible to "jump" to a particular point. On the other hand, the green pointer will allow the user to move. By specifying the borders of the virtual floor, developers can restrict the movements of users if necessary. This tool was adopted from the VRTK.

Figure 5.26: A screenshot, from the MUVR application, demonstrating the "Point and Click teleportation" tool from the user's point of view

2. **"Navigation by Hand"**

   The research showed that physical walking provides the most natural experience of navigating in VR (Ruddle & Lessels, 2006; Waller & Hodgson, 2013). However, this type of navigation requires additional tracking devices that are quite expensive and bulky (see Section 2.2.4) (Wilson, Kalescky, MacLaughlin, & Williams, 2016). The literature provides two motion-based navigation methods that could simulate physical walking and at the same time be more affordable.

   The first is walking in place (WIP) (Williams, Bailey, Narasimham, Li, & Bodenheimer, 2011; Williams, McCaleb, Strachan, & Zheng, 2013; Wilson et al., 2016). This method can be implemented using Microsoft Kinect.

However, the researchers (Williams et al., 2013; Wilson et al., 2016) found some issues using this technology. The most feasible one was the occlusion of the body. Kinect was not able to correctly track the user's body on specific orientation angles. Adding additional Kinect did not provide better results. The research team decided not to develop this type of navigation technique; however, another mechanism that was developed for MUVR did not have such problems.

The method developed and tested for the MUVR system was the "Navigation by Hand" mechanism. This type of mechanism is part of a motion-based locomotion technique (Ferracani, Pezzatini, Bianchini, Biscini, & Del Bimbo, 2016; Wilson et al., 2016) and is based on "Myo Arm Swinging Method" (McCullough et al., 2015). By holding the move button (the blue button under the user's thumb) on the controller and swinging one's arms as if running on the spot (see Figure 5.27), the user is able to move smoothly in the VE without "jumping from one spot to another", replicating a natural walking style. The user's direction of vision is used to choose the direction in which to walk; namely, one walks in the direction in which one is looking.

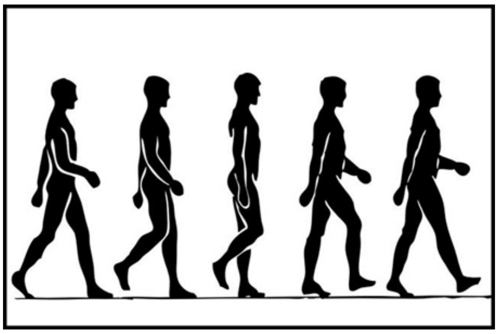


Figure 5.27: The way participants should swing their arms while standing still

5.2.7.2 Users' transition between environments

As different tasks take place in different locations, a mechanism for allowing movement between these locations was required.

1. **Teleportation through doors**
The initial idea was to design a navigation system whereby the participant and the therapist would be able to move between different locations by using everyday objects, such as doors and natural movement to make this process closer to a real-life experience (see Figure 21). Users need to move closer to the door, grab the handle and pull the door towards them so that they are able to see another location behind the door. A visual trick was used in order to optimise the system's performance. The image that users can see through the door is a real-time rendered image placed on a vertical plane from the location that the users need to get to. This location was situated in another part of the Unity scene and the vertical plane was working as a teleport. In order to get to this new location, the users have to cross this plane. This was done to save resources of the PC and VR headset as it was difficult to render a large number of high and low poly objects simultaneously and keep a stable fps.

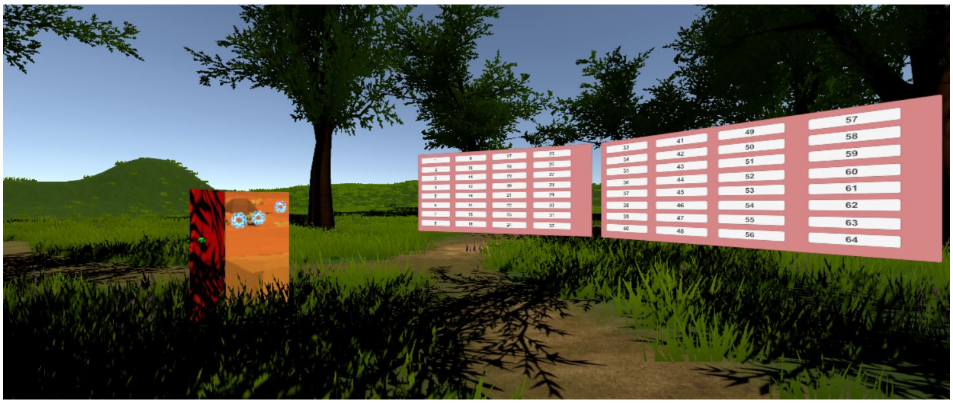


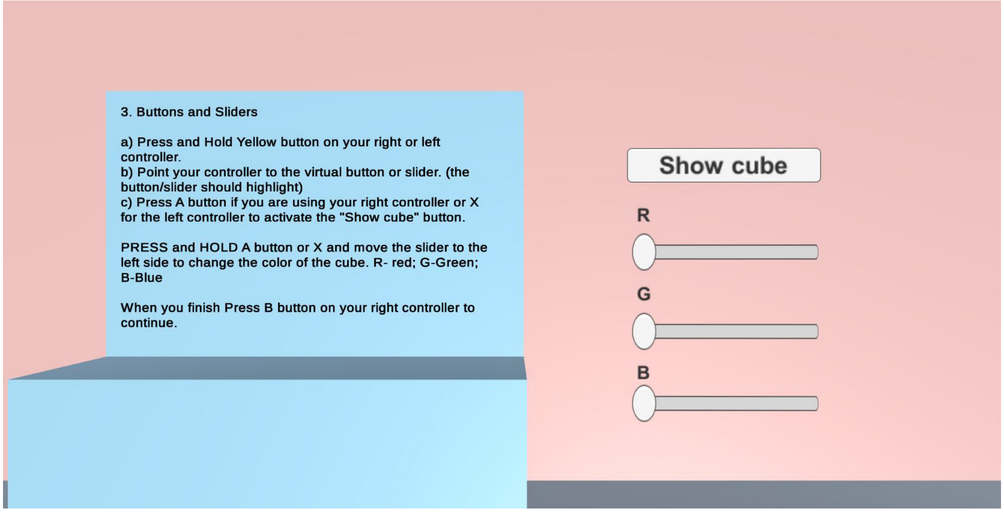
Figure 5.28: Navigation between "Value task" and "Life Map task" for the ACT condition using virtual doors

2. **Teleportation through virtual portals**
   The evaluation sessions (see Section 5.1.2.2) revealed difficulties using the teleportation through doors mechanism. To create a similar teleportation mechanism that is visually enticing for users, the system of navigating between virtual locations was redesigned. In order to make it simpler, virtual portals were created, which users could point at in order to appear in a different location (see Figure 5.29). To activate the portals, the therapist needs to select the location in the control panel menu so that a virtual portal appears in front of the user. Although virtual teleportation subtracts from the realism of the environment, it is much easier for participants and therapists to use.

Figure 5.29: The designed portal that patients and therapists used to move from the "Value task" to the "Life Map task"

5.2.8 Development of the tutorial level for therapists and patients

One of the main concerns raised during the evaluation sessions (see Section 5.1.2.3) was a lack of understanding of the basic controls for the application, for both therapists and representative users. In order to improve the usability of the MUVR application, the research team decided to develop a tutorial level to demonstrate all the necessary tools and controls used in the system. Detailed instructions for performing various tasks (e.g. grabbing the box from the table, using virtual sliders and buttons, etc.) were presented to the users before the therapy. The tutorial covers all the navigation and interaction mechanisms used in the MUVR system. Figure 5.30 demonstrates the UI interaction task for users performing the tutorial level.



3. Buttons and Sliders

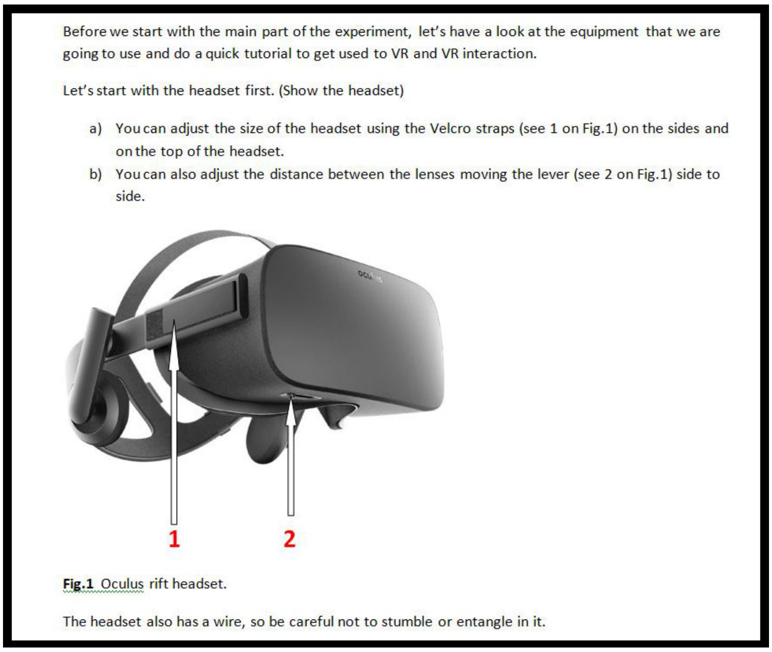
a) Press and Hold Yellow button on your right or left controller.
b) Point your controller to the virtual button or slider. (the button/slider should highlight)
c) Press A button if you are using your right controller or X for the left controller to activate the "Show cube" button.

PRESS and HOLD A button or X and move the slider to the left side to change the color of the cube. R- red; G-Green; B-Blue

When you finish Press B button on your right controller to continue.

Figure 5.30: A screenshot of the buttons and sliders task performed by the participants and therapists during the tutorial

Additionally, a set of instructions was provided on paper for the participants' assistant (see Figure 5.31). The assistant is located in the same room as the participants, and collects data and assists with the equipment. The instructions contain a detailed description of how to use the headset and controllers (see Appendix D).



Before we start with the main part of the experiment, let's have a look at the equipment that we are going to use and do a quick tutorial to get used to VR and VR interaction.

Let's start with the headset first. (Show the headset)

a) You can adjust the size of the headset using the Velcro straps (see 1 on Fig.1) on the sides and on the top of the headset.
b) You can also adjust the distance between the lenses moving the lever (see 2 on Fig.1) side to side.

Fig.1 Oculus rift headset.

The headset also has a wire, so be careful not to stumble or entangle in it.

Figure 5.31: Part of the paper instructions for the participants' assistant on how to use the Oculus Rift headset

5.3 Final MUVR system

At the beginning of the intervention sessions, both the therapist and representative users are taken to the tutorial level (see Section 5.2.8). After they have familiarised themselves with the basic controls, the MUVR therapy begins. There are four virtual environment locations, which include one neutral starting location, two natural locations (a forest and a desert) for ACT and PT activities, and a bedroom location for the ET part to end the therapy. The therapists and participants are represented with coloured cube heads and coloured virtual controllers for hands. A voice chat system is integrated into the MUVR system to allow for communication. To start the application, users select roles by clicking the corresponding buttons from the starting menu. Therapist and participant both appear at the starting location in front of the 3D model of the developed avatar. The therapist greets the participant and the MUVR therapy begins. After incorporating the improvements from all evaluation sessions, a "Point and Click teleportation" tool was chosen to move the users' avatars in the VE; teleportation through virtual portals was used to move between different virtual locations and a "Hold and Release" tool was used for interaction with all 3D objects in the MUVR system.

5.4 Summary of design features, challenges and key lessons learnt

The first design challenge was the translation of an established psychological intervention into a VR environment. The group of psychologists developed the contents of the psychological exercises and selected the evaluation tools needed for participant screening (see Chapter 6). Based on the psychologists' protocol, the HCI experts and the developer made recommendations for the graphic design (colours, texture, look, etc.). In addition, they provided suggestions as to how and what could be realised in the MUVR system in order to build a pleasant, emotional induction environment.

Therefore, a key factor of the MUVR system is the effective facilitation of the interactions between the therapist and the participants. To support ED therapy successfully, there is a need to develop appropriate conditions which allow the participants to feel sufficiently safe to disclose their inner feelings and self-image body perception. Specifically, the designer/developer was presented with two significant design challenges.

Firstly, it is expected that most therapists and patients are not familiar with the use of VR technology; hence, the issue of usability is non-trivial. Previous studies have shown that even advanced users may encounter several difficulties when using a computer system (Pfeil, Ang, & Zaphiris, 2009). Therefore, the simplicity of the VR system is a significant component of the design process. During the evaluation sessions with psychologists, therapists and representative users, various usability/navigation and interaction design issues were discussed as part of the adaptation of the proposed psychological specifications.

Secondly, the MUVR system was designed to support remote therapy, where therapists and participants are located in different geographical spaces and may never meet each other face to face. There was a need to build a friendly and trusting relationship between patient and therapist. Through the co-design process, it was decided that an additional version of the MUVR system should be designed to harness the “playful” and “game-like” features of a VR system, with both patient and therapist engaged in game-playing. The PT condition was developed as an active control to which the ACT condition could be compared. The purpose of this “gamification” is two-fold. Firstly, the research team believed that this can motivate the patient to participate in the therapy programme, due to the “fun factor”. Secondly, as was found during brainstorming session, a verbal communication during virtual games can develop a close relationship between the users within a virtual world (Utz, 2000; Henderson & Gilding, 2004). This is in line with research showing that positive outcomes from the therapeutic process are strongly related to the therapeutic relationship or alliance between the therapist and the patient (Horvath, Del Re, Flückiger, & Symonds, 2011; Horvath & Symonds, 1991; Martin et al., 2000; Norcross, 2002).

A number of lessons were learnt from the co-design and development process laid out in this chapter. The co-design approach allowed clinical psychologists without technical expertise to better understand what is technologically achievable in VR, and thus adjust the therapy programmes accordingly. For instance, the ET part had undergone a number of design iterations before the avatar customisation system was selected. Psychologists were shown the advantages of using such a system (e.g. real-time body shape customisation) and the therapy programme was adjusted as follows: the participants were encouraged to play with the size of the body parts in order to create their “ideal” body shape and then discuss the effects with the therapists.

The evaluation sessions and the iterative development method allowed for the problems encountered by users to be addressed and solutions developed and swiftly tested. This was especially true during the development of the remote VR applications. In order to avoid recruiting a large number of participants, therapists acted as participants during the three evaluation sessions. By assessing what a patient would see through the VR headset, they could provide help during the subsequent evaluation and pilot therapy sessions. Involving therapists in the co-design process enabled them to become familiarised and technologically competent, and thus better equipped to carry out the actual therapy using VR.

In addition, the iterative evaluations allowed us to test the system at various stages, not only to resolve usability issues, but also to test the feasibility of each therapy activity. Compared to the previous mobile VR design and development, the complexity of the application was different. An incremental prototype development approach (Van Hemel, 1999) together with brainstorming sessions allowed the research team to gradually develop the system, and thus design appropriate VR activities and interaction mechanisms.

5.5 Conclusion and chapter implications

This chapter has described the co-design process for the creation of a remote, MUVR system for conducting interventions for people dealing with ED symptoms. Firstly, a focus group study was conducted to identify an approach for designing an appropriate system. Afterwards, the system was iteratively developed, tested and refined. Changes and improvements were introduced based on the key stakeholders’ (clinical psychologists, therapists and representative users) feedback. The final version of the MUVR system was found to be robust; connectivity, synchronisation and interaction difficulties/issues were not identified.

The co-design approach enabled the research team to generate ideas within the context of clinical psychology and technology, as it encouraged a holistic approach to the problem and its eventual solutions. However, some limitations in the use of the MUVR system were found during the co-design process. Firstly, clinicians had to spend time before the study learning how to use the system. Ultimately, this means that training will be required for therapists before the system can be integrated into a clinical environment. Secondly, the avatar customisation part of the system is not fully user-centred. Some of the most common clothing, hairstyles and colours were developed for the system, but the development of a larger variety will require more time and a greater budget.

The co-design and iterative development process of the MUVR system described in this chapter will allow experiments related to remote VR therapy to be conducted more easily, in particular by those who are not familiar with VR technology and computers. The MUVR system will be used in the next chapter to conduct a study with people dealing with symptoms of an eating disorder.

Chapter 6

The Use and Effect of the Remote Multi-User VR System for Representative Users Deemed at High Risk of Eating Disorders

Using the MUVR system developed in the previous chapter, we carried out a remote VR study to investigate the possibility of using remote treatment through the example of Eating Disorder therapy and tried to understand how to design and integrate the Multiplayer VR system for psychology treatments.

This chapter presents the results from this study. In particular, with this study, we aimed to investigate the design opportunities and deployment challenges of introducing MUVR to facilitate remote psychotherapy. The study contributes to the growing research of VR healthcare by: 1) describing the development of a MUVR for psychotherapy through a co-design approach; 2) identifying and understanding design factors which work (or do not work) in MUVR psychotherapy; and 3) the challenges of deploying such systems in real-world psychotherapy sessions.

This chapter is broken down into five sections: Section 6.1 describes the study design and procedure; Section 6.2 provides the description of the recruited participants; Section 6.3 presents instruments used for this study; Section 6.4 presents the findings from the study; and Section 6.5 provides a discussion and conclusion.

6.1 Study design and procedure

The VR interventions were carefully co-designed (see Chapter 5) based on traditional psychotherapy training for the treatment of ED (Hayes et al., 2011), funded by the European Network for Health Promotion. Data were collected over an eight-month period and included Likert-scale questionnaires, interviews and qualitative and quantitative observations for both participants and therapists.

Upon arriving, the participant was asked to complete the Figurative Cognitive Fusion Scale (FCDS; more details about instruments can be found in Section 6.3.2) scale, to identify the cognitive fusion between the self and worrisome thoughts. Then, the researcher measured the participant's weight, body mass, and height and computed her Body Mass Index (BMI), from the formula: $BMI = Kg/M^2$, to identify the relative body weight as a reflection of adiposity. Once this process was completed, the participant was offered a MUVR therapeutic session and was reassured that she had the option to stop the session at any time. A consent form was signed, and then the participant was asked to put on the VR HMD. Both the participant and the therapist (in separate rooms and never met face to face) were instructed to follow the tutorial instructions, with an approximate duration of 25 minutes, in order to become familiar with the use of the VR system and the interactivity devices. Upon the completion of the tutorial, a randomised controlled allocation was used, to assign each participant to an intervention group (ACT group or PT group; more details about different VR intervention strategies can be found in Sections 5.1.1.2 and 5.1.3). Then, the main therapy session began, with both the participant and the therapist "teleported" into a neutral VE location. Qualitative observational notes were captured by the two researchers (one located in the room with the therapist and another located with the participant). The MUVR therapeutic session took around an hour. Once the MUVR session was completed, the participant was asked to complete the post - FCDS questionnaire. Both participant and therapist (in separate rooms) were asked to complete the VR questionnaires, and a semi-structured interview was conducted by the researchers. Overall, the entire therapeutic session lasted approximately two hours. During the experimental process, the therapist was located into a separate room, 50m away, to reassure that the participant and the therapist will not meet in person.

6.2 Participants

We recruited 130 women aged between 18 to 25 years, who claimed to have an unhealthy relationship with food and body image. Only women were recruited in this study as ED phenomenology presents differently between the genders (Stanford & Lemberg, 2012). The degree of gender differences described in the literature depends on the specific symptoms of an eating disorder that are currently being investigated (Striegel-Moore et al., 2009). The research in different eating disorders shows that women tend to have a higher dissatisfaction with the body and a stronger tendency for thinness compared to men (Barry, Grilo, & Masheb, 2002; Anderson & Bulik, 2004; Lewinsohn, Seeley, Moerk, & Striegel-Moore, 2002).

All 130 women were asked to complete two screening questionnaires (Eating Disorder Diagnostic Scale (EDDS) and Weight Concerns Scale (WCS); see Section 6.3.1), to capture the level of possible ED diagnosis, their overall eating pathology and the potential risks of developing an ED with in the following four years. A symptom composite cut-off score of 16.5 was used to reflect the best trade-off of the EDDS symptom composite score regarding the determination of the presence or absence of eating pathology (Krabbenborg et al., 2012). 34 out of 130 participants scored above this cut-off, which signifies that they are at a high risk of developing ED. A more in-depth analysis revealed that 10 out of 34 were identified with a possible diagnosis of having either Anorexia Nervosa ($n = 2$) or Bulimia Nervosa ($n = 8$), according to the criteria specified in the WCS diagnostic scale.

Participants with the possible diagnosis were referred to the University of Cyprus counselling services for a full diagnostic mental health assessment. Three participants were diagnosed with severe Anorexia and Bulimia Nervosa and excluded from the study. Seven participants chose to withdraw from the study and did not attend the session. Therefore, the final sample included 14 females deemed at high risk for ED, with a mean age of 20 years ($M= 19.93$, $SD =$

1.77), with healthy mean weight range, Body Mass Index (BMI) (M= 24.25, SD = 3.23). All female deemed at high risk for ED had a normal or corrected-to-normal vision and no disability in their hand, arm, shoulder, neck, back, pelvis, hip, knee, foot or another area that could affect the use of the VR technology. Seven participants were recruited into the ACT group (PT: n = 7). Table 6.1 presents relevant descriptive data for each case.

	BMI	**Height (cm)**	**Weight (kg)**	**Arm (cm)**	**Waist (cm)**	**Hips (cm)**	**Thigh (cm)**
PT	23.5/3.79	162.43/7.09	64.71/14.15	23.29/3.59	79.86/14.84	99.29/11.91	54.71/7.93
ACT	25.01/2.62	159.71/5.68	64.01/6.81	24.00/1.41	76.93/9.76	101.71/6.82	55.00/4.40

Table 6.1: Descriptive statistics per group (M/SD)

Seven therapists were recruited to lead each therapeutic session. Each therapist was allocated to a different case. The goal was to validate the success of the MUVR therapy within a diverse therapeutic setting. Therefore, the therapist professions included a background in clinical (n = 3) and school psychology (n = 4). All therapists were given a script of tasks, created by the lead clinical psychologists from the research team, to follow during the MUVR session.

6.3 Instruments

6.3.1 Screening questionnaires

As aforementioned, a number of 130 potential participants complete two screening questionnaires recommended by psychologists from the research team:

1. **Eating Disorder Diagnostic Scale (EDDS)** (Stice, Telch, & Rizvi, 2000): a self-report scale consisting of 22 statements based on DSM-IV criteria for capturing the level of possible ED diagnosis and participant's overall eating pathology. Items were measured in a variety of formats, as determined by the nature of the question including a 6-point Likert scale (1 = not at all, 6 = extremely), yes/no responses and frequency ratings that range from 1 to 14. The EDDS was recommended as a high validity questionnaire for measuring ED symptoms (Stice et al., 2000) and was used to identify if the participants meet the criteria for possible ED diagnosis.

2. **Weight Concerns Scale (WCS)** (Killen et al., 1996) is a five statement self-report scale assessing the participant's risk for developing ED in the next four years. Items were measured on a 4-point, a 5-point, and a 7-point Likert scale (1 = lower rate, and 4 − 7 = higher rate). The WCS provides an adequate validity and reliability (Dias, Maroco, & Campos, 2015) and was used to identify if the participant is at high risk for developing an ED.

6.3.2 Pre and Post questionnaire

The following measure was completed by the participant for pre and post MUVR therapy: **Figurative Cognitive Fusion Scale (FCDS)** (Killen et al., 1996): a single item self-report scale capturing the relation and level of cognitive fusion between participant's self and worrisome thoughts. This was done via a digital scale that ranges from 1 (extremely fused with troubling thoughts about body shape and weight) to 10 (extremely defused from troubling thoughts about body shape and weight). The FCDS was used to schematically assess the participant's thoughts regarding their body schema and was used in the previous studies in eating disorders conducted the psychologists from our research team (Nikolaou, 2017).

6.3.3 VR questionnaires

Two questionnaires were completed by both therapists and participants so as to capture the level of usability, presence and immersion the users engaged to:

1. **System Usability Scale (SUS)** (Brooke et al., 1996): a self-report scale consisting of 10 statements was used to evaluate the effectiveness, efficiency and satisfaction from the system. The SUS was rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). This questionnaire was proved to be effective and efficient and it should be also noted that it provides the reliability (r^2) of .047, which is very small (Peres, Pham, & Phillips, 2013). However, for a pilot study this is enough.

2. **Presence** (Nichols, Haldane, & Wilson, 2000): a self-report scale consisting of a six-item was used to evaluate: a) the sense of "being there" in the scenarios as compared to being in a place in the real world, b) how much the scenarios became the dominant reality, and c) the extent to which a participant remembered the scenarios as a place visited, rather than as a computer-generated text or image. The presence was rated on a 7-point Likert scale that ranged from 1 (strongly disagree) to 7 (strongly agree).

6.3.4 Qualitative measurements

Semi-structured interviews were conducted by two researchers who are experts in the field of psychology and HCI in healthcare. The interviews were conducted with an aim to reflect on their experience using VR focus on issues on technology acceptance, the impact MUVR can have on the user, and the emotional reactions. In particular, the interviews with the participants focused on three main areas: (a) Systems Usability (e.g., "How easy did you find the systems use?"); (b) Attitudes towards the MUVR session (e.g., "What did you like/dislike about the VR session?"); and (c) Emotional reactions toward the virtual psychotherapy in comparison to traditional practices (e.g., Which type of psychotherapy do you prefer more: VR or traditional face to face?").

The interviews with the therapists aimed to reflect on their observations of the participants using VR and sought their professional opinion on the usability and suitability of VR to support remote psychotherapy in a simulated environment specifically designed and personalised to optimise the therapeutic benefits. The interviews focused on three main areas: (a) Usability Evaluation (e.g., "Did you find the VR use simple?"); (b) Emotional reactions towards the MUVR (e.g., "What kind of emotions emerged during the session? How the system affects those emotions?"); and (c) Reflections on the participants (e.g., "What are your observations regarding the participant?"). To ensure the reliability of the interviews, the same questions were asked more than once and sometimes in a different format.

Detailed **Observation Notes** were also taken by the two researchers; one located in the room with the therapist and another located with the participant. The goal of these observations was to classify the interactions and behavioural responses towards the VR experience. This was done to identify the design and deployment opportunities and challenges, which can help inform future VR deployment in healthcare settings. To ensure the reliability of the observational notes, video recordings were collected, and a corroborated analysis was conducted.

6.3.5 Apparatus

Two Oculus Rift VR HMD systems were used to stream the audio and visual content (one was given to the therapist and another to the participant). Two sets of Oculus Touch Controllers were used as interactivity devices to allow the users to navigate through the VE. The system was paired to two sets of Oculus sensors so as to capture the user's physical position and movements and incorporate them into the VE. The Oculus Rift tracks the head movement to present the correct virtual-world image to the eyes (LaValle, Yershova, Katsev, & Antonov, 2014), and it analyses the user's head movement in real-time to control the view. This results in natural interactions between the user and the VE, leading to high levels of presence and immersion (Desai, Desai, Ajmera, & Mehta, 2014). The HMD includes an adjustable head strap setting the hands-free for the controllers. The combined weight of the HMD (470 grams) and controllers (169 grams/per controller) is 808 grams, which facilitates comfortable use for extended periods.

The VR content was streamed to an external laptop screen, mirroring the user's real-time virtual interactions; allowing the two researchers to observed the procedure silently. Open Broadcaster Software[1] 23.0.1 was used as a video screen recorder to record the virtual session, the interactions and the discussion between the therapist and the participant. Two Dictaphones were used when interviewing the therapists and the participants, and 2 separate laptops were used to answer the questionnaires by both participants and therapists.

6.4 Results

A range of quantitative and qualitative data sources were analysed to assess the effectiveness of MUVR and how the technology was used to support ED therapy. As can be seen from the results detailed below, there was a general coincidence in the positive acceptability of remote MUVR psychotherapy used by younger females deemed at high risk for ED.

6.4.1 System usability

The overall System Usability Scores (SUS) for both participants and therapists indicated high rates of system usability, in the order of 81.5%. The results showed that the therapists' SUS rating was slightly higher than the participants.

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[1] https://obsproject.com/

Further usability analysis was done for users in both groups (ACT and PT). It was found that participants assigned to the PT group rated SUS slightly higher in comparison to those in the ACT (see Table 6.2).

6.4.2 Presence

High rates of presence (max score of 7) were reported by both participants and therapists (M = 5.15, SD = 0.95). The results showed that the therapists gave slightly higher rates of presence compared to the participants. It was also shown that both participants and therapists were reporting to be more immersed during the ACT session. Table 6.2 presents relevant descriptive data for each group.

	SUS		**Presence**	
	Participant	**Therapist**	**Participant**	**Therapist**
PT	82.50%	84.29%	4.55/0.96	5.60/0.58
ACT	75.36%	85.63%	4.86/1.02	5.92/0.62

Table 6.2: Descriptive statistics per group (Percentages, M/SD)

6.4.3 Figurative Cognitive Fusion Scale

To assess the effectiveness of MUVR on ED therapy, we examined the cognitive fusion between the self and worrisome thoughts. This scale schematically measures the participant's thoughts regarding their body schema. The results revealed that the level of cognitive fusion between participant's self and worrisome thoughts reduced significantly after the MUVR remote psychotherapy (see Table 6.3).

	FCFS		
	Pre-Test(M/SD)	**Post-Test** (M/SD)	t
PT	3.71/1.60	5.71/1.11	6.13***
ACT	2.86/2.12	5.14/2.91	3.57**

(***p <.001; **p<.05)

Table 6.3: Pre and Post Analysis of the Figurative Cognitive Fusion Scale

6.4.4 Interviews and observations

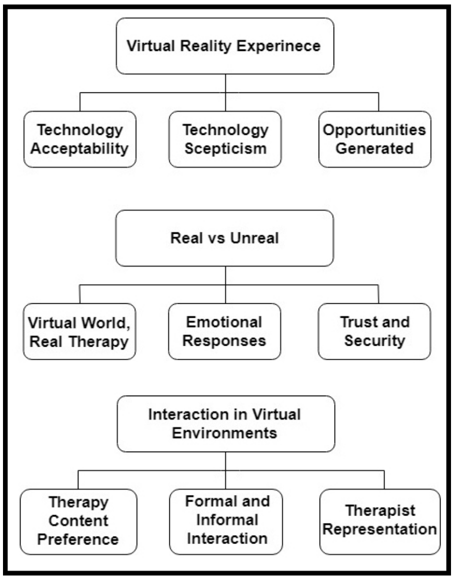

Figure 6.1: Therapists and Participants Themes

To explore how MUVR was used by participants and therapists, and to identify design challenges and opportunities, in-depth thematic analysis was carried out on interviews data and observation notes made by the researchers. The analysis revealed three core themes and nine subthemes (see Figure 6.1): 1) "Virtual Reality Experience"; 2) "Real vs Unreal" and 3) "Interactions in Virtual Environments".

Virtual Reality Experience. This theme is concerned with the general relationships between the users with the VR technology, and it consists of three subthemes: (1) Technology Acceptability; (2) Technology Scepticism and (3) Opportunities Generated.

Technology Acceptability. Supporting the quantitative analysis of SUS and presence, our interviews suggested that in general, both therapists and participants indicated that they are open to using MUVR therapy in the future. The therapists found the system useful in facilitating therapy and at the same times, user-friendly.

> *"I found the system very easy to use, and in general, the graphics were nice and helped the participant to work with her body image"* [T1, 6, 3].
> *"I can see myself using this system in future to run more therapeutic sessions and I trust that once I get use to the system use the sessions will improve a lot [. . .] What I am trying actually to say is that, this was my first use of VR to run a psychotherapeutic session, and so I was very concentrated to use the system correctly, this might have affected a bit negatively my performance at the session"* [Int: T2, 5][2]

Participants deemed at high risk for ED also provided feedback on the usability of the MUVR remote psychotherapy, sharing their positive attitude toward

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[2] Source: Int=Interview or Obs=Observation; P=Participant deemed at high risk of ED or T=Therapist; interview number.

the system. Their statements also emphasised the need for learning user interfaces prior to the therapy. Specifically, they claimed that the tutorial included in MUVR has been crucial in improving technology acceptability.

> *"I found myself feeling comfortable using the system. It was easy for me to memorise all the buttons because of the tutorial. I was able to interact naturally with the VR system, the objects and the therapist"* [Int: P1, 1].

Technology Scepticism. Even though most participants responded positively towards the VR experience, from the observations, we found that highly anxious individuals faced substantial difficulties in the relationship with VR. Fearful, tensed and worried reactions were observed due to unfamiliarity with VR. The therapist suggested that some of the participants were very stressed at the beginning of the session because of the VR technology.

> *"I felt that she was quite tense, and for sure she was sceptical about the VR use. She was very introverted but, during the PT, something magical happened, she started to enjoy the VR and engage with the activities. She was interacting with me, and at the same time, she was revealing her worrisome thoughts"* [Int: T1, 14].

The above was further supported by the refusal of three participants to respond to the therapist at the beginning of the virtual therapy. Specifically, they referred to the therapist in an impersonal way, as if the therapist were not a human being but an object ("something") and sought help and reassurance from the researcher who was physically in the room with them. Notably, one highly anxious participant was ignoring the therapist instructions in the VE, and she kept communicating with the researcher in the physical room. She was seeking help, and her tone of voice sounded stressed.

> *"I am so scared, I don't want to touch the virtual object. I am scared, I don't want to move from my spot, I might get hurt"; "Oh God, something is talking to me is this normal? [Referring to the Therapist Avatar] Oh My God! [Researcher's name] Do I have to reply to this?"; "I am lost. I am in the middle of nowhere, I am in a desert. [Researcher's name] did you lose me? I don't know where I am!"* [Obs: P10].

However, the participants' initial hurdle and sceptical attitude were overcome through the virtual interactions.

> *"At the beginning of the session, I got frustrated and stressed but during the activities [. . .] for example, the basketball game, I got relaxed. I felt closer to the therapist, I started trusting her. During the games, she was hearing me illustrating my problem very kindly and responded to my worries appropriately. [. . .] I mean her words; her statements were very straight forward she made me think of my self in a way I haven't thought of me before. To be honest, I was not expecting it, but via this VR therapy, I got that much help that I feel that I was not the one who gave [time participating] to this research. This research helped me so much, the experiment on its own was my reward. Thank you"* [Int: P10, 10].

Opportunities Generated. Quantitative analysis has shown that troubling thoughts about weight and body schema conception were reduced after the MUVR psychotherapy. Qualitative quotes were found supporting these positive results. Therapists reported that participants deemed at high risk for ED were found to engage with the virtual therapy experience, expressing their thoughts and emotions and were trying to accept their body schemes.

> *"I felt that the participant was sharing with me her troubling thoughts and emotional concerns. I can surely say that at the beginning of the ET she got frustrated about the way she looks [. . .] her voice was breaking, and I could observe a tremulous voice but as the time passed she started being more confident. She was engaging with the exposure and accepting her looks [. . .] I think in the end of our session she was pretty optimistic about herself, her body and the future"* [Int: T3, 9].

Participants stated that ET helped them to accept their body image. In particular, we asked them to provide a general feedback about the MUVR remote psychotherapy and most of the participants focused on the positive attitudes toward their bodies after the MUVR remote psychotherapy.

> *"Via this VR app, I was able to create my "true" self. Through this process, I felt capable enough to see and create my body accurately. I started creating a large body figure, but through the app and the whole process, I realised that I was overreacting. At the end of the process, I was able to create an avatar similar to my body. Some parts of my body are still bothering me but not that much anymore. I am not that strict and judgemental with myself anymore. I feel that this is myself and myself -the avatar that I am looking at is a normal person. It was like all of these years I was looking to myself, but I didn't see myself, I never concentrate and focus on what really my body looks like. This VR app did it. For the first time, I realised that the idea I have about my body is different from my actual body"* [Int: P6, 6, 1].

Real vs Unreal. This theme describes the interplay between what is real and what is unreal (virtual), and how this has an impact on the therapy. Three subthemes were identified: (1) Virtual World, Real Therapy; (2) Emotional Responses and (3) Trust and Security.

Virtual World, Real Therapy. A key design challenge is to ensure that the therapy experience provided in MUVR is authentic. Therapists reported that via MUVR, the participants deemed at high risk for ED were able to experience a realistic ET where the therapist was able to observe and intervene when necessary.

> *"I think that this kind of technology-based therapy is very useful for people who are dealing with any kind of phobias since it provides the therapist and the participant with many options in regard to accurately experience the phobic situation. During this ED session, the participant was not only able to observe, discussed and shaped her body, but she was also able to share this image with me. Which placed me in the position to help her to deal with her troubling thoughts"* [Int: T4, 10].

Participants supported this notion that MUVR is providing a realistic experience with emotional responses especially through the discussion they had with the therapist, where the participants not only reacted emotionally but also referred to their online avatar as if it were their physical self.

> *"The mirror phase made me uncomfortable. It was a realistic experience, I was feeling like I was looking directly at myself in a real mirror and that was kind of disturbing" [Int: P9, 9]. "I don't want to remove my clothes. I feel that I will be embarrassed to be close to being naked in front of you, in front of another person"* [Obs: P8].

A key observation that showed that the VR system provided a realistic experience for the participants was the avatar customisation activity. From the existing literature, it is known that many people dealing with ED symptoms tend to overreact when they describe their body schema (Bruch et al., 1974). Participants with concerns about their body schema created a much bulkier virtual body figure compared to their real body (see Figure 6.2). When the therapist asked the participant to explain the similarities between the way they look and the way their avatar looks, they all said that this is exactly what their real body looks like. This suggested that the participants were able to engage with the virtual activity as part of the therapy programme, exhibiting symptoms of ED and expressing their concerns in a virtual environment. This led us to believe that it is possible to design a VR system to create a realistic therapy experience, which is key to help people participants overcome their ED symptoms.

Figure 6.2: To the left: participant's body. To the right: Avatar created by the participant, to represent her Body Schema

Emotional Responses. A part of the therapy program was to help participants to develop a more realistic and positive attitude towards their body schema; hence it is important that participants are able to express emotional responses in a safe and supportive environment. From the interview, therapists mentioned that they observed participants facing negative emotions during some parts of the therapeutic process.

> *"I felt that during the exposure psychotherapy she got very stressed and frustrated. However, through our talk, she started accepting her emotions, and instead of avoiding them, she communicated and embraced her feelings"* [Int: T5, 12].

The above observations were in line with the participants' statements. Participants stated that the process was emotionally challenging for most of them. Nine out of fourteen participants described the exposure as helpful but sad.

> *"I felt uncomfortable in front of the VR Mirror. Trying to create your self – not who you want to be but who you really are is not just uncomfortable, is miserable [...] However, I really–really liked it. It was a great experience, and it helped me a lot, it helped me to understand several things about myself and my body and all the concerns I have. I enjoyed it, and it made me think, [...] it made me think a lot"* [Int: P12, 12].

Interestingly in this study, we observed that the therapist was not only able to interpret correctly the participant's emotions but was also able to respond effectively. We believe this is partly because the VR was designed to establish a friendly relationship between the two users through game playing. This is particularly true for the PT condition, as the participant stated:

> *"Playing games made me feel closer to the therapist; it was like we bonded, like having fun with a friend. This helped me to trust her and feel that I can share my emotions and thoughts with her. She was not a therapist; she was a friend with whom I had some fun and shared some thoughts and emotions, a friend that counselled me"* [Int: P10, 10].

Trust and Security. One of the most important findings was that all four therapists and 11 (out of 14) participants in both groups reported to have experienced a sense of trust and security. The therapist observed emotional and personal information disclosure by the participants, while the participants described the whole process as safe, which helped them to disclose information about their feelings.

> *"I feel that the VR remote psychotherapy allows the participant to express her emotions more freely. Not being able to be seen makes her comfortable to disclose emotions and ideas about her body shape that troubles her. I feel that this kind of psychotherapy will be more suitable than face-to-face psychotherapy for the introverted individual"* [Int: T7, 11].

The findings pointed to "two levels of safety" perceived by the participants. On one level, the VR was an insulated world shielding the participants from the messy outside world they are struggling to cope with. We can draw a parallel between "entering the VR" and "entering the therapist room" in a face-to-face session. In this sense, one can argue that MUVR may offer a stronger sense of safety than other forms of remote therapy (e.g., via phone or skype) as the participant virtually "enters" a new space that is the VR. The "second level of safety" refers to the protection of the private personal emotional space of the participant from the therapist. For instance, participants liked the fact that the therapist could not see their true self physically:

> *"I felt that the virtual environment was a safe and protected space where only the two of us exist" [Int: P1, 1]. "I liked that the therapist was not able to see me, and therefore, she was not judging me because of how I look. I was my avatar, and that was a safety net for me"* [Int: P13, 13].

Interactions in Virtual Environments. This theme captures various issues regarding interactions in the virtual environment and potential design directions. Three subthemes were highlighted: 1) Therapy Content Preference, 2) Formal and Informal Interactions, and 3) Therapist Representation.

Therapy Content Preference. Given the diversity of participants' personal backgrounds and interests, it is not surprising to observe variations in engagement level among the participants. The therapists suggested that individual differences may affect the effectiveness of the MUVR therapy and that the type of virtual activities should be in line with the participant's interests.

> *"My personal observation is that the use of playful or game-like activities within the psychotherapy process promotes a sense of trust and understanding between the therapist and the participant in such environments, even for highly anxious individuals. However, the type of virtual game should be in line with the participants' interests since it was found that some individuals benefited more from colouring activities, whereas others were interested more in active types of games such as basketball"* [Int: T1, 5].

Participants' statements largely supported the therapist's observation. Presented below is a participant's statements in support of the two PT activities.

> *"In general, my stress levels are high, and several worrying thoughts are troubling me a lot. During the VR colouring game, I concentrated on the virtual colouring, and this distracted me from my anxious thoughts. In the end, it made me feel much calmer. I would like to do this activity on a regular basis. I believe it will help me to calm"* [Int: P5, 5]. *"I don't want to move to the next task, but since I have no other option I have to agree... Let's move, however, if I could I would have chosen to stay here for much longer, but I understand, there are other tasks and we have to move on"* [Int: P14, 14].

Formal and Informal Interactions. It became obvious to us that participants in PT+ET group were much more expressive and expressed more of their thoughts to the therapist. As the therapists alluded to, PT situates psychotherapy in an informal context, hence lessen the "authority" of the therapist, which can be beneficial because the participants are usually in an emotionally vulnerable position.

> *"During the PT session she was interacting more naturally with me... I got a second role, I was not only her therapist, I was her friend as well [...] In some cases she was less concentrated to out talk, but generally this made her much more talkative and a lot less worried about the way she had to express herself"* [T4, 14].

> *"I feel that exercising is offering [. . .] my basketballs are gone, I need extra ball [Therapist fills the tray with balls] is offering you a good quality of life [. . .] can you give me some more balls? I really liked this task even though I didn't reach the target [giggles] I really liked it, oh thank you for the balls, so I was saying that exercising is helping me to maintain a good quality of life [. . .] balls please, my basket is empty. In general, I prefer to train early in the morning, this improves my mood and makes me feel more energetic [. . .] can I get unlimited balls? [giggles]] exercising is my hobby, is my everyday life routine, I cannot see myself without exercise, balls?"* [Obs: P14].

Notably, this informal interaction was not observed for participants in the ACT+ET. Those participants tended to behave and interact with the therapist in a formal manner. However, from our observations, there is no evidence to suggest that the formal behaviour observed in ACT condition reduced the sense of trust or the positive responses and attitudes of participants toward the VR therapy. As participants said, the ACT+ET condition proposes a novel way of introspection.

> *"I think during the ACT therapy [. . .] the participants were behaving more [. . .] let's say more formally. They were behaving similarly to face-to-face therapy. This time I had just one role, I was their therapist. [. . .] And they were taking their time to form their phrases correctly, [. . .] they were less spontaneous"* [Int: T4, 11].

> *"Please allow me to move into the virtual space so as to have a full view of all the virtual world" [Obs: P12]. "In general, the VR helped me to recognise my emotions toward myself. It made me think about my values and the important things in my life but in a fun and entertaining way"* [Int: P11, 11].

Therapist Representation. In the virtual environment, the therapist was presented as a computerised cartoon avatar and not as a realistic human figure. This was a design decision made during the iterative co-design process, where the therapists believed that MUVR design needs to ensure the sense of emotional safety in the participants for the therapy to be successful. Indeed, the therapists observed positive reactions in regard to their appearance by the participants, while the participants confirmed the above option. This further creates a virtual therapeutic milieu which is positive, and is based upon trusting relationships, potentially leading to better outcomes.

> *"Well, I was positively impressed by the participants' reactions. Some of them were initiating the talk as if I was not their therapist, or even a human-being. One of the participants actually said to me: Oh, you are so cute!"* [Int: T6, 13].

> *"It was easier to express my feelings because the therapist was just a cute cube, she had no human face, and therefore she could not judge me. It was like talking to myself. I could be myself without feeling*

> *threatened, without being worried about what she is thinking about me. I feel that this was the most important part of this psychotherapy. I was free to be myself. I was free to be my ideas. I was free to be me. If the therapist was standing next to me, I wouldn't be able to express my emotions, my worries, my concerns. I would have been more reserved"* [Int: P13, 13].

6.5 Discussion

The key motivation for this study was to investigate the potential for using VR to support MUVR remote psychotherapy. Our results showed that MUVR can be an effective tool for the treatment of ED symptoms. We found that the participants reacted positively to the virtual therapy reporting reduction in the occurrence of troubling thoughts. We believe that future studies need to validate the sustainability and the long term effectiveness of the findings as previous research showed that most participants regress to worrisome thoughts that can lead back to the development of ED (Ben-Tovim et al., 2001).

In terms of design challenges and opportunities for MUVR, our results point to the importance of the high level of presence and immersion of the VR system. This is in line with previous research that suggested that VRET can create an emotional and intensive experience. Past research indicated that if the participants could experience the virtual environment as if it were real, and the therapist would be able to intervene and regulate their emotional responses, this could result in improvements on the outcomes of the therapeutic session (Eichenberg & Wolters, 2012; Botella, Osma, García-Palacios, Quero, & Baños, 2004; Gregg & Tarrier, 2007; Glanz, Rizzo, & Graap, 2003; Tarrier, Liversidge, & Gregg, 2006). It is important to highlight that previous studies only looked at sessions where the therapist was in the same physical space as the participant. Our study showed that the participants were able to communicate their emotional states effectively with the therapist via MUVR even without being in the same physical space, and without having met the therapist face-to-face before. In some cases, participants indicated that this was an advantage as it removed any feelings of being judged by a therapist for their appearance, and thus allowed them to express themselves more freely. Similarly, the therapist was not only able to interpret participants' emotions correctly but could also respond effectively. This may be in part due to people's general familiarity with online communication in recent years stemming from the popularity of technologies such as Skype.

As hypothesised, MUVR may present with the advantage of providing patients with an anonymous non-threatening and non-judgemental platform to communicate their inner thoughts and feelings, without removing the availability of a real therapist. Therefore, MUVR can be an alternative and a more advanced solution to other therapeutic modes of delivery, such as telephone-based therapy, which demonstrated effectiveness in the past (Simon et al., 2004; Mohr et al., 2005; Brenes et al., 2011). I believe that MUVR could be potentially even more beneficial due to the immersion of the participant in a virtual safe space, an aspect that cannot be easily simulated by other digital technologies such as telephone and video conferencing. However, this is something that will need to be examined in the future in a large-scale study along with the effectiveness of this approach for dealing with Eating Disorders and other mental health concerns.

Furthermore, it was noted that the effectiveness of remote communication was enhanced through establishing a friendly relationship via informal and playful collaborative activity in MUVR. The importance of this finding should not be understated since a plethora of research has shown that empathic responses towards negative feelings (e.g., sadness) are of major importance for patient recovery (Gladstein, 1984; Hackney, 1978; Marcia, 1987; Ellis, 1962; Luborsky et al., 1986; D. D. Burns & Nolen-Hoeksema, 1992; Paul & Beernink, 1967). Our findings suggest that a well-designed VR can facilitate a friendly and playful discussion enhanced by PT interventions, allowing the participant to express her emotional concerns freely, and enabling the therapist to support and understand participants effectively.

The positive effects reported in the study can also be attributed to the sense of trust and security the participants felt throughout the virtual session. Previous studies that examined telehealth reported similar trends (Mohr et al., 2005; Brenes, Ingram, & Danhauer, 2011). Specifically, research has shown that blind telephone counselling could not only improve patient mental health but could also benefit patients with depression more in comparison to face-to-face care (Simon, Ludman, Tutty, Operskalski, & Von Korff, 2004). It was found that the therapeutic alliance between the therapist and the patient during the telephone therapy was particularly high, resulting in subsequent improvements in depression symptomatology (Beckner, Vella, Howard, & Mohr, 2007). I believe that MUVR could be potentially more beneficial due to the immersion of the participant in a virtual safe space, an aspect that cannot be easily simulated by other digital technologies such as telephone and video conferencing.

It was found that the sense of security and trust was an important component of MUVR therapy, not only between participants and the therapist but also between the participants and the VR system. It was observed that when VR therapy was enhanced by PT and game elements, participants behaved more spontaneously, had more fun and were more willing to continue with the virtual therapy. Expectedly, and as PT reports (Schaefer, 2003), personal interests play an important role, since some of the participants preferred low energy tasks such as painting while others engaged better with active tasks such as basketball. We suggest that personal interest should be taken into consideration when designing a virtual session.

Furthermore, the study shows that the virtual representation of the therapist was important. We used a cartoon-like cube to present the therapist to the participants, which turned out to be a successful approach. Participants claimed that a human figure connotates judgemental behaviour, whereas a cartoon-like representation is less stressful. This further enhances the feeling of trust and a positive relationship between participants and therapists. Therefore, designers of VR remote psychotherapy should not only focus on the virtual presentation of the VE, but also on avatar design of the therapist. Animated cartoon-like virtual elements, as opposed to photo-realistic representations, should be considered by designers so that anxiety and negative biases regarding body image arising from reality can be reduced. Similar observations have been made in previous research showing that the view of animated cartoons reduced stress and anxiety in clinical environments (Cohen et al., 1997).

However, the potential negative side effects of presence brought by the VR technology should be taken in account, as the phobic reactions among some participants were observed, especially those with a high level of anxiety. Previous research suggested that phobias, anxiety and the level of presence are correlated. Indeed. Past research has shown that high presence can increase anxiety in highly anxious individuals (Robillard, Bouchard, Fournier, & Renaud, 2003), since presence considers to be a psychological state in which the person is not able to vitalise the experience (Lee, 2004). It is, therefore, possible that the increased level of anxiety and the phobic reactions of some of our participants during the VR psychotherapy was caused by the high level of presence. In this case, presence in VR may act as a double-edged sword, an issue which needs to be considered carefully in VR design for psychotherapy.

Indeed, both therapists and participants presented with high levels of presence in this study. Even though the participants cognitively knew that this was a VR simulation and not a real-life scenario they tended to behave as if it was completely real (Slater, 2003), which led to the triggering of phobic or embarrassing reactions (e.g., being unconformable to remove the avatars' cloths during exposure). Interestingly, despite strong feelings of stress or fear, none of the participants chose to end the session prematurely and instead proceeded to complete the whole MUVR trial. This can in part be attributed to the degree of social presence experienced. Social presence via a communication medium has been defined as the degree of being present and able to determine the way people interact and communicate (Lowenthal, 2009). Overall, presence in VR may result in different consequences, an issue which needs to be considered carefully in VR design for psychotherapy. For purposes of exposure to ones' worries about body shape and size however, the ability to exhibit anxious reactions and feel like that the VR situation resembles real-life (high levels of presence), may have the effect of enhancing new learning and thus have the potential to result in greater effectiveness (Craske et al., 2014).

Finally, the research team acknowledge that the effectiveness of a MUVR in remote psychotherapy depends on the requirements of the participant population. Different design factors were found to support highly anxious participants and those who are less anxious. To overcome this challenge, some information regarding participants' personality and background should be investigated before the VR session can be suggested for collection. This will allow the therapist to identify the specific needs of each participant so as to personalise the therapy experience in MUVR.

6.6 Limitations

Being the first study on using MUVR system, this study was primarily concerned with examining the feasibility and acceptability of the MUVR approach. The researcher team have explored the more qualitative aspects of the results so as to highlight the users' experience with this approach. However, a primary limitation of this study is the absence of inter-coder reliability check in qualitative analysis. It is clear that a relatively small sample and the absence of inter-coder reliability check does not allow for examining the effectiveness and reliability of this approach. More data need to be collected so as to be able to actually talk about the acceptability and especially the effectiveness of this type of intervention.

In addition, despite all therapist were given a set of questions and instructions for each of the psychological tasks, it is impossible not to take into account the various potential deviations from the scenario that could affect the results. Furthermore, the experiment was conducted in a controlled location. Conducting subsequent experiments in the psychologists' office and participants' home as well as with the participation of more psychologists will allow seeing a bigger picture of the results. A larger-scale study with more participants and qualified therapists should be conducted.

It should also be noted that participants were asked to express whether they prefer face-to-face or MUVR intervention; however, prior experiences with therapy were not assessed. Thus participants may not have had direct experiences to be able to choose face-to-face over MUVR. All these lead to the need for future research to examine the application of MUVR, using psychology inventories.

6.7 Conclusion

To conclude, the work presented in this study provides a foundation for future research related to MUVR psychotherapy, going beyond current work, which tends to focus on single-user VR or co-located VR therapy experience. Crucially, we identified some key design issues, pointing to the benefits and potential pitfalls of using MUVR in real-world therapy sessions. Apart from ensuring a high level of usability design of the system, designers of MUVR need to: (a) consider conflicting design requirements on VR presence/immersion, (e.g. high level of immersion for more effective participant-therapist relationship building vs anxiety-inducing immersive world), (b) balance private and social space design in VR to ensure that participants can feel safe with emotion disclosure and at the same time feel secure knowing the therapist is “there” with them when needed, (c) design an activity based on the principles of PT which helps strengthen the bond between therapist and participants without undermining the therapeutic benefits of VR, (d) VR design needs to accommodate for different participant preferences and therapeutic needs, allowing the therapists to customise the therapy pathway as they see fit. Finally, we believe that what we found in the context of ED can be potentially translated to other mental health treatment, provided that the characteristics, preferences, and skills of participants are being taken into account.

Chapter 7

Discussion and Conclusion

This thesis presents the results of a series of studies carried out to expand knowledge of the co-design process of VR applications for psychological interventions. The findings of these studies are summarised in this chapter. Based on these findings, a set of guidelines for designing VR applications was proposed to effectively deliver VR psychotherapy. This set of guidelines allows for all relevant stakeholders and representative users to engage in a co-design process for the development of a VR system.

In this chapter, the results of the studies, alongside reference to the research questions they set out to address, will be discussed in greater detail. The first part of this thesis focuses on understanding the co-design and technical challenges of the development of the mobile VR applications. For this purpose, two case studies (Chapters 3, 4) will be discussed. In the second part, focuses on the more advanced VR system development to assess the potential for the application of remote VR therapy (Chapters 5, 6). This chapter is broken down into 4 sections: Section 7.1 addresses the research questions; Section 7.2 describes the set of guidelines on the co-design approach and practical use of VR applications is provided; Section 7.3 describes the contribution of this thesis for researchers and practitioners; and Section 7.4 discusses the potential future work.

7.1 Research questions addressed

Overall this thesis has addressed four research questions:

1. *Why is a co-design approach important for designing effective psycho-therapeutic VR applications?*

   Due to the popularity of VR in recent years, many researchers in psychology may now have a certain amount of knowledge of VR systems; some may have seen demonstrations or tried on an HMD. Fewer, however, have set up VR projects as they require specific technical knowledge. In such cases, co-design can be utilised very effectively. Co-design enables all stakeholders to be part of the design process allowing them to mutually benefit from the expertise of all members of the research team. In our study, for instance, the psychologists had little knowledge about VR systems and their application design and were more accustomed to using specific psychological software, e.g. E-Prime[1] for the development of the 2D flat screen applications.

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[1] https://pstnet.com/product_category/connect-to-eprime/

In comparison with flat-screen PC-based psychological applications, VR application development has additional technical challenges which require rectification in order to deliver usable VR experience. A translation of an existing psychological intervention into a VR form is likely to require a considerable amount of knowledge of the application design and development. The translation of the same intervention into an E-prime application, for example, would require less effort due to the familiarity of this software to many experts in this area. 3D environment is synthesised as a compilation of 3D objects which are rendered in real-time. Rendering engines have technical limitations, and poor optimisation can lead to consequences in terms of VR experience, as well as the run of the application. Therefore psychologists alone are unlikely to be able to perform such tasks. The co-design approach would help with the correct translation of the intervention into a VR application and its necessary optimisation.

On the other hand, developers who receive recurrent feedback and guidance from the specialists in the area of psychology stand a much better chance of developing an application that satisfies the requirements of the therapy. Incorporating end-users and clinicians in the early stages of the design process can also result in the potential improvement of the design. The feedback received from end-users can be reflected in the process of designing and developing of the VR application and can help reduce negative effects such as, for example, psychological barriers of using VR. Additionally, clinicians can interact with patients on a daily basis and assess the problems they are facing should there be any. This information can be forwarded to the developers who can reflect it in the application. The end-product can, therefore, be more user-specific and thus clinically effective.

Moreover, VR experience differs greatly in navigation, interaction and information display as it happens in a 3D virtual space. Therefore, co-design can play an important role in helping to ensure that VR can be designed to not only provide good user experience but also remain clinically and scientifically relevant to their flat-screen counterparts.

Interaction. On a 2D flat screen application, interaction between user and application is typically provided via the WIMP (windows, icons, menus and pointers) interface design regime with the use of mouse and keyboard. Unlike 2D applications, the interface design elements of VR have not yet been standardised in the same way conventional flat screen UI has. In addition, the interaction in VR is more complex and is carried out via spatial user interaction (hand tracking, gesture recognition, pointing, gaze direction) using different types of physical controls (controllers, joysticks, data gloves) and virtual controls (3D objects in VE) (Mine, 1995). Manipulation and selection of virtual objects as well as UI interaction is different from 2D flat screen applications and has its own implementation issues that need to be taken into account during the development. Different interaction techniques can be applied depending on the tasks that need to be performed. The co-design approach will allow to minimise the usability issues in VR.

Navigation. Navigation in 2D and VR applications is also fundamentally different. 2D-flat screen applications have 2DOF (two-axis motion). In VR, the addition of a third dimension increases the DOF parameter from 2 to 3 or 6DOF (see Section 2.1.2). The locomotion in a 2D application for users is usually done via the input devices (mouse, keyboard), whereas in VR, he or she uses his own body to perform the actions. There are different design methods to facilitate navigation in VR, such as synchronisation between physical and virtual movements; other methods may include special gestures or actions (see Chapter 5). VR offers great possibilities in navigation, unlike conventional flat screen applications. Poor navigation design can affect users' experience, cause physical harm for them and can lead to damage the equipment and/or the real-world environment (Santos et al., 2009). Using the co-design approach can help avoid issues with navigation. During the application design, the developers can offer different solutions and methods of navigation depending on the preliminary conditions.

UI. VR applications have much greater flexibility in terms of displaying information than 2D applications. HMDs allow displaying new visual perspectives which the user can scan through by moving his/her head in 360 degrees (Wann & Mon-Williams, 1997). As VR adds depth to the user interface, this allows the developers to layer information. There are options to make the information appear fixed or follow the movement of the user's hands or head. These qualities allow for more information to be presented for the users but also require a systematic design for such interfaces. Poor UI design can lead to visual fatigue and/or ineffective interaction as the users switch between unsystematic UI elements (Gupta, 2004). Moreover, the appearance of information can vary greatly in a 3D environment. This is due to such factors as the position of the user in 3D space and/or hardware specifications of the VR system, such as FOV of HMD (see Section 2.1.2). These variations in information display must be addressed by the designers by the proper selection of menu dimensionality and the UI design that compensate for limitations in the current technology (Mine, 1995). Thus, the co-design approach can help to design of information visualisations for psychological VR applications.

It becomes obvious that for designing an effective psychological VR application, a collaboration between developers, designers, psychologists and other stakeholders is of utmost importance. The co-design approach adopted in this research has made the application design process more efficient and productive, as well as improved the outcomes for the VR applications and helped to bridge the gap between the members of the research team.

2. *What are the potential benefits and challenges of using mobile VR tools in psychological treatment?*

   Currently, mobile VR is the cheapest way for consumers to immerse themselves in VR; there are many mobile devices that support VR as well as VR glasses which are available at a low cost (see Chapter 2).

   The results from the study on anxiety disorders (see Chapter 4) showed that mobile VR-CBM-I training had significantly higher levels of perceived presence, immersion, control, emotional and cognitive involvement compared to a standard training on a flat-screen. Additionally, the experiment for pain management (Chapter 3) revealed that mobile VR can provide high enough levels of immersion that can help reduce the level of perceived pain. This means that modern mobile VR technology could achieve a comparable level of immersion as more advanced PC-based VR systems, and provide the advantage of portability and cost-effectiveness at the same time (Buttussi & Chittaro, 2017). This, in its turn, can lead to wider adoption of mobile VR tools.

Therefore, given the recent advances in mobile technology, mobile VR can now be seen as a viable platform for traditional psychological interventions. Mobile VR offers possibilities for the creation of easy-to-use, customisable applications that can be designed and adapted in the real-life context of the patients to meet their needs, for example, real-time monitoring and assessment of psychological stress (Gaggioli et al., 2014; Pallavicini, Algeri, Repetto, Gorini, & Riva, 2009; Wiederhold & Riva, 2008). As these studies have shown, the ability to exercise with the help of therapists in real life has several functions. Firstly, the execution of CBT tasks needs to be studied and repeated over time for proper application and effectiveness. The use and availability of VR outside the therapy room play an important role in speeding up the learning process and achieving clinical results quicker. Secondly, due to everyday life situations, a person may experience spontaneous emotions of fear and anxiety. In these cases, VR can act as a portable device to deal with stress through relaxation exercises. The most suitable device for this, which meets the technical requirements for immersion in VR and at the same time is portable and easily accessible, is a mobile phone. By utilising widely available low-cost mobile VR devices, an effective VR training/therapy platform could be provided which can be accessed by a large number of patients whenever required.

In comparison with PC-based VR systems, mobile VR can be a preferable option for certain types of psychological interventions. In treatments where a high degree of interaction between user and the VE is not required (e.g. studies with simple observation of VE), it is economically viable and considerably easier in setting-up to use a mobile VR system. Using mobile VR can also be advantageous in situations where the physical activity or additional equipment is required. When using a PC-based system, the wires connecting the VR equipment to the computer can interfere with the therapy objective. For example, the pain management study required to hold additional sports inventory in a gym environment. Using wired headsets and controllers was therefore highly inconvenient. In addition, in certain circumstances, it is not possible to use bulky equipment, such as the treatment of vulnerable patients (Tabbaa et al., 2019); this is another area where mobile VR offers solutions.

This evidence proves that mobile VR has the potential to be seen as a viable and highly promising platform for traditional psychological interventions. By utilising widely available low-cost VR devices, an effective VR training/therapy platform could be provided which can be accessed by a large number of patients whenever required.

The main challenge of using of mobile VR for psychological therapy is the lack of controllers and other input devices. The VR systems, where a smartphone is used as a display, are capable of tracking the rotation of a user's head and can provide an option of one hand tracking. In the pain management study (see Chapter 3), to overcome the absence of hand tracking controllers and specifics of the exercise task, an additional device (Microsoft Band) and software (Microsoft SDK) were integrated into the system. Doing so, however, can lead to another disadvantage as adding extra tools and devices puts pressures on the mobile phone CPU, which can result in overheating and a decrease in performance. In the anxiety disorders study, a similar issue was noted. During the testing of the prototype, the 3D environment had not been optimised sufficiently, which resulted in a jittering effect and overheating of the smartphone. Further optimisation allowed to overcome those issues. Thus, in views of long term usage, the performance of the mobile phone has to be taken into consideration as was shown in both pain management and anxiety disorders studies.

3. *What are the benefits and design challenges of remote multi-user VR psychotherapy?*

   Based on the eating disorder study (Chapters 5 and 6) a number of benefits and design challenges of remote MUVR psychotherapy can be identified.

   One of the features of the developed MUVR system was the use of animated avatars. The use of avatars in MUVR psychotherapy provides a degree of anonymity and security for participants. Anonymity allows participants to feel safer and makes it easier for them to open up (Stephen et al., 2014). By not exposing their real appearance, participants might feel more at ease, knowing that they are not judged by their looks. The study by Garau et al. (2003), demonstrated that computer-generated avatars have a very strong influence on how people react to each other in VE. Many psychotherapists are reluctant to conduct remote psychotherapy with patients via a video conference due to the nature of this method not allowing them to convey warmth, empathy and understanding. Most of the practitioners are concerned it would therefore not be possible to build a therapeutic alliance in a video-conference, even less so, a strong therapeutic bond (Rees & Stone, 2005). However, the positive effect of blind psychotherapy (i.e., remote technology-based therapy in which the patient and the therapist are not in the same physical space) has been documented by studies that examined blind telephone counselling and found that adherence rate is significantly higher than face to face sessions (Simon et al., 2004). Whether or not it's the same for VR is debatable.

   I believe VR can do more than telephone-based therapy. The previous research examined the impact of agents and avatars on the level of social influence in VE (Fox et al., 2015). It was found that cooperative tasks enhance the effect of agency as opposed to neutral tasks. In our eating disorder study, we found that in a remote shared VE, the inclusion of additional activities such as play therapy (PT) helps to strengthen the bond between therapist and patient without undermining the therapeutic effect of the treatment.

   Additionally, MUVR can also be developed to cultivate of trust between participant and therapist through generating a strong feeling of social presence. This is a critical requirement for establishing a long-term therapeutic alliance (Gaggioli, Gorini, & Riva, 2007). Enabling both participant and therapist to appear in the VE simultaneously and with convincing user representation can generate a feeling of social presence. In the eating disorder study (Chapters 5 and 6), the VR application supported a voice chat which provided real-time communication between participants and therapists. The avatar's facial features were synchronised with the speed of speech (facial lip sync). Additionally, the application supported the acoustic replication of voices in proximity, enabling them to be recognised in a 3D space. This made the avatars look and feel semi-naturalistic and thus increased the sense of social presence.

Although the system supported voice communication in a shared VE, many social interaction signals were absent, such as body signals. Some studies (Yee, Bailenson, Urbanek, Chang, & Merget, 2007; Guye-Vuillème, Capin, Pandzic, Thalmann, & Thalmann, 1999) show that although nonverbal communication is sometimes used in VE, it is not as common as it is in face-to-face communication. For example, turn of the gaze in the direction of your interlocutor or other facial non-verbal expressions. With the development of VR technologies, the use of non-verbal signals could allow to increase the sense of presence and social presence.

The MUVR system developed during this research, combines a high degree of presence with a social presence, due to the notion that a sense of presence and social interaction reinforce each other. The research showed that these two phenomena (presence and social presence) are always interrelated, but there is not enough research that would compare a number of settings between them to study this issue (Schroeder et al., 2001).

Lastly, the VR design needs to accommodate different patient preferences and therapeutic requirements, enabling therapists to adjust the therapeutic process accordingly. Customisation of the avatar representation is also advantageous. Participants can select and customise their own avatar, providing them with a sense of control in a clinical setting that can significantly reduce stress (Won et al., 2017). In the near future, it may be possible for the avatar to incorporate computer-generated imagery with real-time images of users. This could further increase the avatar's level of realism. In the eating disorder study, both avatars were created in the form of a cartoon-like style. According to the previous research (Cohen et al., 1997; Lee et al., 2012) and users' feedback from eating disorder study, this design feature proved to be effective in reducing anxiety levels. Previous research has also found that users may choose an avatar that is neither too abstract nor too realistic. It is therefore too early to say how much avatar customisation will, in fact, be required by users (Cheng, Farnham, & Stone, 2001).

During the customisation process, clinicians would have an opportunity to tailor therapy in order to either find out the necessary information about participants or to be able to guide the participants conform their behaviour to their preconceptions about the avatars they embody (Fox, Bailenson, & Tricase, 2013). Customisation of the current MUVR system does not include a lot of application customisation options that will allow therapists to adapt to different types of psychological interventions. The development of the additional 3D libraries and capabilities for MUVR could possibly allow to provide practitioners with a wider range of treatment.

4. *What design guidelines could be derived for the co-development of VR applications in psychotherapy?*

   This question was addressed through the lessons learned from the co-design process of three VR projects, reported in Chapter 3 and Chapter 5. Based on the comprehensive studies that were carried out, this thesis proposes a co-design and development process with the aim to address the lack of methods or frameworks for developing psychological VR applications. A three-phase set of guidelines is presented, which addresses the important stages that should be considered during the development of the VR application for psychological interventions. The proposed guidelines (see Section 7.2) inform both designers and psychologists on the steps they could follow and key issues to consider during the design process. The main phases include a) Cross-disciplinary information gathering and exchange, b) Prototyping and testing and c) The pilot testing of the application. This co-design guideline was used in designing and development of VR applications for anxiety disorder, pain management and eating disorder, in collaboration with target users, clinicians and psychologists. The VR applications developed during this research resulted in the reduction of students' anxiety levels, helped increase exercise performance and reduced muscle pain in participants. It also showed great promise in the prevention and reduction of ED symptoms amongst young women.

7.2 Guidelines for VR application development

VR technologies are becoming a popular and potentially safe alternative in the application of psychological treatments. Due to the increasing application of VR systems, it becomes necessary to advance the existing design methods and provide a set of guidelines for the development of VR applications. This section combines the results and lessons learned from the three studies to provide a generalised co-design methodology on how VR applications could be designed for psychological interventions. The proposed VR Application Co-Design Guidelines consider the software components, networks and interaction tools, hardware and iterative testing with the stakeholders. Both researchers and practitioners could hopefully benefit from this guidance for designing systems for experimentation's or deployment.

Based on the results of the three studies, a three-phase set of guidelines is proposed for the design and development of VR psychological interventions:

1. Cross-disciplinary information gathering and exchange process phase, which focuses on sharing the expertise knowledge among stakeholders and brainstorming the design ideas for therapy translation into VR.
2. Prototyping and testing phase, which focuses on the content development by working with representative users and psychologists.
3. The Pilot phase which conducts early testing of the application in the experimental/clinical environment.

The co-design guidelines presented here highlight issues and considerations specific to VR and psychological interventions, with a potential to be generalisable to other VR application domains.

7.2.1 Cross-disciplinary information gathering and exchange process phase

During this research, three stages that are crucial to cover in this phase were identified. These aspects are summarised on the Figure 7.1: 1) Pre-design introductory stage, 2) Selection of Equipment and Gathering of User Data and 3) Design Ideas and Translation of Therapy. The purpose of this phase is for the research team to share the knowledge about different psychological treatments and capabilities of VR technology, identify key elements of the treatments that need to be transferred into VR and select the appropriate hardware. VR designers and developers should aim to gain an in-depth knowledge of the psychotherapies that the applications will be based on. To achieve this, initial meetings with psychologists and other clinical personnel may be organised. These meetings are meant to help the designers and developers understand the characteristics of the target psychotherapy treatments and specify the system requirements. The design of the VR system will be discussed in collaboration with members of the research team. For example, during the studies that were presented in this thesis, the research teams required several numbers of meetings in order to gain knowledge of the intervention/therapy and identify the design aspects of the application. All these stages will be covered in depth.

Figure 7.1: Cross-disciplinary information gathering and exchange process phase

7.2.1.1 Pre-design introductory stage

The main objectives of this stage are to share knowledge about the technology and therapy among the research team members and determine the psychological intervention that is going to be transferred in VR. Table 7.1 demonstrate the objectives and provide ways how to achieve them.

Who is involved	Objectives of the meeting	How to achieve
All members of the research team (e.g. designers, developers, HCI experts (hereafter referred to collectively as technologists), psychologists, clinicians)	Gain knowledge about VR technologies and psychological therapies	Designers and developers should introduce and present the capabilities of VR technologies. Technologists can use off-the-shelf applications to demonstrate navigation and interaction techniques as well as different VE's
	Determine the intervention that needs to be transferred into VR	Psychologists and clinicians should describe and/or demonstrate the interventions they use in practice or the therapy that has been chosen for translation into VR. This could be done by video recordings, existing web based platforms and protocols, and real-life demonstration of therapy in practice

Table 7.1: Objectives of the Pre-design introductory stage

During the first meeting, the designers/developers demonstrate the possibilities of VR systems for the psychologists to familiarise themselves with the technology. Standard off-the-shelf applications could be used for the demonstration purposes which are available to purchase from the online application stores (e.g. Oculus App store, etc.) or examples of the developers previous VR projects. Based on these applications, different versions of environments (3D generated, media environments), interaction and navigation techniques could be demonstrated to psychologists/clinicians. This would allow psychologists to better understand what can be achieved in VR applications. For example, during the first meeting for pain management study applications like Jurassic World: Apatosaurus[2] and Fulldive VR[3] were introduced to show different types of VE.

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[2] https://www.oculus.com/experiences/gear-vr/1096547647026443/

[3] http://fulldive.com/

In return, psychologists could demonstrate current treatments and practices. This is required in order for the technologists to get an understanding of how the treatments work and to identify their most important aspects of them. These demonstrations enable the research team to choose a therapy for which a VR application is going to be built. For example, for the eating disorder study, relevant video materials, the AcceptMe web-based platform (see Figure 7.2), as well as existing protocols based on previous research in eating disorders, were introduced. In addition, a PC-based application for CBM-I training was demonstrated for the anxiety disorders study. Finally, mirror exposure therapy and altered visual feedback strategy were discussed for the pain management study.

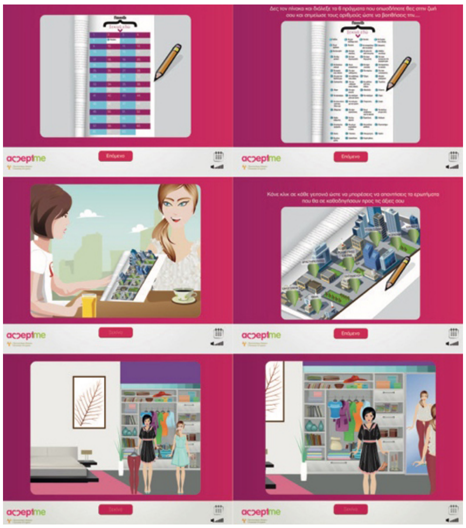


Figure 7.2: Example of the Web based AcceptMe platform from the eating disorder study

Information about the therapy could allow designers and developers to identify the key elements of the intervention required for the VR application. For example, in the pain management study, after demonstration of the Mirror ET designers/developers defined, that hand synchronisation will be required. At the same time, the demonstration of the web-based materials for the eating disorders study helped to identify the psychological tasks that need to be transferred. At the end of this stage, the research team should establish the intervention that needs to be transferred into VR. This could help them to determine the hardware.

7.2.1.2 Selection of Equipment and Gathering of User Data stage

The next stage in this phase includes the gathering of user data and the selection of appropriate equipment. The objectives of this stage are presented in Table 7.2.

Who is involved	**Objectives of the meeting**	**How to achieve**
All members of the research team (e.g. technologists, psychologists, clinicians)	Define the targeted VR device	Technologists can suggest the technology that is suited the best for selected intervention
	Identify target users for the selected psychological intervention	Psychologists should provide detailed information about possible participants (health conditions, age, ethnicity etc.)

Table 7.2: Equipment selection and Participants information gathering stage

Once a certain therapy is chosen, the research team can select a VR system suitable for the treatment. The requirements and conditions of the therapy, as well as target users' data, will determine the choice between mobile and PC-based VR system. In cases where, for example, the level of interaction between user and VE is minimal, environmental restrictions are put into place, or users have limited abilities and use of bulky equipment is not recommended, it may be advisable to use mobile VR. For example, using a PC-based VR system in a gymnasium or fitness centre could be difficult as these places have limited space and are generally busy and therefore may not have enough room for the system setup (see Chapter 3). Environmental restrictions pose a problem in places where the physical structure of the building has to be taken into account. In a hospital environment, for instance, carrying cumbersome equipment can be inconvenient and hazardous; in such cases, the use of mobile platforms can be advantageous (Tabbaa et al., 2019).

Careful consideration of target users' information is another important aspect of VR application design. Lack of such data is one of the most common factors that result in the failure of digital interventions (Granja, Janssen, & Johansen, 2018). During the three studies carried out as parts of this PhD research, the information regarding target users' age, gender, ethnicity and health conditions was taken into account and reflected in the design of the developed applications. The application which has been developed to accommodate specific qualities and attributes of the user is likely to be more user-centred and thus result in a more effective treatment.

For example, due to the eating disorder study taking place in Cyprus, the spoken language was taken into consideration (Greek). All verbal information visible in the VE, as well as written instructions for the participants, were translated for the ease of use of the application. Information about participants' physical and mental health also plays an important role. For instance, having patients in the study who exhibit behaviour that challenges, could not only affect the choice of the VR system but also put some restrictions in terms of interaction and navigation mechanisms (Tabbaa et al., 2019).

Information about users' previous experience with VR systems can also be useful. The eating disorder study showed that for people who had never experienced VR before it was difficult to memorise the controls and buttons. For this reason, an additional tutorial scene was created. The tutorial scene included instructions and a number of tasks so the users could familiarise themselves with the application. Additionally, the design of the virtual controllers was adjusted. Different colours for the buttons of the virtual controller were used to help users memorise the corresponding actions.

7.2.1.3 Design Ideas and Translation of Therapy stage

Table 7.3 presents the last stage of the Cross-disciplinary information gathering and exchange process phase and is used to help researchers translate the selected psychotherapy into VR.

Who is involved	**Objectives of the meeting**	**How to achieve**
All members of the research team (e.g. technologists, psychologists, clinicians)	Translate the proposed psychological intervention tasks into VR	Identify the main tasks of the proposed intervention and brainstorm the design ideas on how to translate those tasks into VR (required actions, environment design etc.) Discuss requirements that could affect the design of the application (specific equipment, interaction techniques, clinicians role in the intervention)

Table 7.3: Objectives of the Design Ideas and Translation of Therapy stage

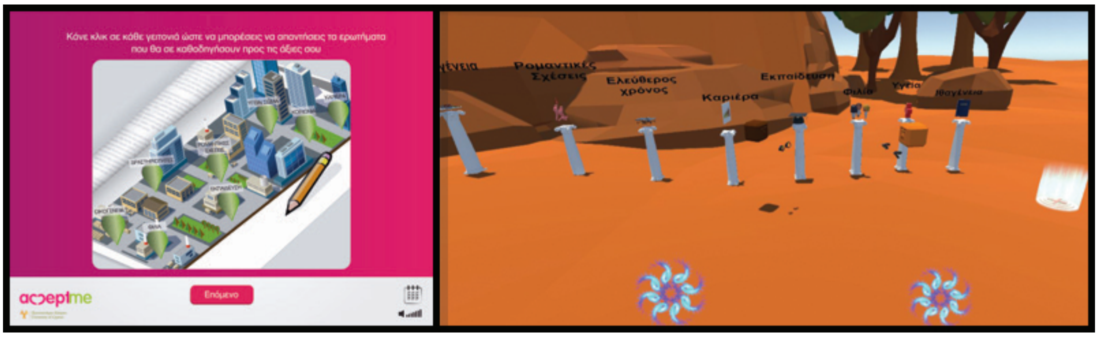
Identification of the tasks and brainstorming the design ideas.

Once the equipment has been selected, and the target users identified, the psychologists should assist the developers in providing a protocol for the experimental session. The developers should discuss the protocol tasks with the psychologists to translate the current therapy into a VR application. Psychologists, designers and developers should work together to define the elements of the VR interaction mechanisms, interfaces and content. The research team members should brainstorm ideas and make notes or create an online shared document for reference and further discussions on the subject.

The first step in designing and translating of treatment into VR experience is to identify the proposed tasks that VR application should address. Based on the proposed therapy protocol, psychologists should express their views in regards to the tasks they would like to see in the application and the execution of thereof. Meanwhile, designers and developers should analyse those ideas and advise whether or not it is possible to deliver these concepts and what options should be taken into consideration. For instance, for the eating disorder study, the MUVR system was designed to help people to cope with their eating disorders symptoms and accept their body image. The brainstorming sessions with clinical psychologists, HCI experts, developers and designers allowed to identify the design tasks and the ways to translate the 2D design intervention into a 3D one. The main tasks for the system design were: 1) support remote multi-user VR sessions where therapists are actively involved in the VR process; 2) allow participants to perform different psychological tasks where they could interact with information tables and various 3D objects; 3) incorporate VRET where participants would be able to stand in front of a mirror and see their reflection.

To understand how to translate the identified design tasks into VR, the research team should establish for themselves what the user needs to do in order to accomplish the tasks and how he/she can do it (what VR tools are needed). For example, for the first design task of the eating disorder study, a stable network connection and a communication system were required to let users communicate with each other. Photon Networking and the developed Voice communication system were used for these purposes (see Section 5.2). The AcceptMe web-based platform, which was taken as a reference, does not provide any means of communication. The ability to communicate was crucial for the MUVR system. To address this, the research team brainstormed different ideas and decided to develop a voice chat communication system to provide the ability of a real-time conversation, which proved to be crucial for the intervention. There was also a need for some form of controls for the therapist to manage the VR session. For that, an interactive menu was designed to allow therapists to switch between different tasks of the therapy.

The second design task addressed the form of interaction required for the participants to perform therapy tasks. Alongside the discussion of the therapy activities (Value and Life Map tasks), different UI and object interaction mechanisms were suggested to psychologists. Some tasks were agreed to be transferred from the web-based platform as is. However, other tasks could be enhanced to further increase the engagement and interactivity with VR. For instance, there were several brainstorming sessions on how to translate the "Life map" task into VR (see Section 5.1.1.2). The web-based platform provided the user with a 2D map with the values in it. The designers proposed another idea on how this task could be performed in VR. Various modalities were discussed, and the research team arrived to the conclusion that instead of using a ready-made map, it could be more enjoyable for the participants if they could create their own maps with the available 3D objects (see Figure 7.3).



Κάνε κλικ σε κάθε γειτονιά ώστε να μπορέσεις να απαντήσεις τα ερωτήματα που θα σε καθοδηγήσουν προς τις αξίες σου

Figure 7.3: On the left is a Web based AcceptMe platform "Life map task"; On the right the same task redesigned for the MUVR

For the last design task, there was a need to somehow represent the participant in a VE. For this purpose, different ways of representing a human figure in VE were discussed during the brainstorming sessions (see Section 5.1.1.2). One of the suggestions was the use of a mirror reflection as in the AcceptMe web-based platform. It was concluded that, albeit an appealing option, the use of a mirror reflection could be resource-consuming and would require a full-body tracking which the VR system did not provide. As an alternative, a system for avatar customisation was also considered. It was agreed that using a customisable avatar in the form of a 3D model would be a preferable option (see Figure 7.4). The avatar customisation system enabled participants to create virtual representations of their bodies the way they saw themselves; the created avatars would appear it in front of them. In comparison to the Accept-me web-based platform, the customisation system allowed therapists to discuss participants' 'real' body representation as well as their desired 'ideal' body. It led the research team to create an immersive experience without compromising the protocol of the intervention.

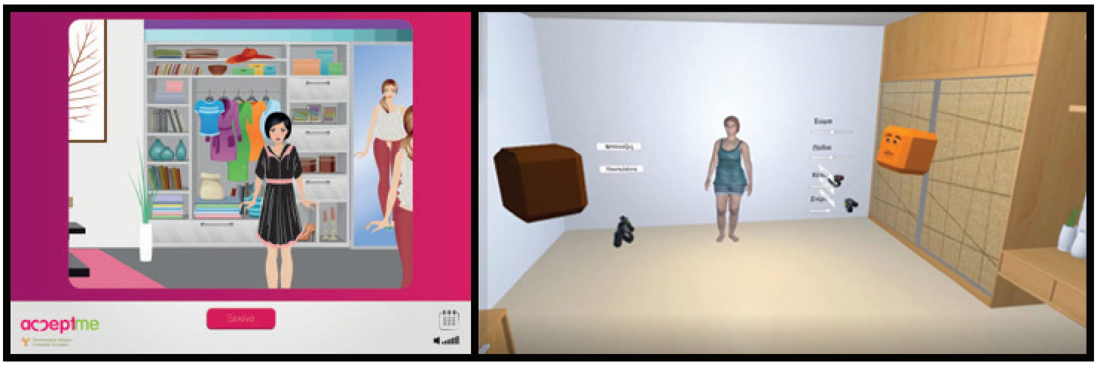


Figure 7.4: On the left is a Web based AcceptMe platfom "Mirror ET"; On the right the same task redesigned for the MUVR

In our studies a number of proposals had to be turned down due to their impracticality. As a range of ideas are generated, some of them might be overambitious, like the idea with the mirror reflection, whilst others seem more feasible. The ability to think through and discuss these matters collectively is, perhaps, why brainstorming offers such valuable opportunities.

Therapists' and researchers' involvement in VR intervention. Depending on the aims of the VR intervention, the research team should decide whether or not therapists should be inside the VR with the participant. Therapists' involvement in the process can be active or passive, i.e. plain observation. For example, for the pain management study, a special control panel was integrated into the application to assist the therapist, who was actively involved in the process, with the setup and troubleshooting of the application. The control panel enabled the therapist to prepare the application so that the participant was unaware of the difference between the real and virtual weights. In addition, it provided information on any device connectivity issues if those appear (see Section 3.1.6). In the eating disorders study, the therapists were also actively involved in the therapy process. To let participants and therapists communicate remotely in real time, a voice chat system was created in the MUVR application, and additional controls of the application were provided for the therapists. Whereas, the anxiety disorders study did not require any setup or interaction between the researcher and participants while the latter performing required tasks. The researcher, in this case, was a passive observer.

The role of clinicians within VR interventions is still important. There is no doubt that with the development of these technologies, it would be possible to further equip healthcare professionals with the tools required for assisting patients (Tabbaa et al., 2019). It would be possible to provide a wide range of therapy modalities, including remote VR therapies. VR systems are not yet sophisticated enough to adjust in real-time to participants' progress and their individual requirements without clinicians' assessment (Levac & Galvin, 2013). It is clear that at this level of development, VR systems serve as a tool and require clinicians' decisions in terms of therapy setup and its progression. Even if a VR session does not require clinician's active participation, he or she must monitor the interaction and safety, and be able to simplify or advance the tasks and evaluate the results (Levac & Galvin, 2013). For instance, during the pain management study, after the setup of the application, the therapist monitored participants' progress and controlled the safety of the session.

All design ideas suggested for development during the cross-disciplinary information gathering and exchange phase must satisfy the time and budget constraints. After the consultation and consideration of all ideas, as well as the technical and software requirements, the most feasible and appropriate ideas will be put forward for further development. The ideas that are not agreed upon during the consultation can be investigated further during the prototyping and testing phase.

7.2.2 The prototyping and testing phase

The purpose of this phase is to iteratively develop and test the VR application together with psychologists, clinicians and target users in the laboratory conditions. During this phase, the research team will be able to test the design ideas and modify them to correct any flaws and shortcomings should those be revealed during the testing. The use of an iterative development approach could help resolve uncertainties among members of the research team regarding the design, whilst also improving the final application with the help of target users. Figure 7.5 summarises the crucial stages of this phase: prototype development and prototype technical testing, evaluation with test users and identification of possible issues. We will first focus on the prototype development and technical testing stage.

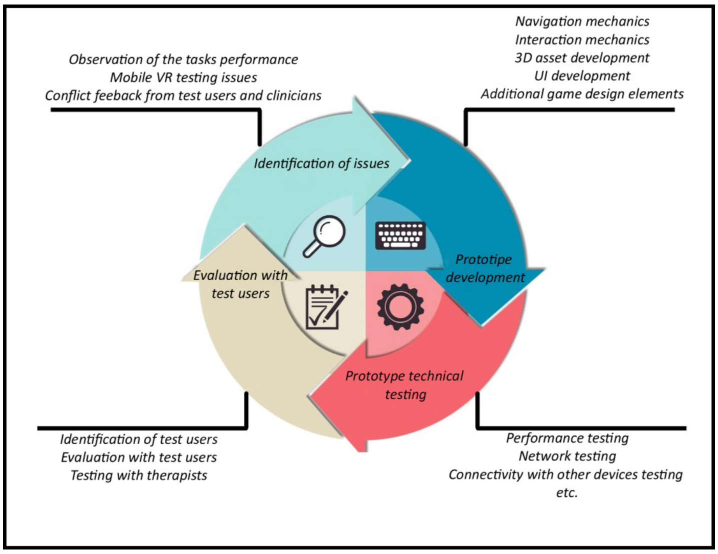


Figure 7.5: The Prototyping and Testing Phase

7.2.2.1 Prototype development and technical testing stage

With the data collected during the cross-disciplinary information gathering and exchange process phase, designers and developers should be equipped with the knowledge related to the discussed design ideas and chosen VR devices. This should enable them to determine the software for the development of VR applications. During the initial stage of the project, 90% of the development work will be dedicated to prototyping of the VR application. Table 7.4 demonstrates the aims and objectives of this stage.

Who is involved	Objectives of the meeting	How to achieve
Developers, designers	Iteratively develop VR application	Identify the prototype development approach Consider game design elements (VE, animation, interaction and navigation mechanisms, etc.) Perform application testing to ensure smooth operation of the system for test users.

Table 7.4: Prototype development and testing stage

Identification of the Prototype development approach.

The literature provides several approaches when it comes to the development of prototypes (e.g. throw-away, incremental, evolutionary, horizontal, etc.) (Van Hemel, 1999). I found that incremental and evolutionary were the most useful approaches when it came to designing VR applications for psychological interventions. The throw-away approach might not be suited as its result would present a rather basic form of the system. A VR application should provide a degree of interaction, navigation, as well as incorporate therapy tasks; neither of these components would be possible to demonstrate using this approach. Due to the complexity of the applications, the throw-away approach is not appropriate. On the other hand, incremental and evolutionary prototyping would allow us to iteratively develop and test the system.

With the incremental approach, the overall design prototype is created as small parts of the system, feature by feature (Van Hemel, 1999). The final prototype is built of separate components merged together, one at a time based on the overall design of the final system. For example, the MUVR application consisted of three main parts: "Value task", "Life map task" and VRET. After the development of the "Value task", the two other parts were built, one at a time, each time complementing the system. The incremental approach allowed to thoroughly test the application with each added task.

With the evolutionary approach, the whole system gets developed at once and is later continuously adjusted and updated, which allows to constantly refine it (Van Hemel, 1999). This approach was used during the development of the pain management application. The main feature of the application (synchronisation of the participant's hand with the 3D model) was developed at once. Afterwards, additional features were added on top such as: therapist menu, weights adjustment, and T-shirt and skin colour customisation.

Drawing knowledge from the areas of Film and Video Games.

The creation of VR applications is very similar to that of video games, rather than, for instance, websites or 2D applications (e.g. E-prime). And although software development for VR is a relatively unexplored area, the history of video games and computer-generated imagery (CGI) film industries exists much longer. For that reason, much insight and practical knowledge could be drawn from the process of creating CGI films and video games, certain mechanisms and design elements of which could be very useful for the development of VR prototypes.

As was mentioned earlier (see Section 7.1) the navigation and interaction mechanisms for VR are different from flat-screen applications and are playing an important role in user experience.

The first aspect is the navigation. During the development of the navigation mechanisms, the designers should consider the environmental restrictions of the target location. There are a number of different techniques to implement navigation in a VE. The simplest way for users to "move" in a VE is by mapping their movement in VR to that occurring in the physical world (Mine, 1995). This method is supported by all PC-based VR systems by default. However, the size of the space in VR can go beyond the physical environment, where the system is planning to be used. Therefore this imposes certain difficulties on the navigation in VE. The distance of the user's physical movement will be restricted by the real-world environment (room) or supported tracking area of the chosen system (see Section 2.1.2). To overcome these issues, different locomotion mechanisms

(Mine, 1995) can be adopted by designers/developers to enable participants to navigate freely in a VE.

The navigation mechanisms for the MUVR system included the Point and Click Teleportation method, which was found to be best suited for the purpose (see Section 5.2.7.1). This method allowed the user to move around the VE whilst physically remaining at the same spot. In comparison with the motion-based navigation (Navigation by Hand method, see Section 5.2.7.1) can sometimes cause motion sickness in users, Point and Click Teleportation did not cause such side effects. In case of motion-based navigation, attention should be paid to different parameters, such as speed, acceleration and the direction of motion (Kemeny, George, Mérienne, & Colombet, 2017; So, Lo, & Ho, 2001), in order to minimise motion sickness, otherwise different locomotion techniques should be applied (W. Chen et al., 2013; Fernandes & Feiner, 2016).

Moreover, previous research showed that navigation performance depends on the environmental difficulty (Bozgeyikli et al., 2016). Depending on the size of the VE and its the difficulty, different navigation mechanisms can be applied. One option of navigation that could be applicable to any kind of VEs is Worlds-in-Miniature (WIM) (see Figure 7.6). Berger and Wolf (2018), studied the application of WIM for navigation in different environments (park, city, building) with different levels of difficulty. The study showed that for a long-distance movement, WIM outperformed both Continuous Motion and Point and Click Teleportation (Berger & Wolf, 2018). The WIM method is similar to that used in video games. An environment of a video game can be quite large. In order for players to move from one location to another, game developers use the "fast travel navigation" elements. When a player opens a new location, it appears on their map, and they can relocate to it whenever they like by selecting the place on the map. An example of this design element can be seen in Assassin's Creed[4] game.

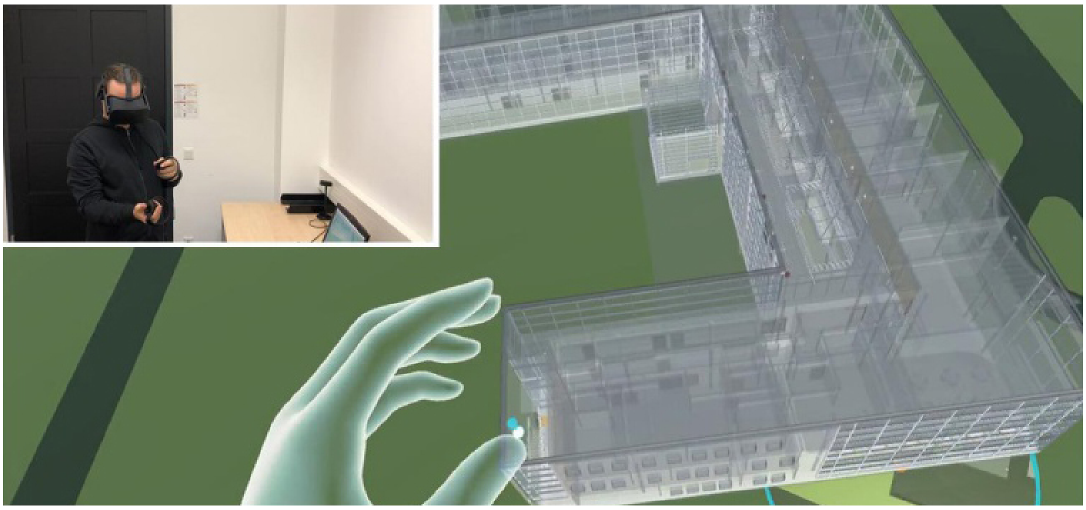


Figure 7.6: WIM navigation using miniature version of VE (retrieved from Berger & Wolf, 2018)

The other aspect is the interactivity. Jaron Lanier describes interactivity in VR as "not just a feature or a quality of VR, but the natural empirical process at the core of experience" (Lanier, 2017). Interactivity in VR has not yet been

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[4] https://assassinscreed.ubisoft.com/game/en-gb/home

fully researched. Its unique properties differ greatly from those attributed, for instance, to the interactivity of Web interfaces. The principles of interactivity and navigation for Web interfaces have been extensively researched and documented. A well-designed web interface allows users to interact with it intuitively (Islam, 2012) and thus can reduce users' cognitive and perceptual burden (Galitz, 2007). There are numerous guidelines regarding the design and development of interactive web interfaces (Chou, 2003; Iuppa, 2001; Khan, 1997). However, there is a definite lack of such studies when it comes to the development of VR applications.

Due to the relatively recent emergence of the technology, the design of interaction in VR is still in its early phase of development (Olszewski, Lim, Saito, & Li, 2016; Sun, Li, Zhu, & Hsiao, 2015). For certain aspects of the design, such as how to guide the user in VE and provide him/her with appropriate feedback, VR designers can refer to the games industry. Rogers (Rogers, 2009) described several techniques that can guide users in the video game VE. Game elements such as music and light can grab the attention of the players as well as different level design elements such as reinforcements and obstacles along the path could also affect the players' movements (Milam & El Nasr, 2010).

In a VE, not all objects will be made interactive. Attention should be paid to the appropriate feedback given to users about the interactive objects, i.e. how a user can understand which object he/she can interact with and which not. There are several ways to provide such feedback (Mine, 1995). One of them is through the use of visual cues. In the eating disorders study, the colour of an interactive 3D object would change when the user touched it with the virtual controller (see Figure 7.7). This enabled users to identify whether or not a certain object was interactive. Other ways of providing such feedback may involve additional visual or haptic feedback, such as the techniques used in game design. For instance using specific colours, sounds or animation, as was done for the "Life Map task" in MUVR (see Section 5.1.1.2), can help users understand what objects they can interact with.

Figure 7.7: An example of visual feedback when interacting with 3D objects in MUVR

Navigation and interactivity are not the only aspects requiring developers' attention. VE's, 3D models and their animation, and other related elements also play an important role in creating pleasant experiences as well as possible therapeutic effects for users.

One more aspect that should be taken into account is visual effects. One's experience of VR through an HMD is incomparable to other visual simulations (e.g.

flat screen) due to the level of presence and immersion this technology provides. High level of immersion and presence can provide a means for influencing participants' emotions and thus potentially result in more effective treatment. However, the content presented in VR can cause adverse effects in certain individuals, for example, an increase in levels of anxiety (Robillard et al., 2003). For that reason, designing an immersive VE has to be done with great consideration. Boosting of the realism can lead to an increase in a user's negative emotional response, such as fear, shock, disgust etc. The challenge for a designer, therefore, lies in finding a balance between the realism of the VE and the effect it can have on users.

During the course of this research, the utilised co-design approach has helped to ensure the developed VE's would suit the requirements of the specific psychological applications. For instance, depending on the therapy task, the psychologists could choose to either include more anxiety-provoking elements in the environment or remove them.

Manipulations with sound effects, textures, lights and shadows (see Figure 7.8) should be taken into consideration as they all have the ability to influence users' emotional state (Riva et al., 2007). Much knowledge regarding these aspects can be learned from the film industry. Thus, when co-designing VR applications for psychological interventions, the research team could refer to the film industry for practical ideas and insights.

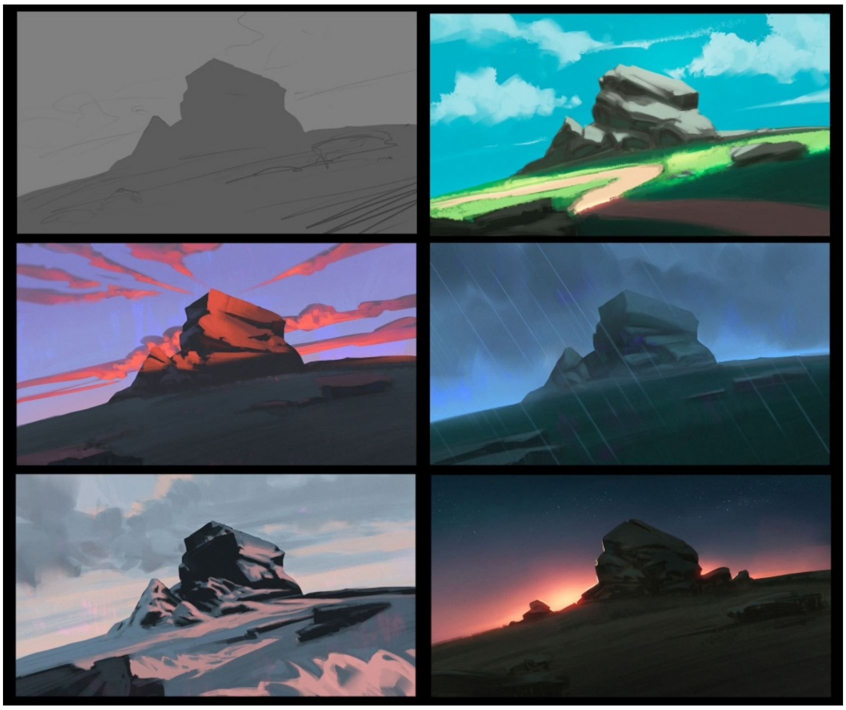

Figure 7.8: An example of environment with different visual effects that could cause different emotions (retrieved from Scuccimarra, 2016)

Finally, designers/developers should pay attention to aspects like motivation and engagement. Other game design elements such as points, badges, performance graphs etc. can also play an important role from the psychological perspective (Sailer, Hense, Mayr, & Mandl, 2017). The feedback function of these elements is directly related to the feeling of competence (Rigby & Ryan, 2011; Vansteenkiste & Ryan, 2013), thereby motivating users to continue using the application. The idea of gamification (Huotari & Hamari, 2012) and use of game design elements that motivate and increase enjoyment/engagement in non-game contexts is becoming increasingly popular (Deterding, Dixon, Khaled, & Nacke, 2011). Psychological experiences invoked by gamification are highlighted in the systematic literature review by Lumsden et al. (2016). Some game design elements, for example, were integrated in the tutorial for the MUVR application to trigger the participant's emotions. During the tutorial, upon completion of the tasks, users were provided with feedback. The positive feedback was enhanced through the use of visual text elements and sound effects (see Figure 7.9). The literature shows that sound can be an effective element for psychological stress recovery (Annerstedt et al., 2013).

Additionally, the studies by Ryan et al. (2016) and Mekler et al. (2017) showed that certain game design elements can influence the enjoyment, future game-playing behaviour and performance of users. Through the understanding of the role and importance of each game design element, it would be possible to design a VR application which would motivate and produce positive psychological effects in users. Thus, when co-designing VR applications for psychological interventions, the research team could also draw ideas and inspiration from the games industry.

Congratulation!!! You have completed this tutorial successfully!!

You can now practice more or take off the headset.

Figure 7.9: The feedback provided during the tutorial for psychologist's and therapist's

Prototype testing by developers To ensure a good run of the system, developers should perform an assessment of the application without test users prior to offering the system for evaluation sessions. Depending on the prototype approach being used, the complexity of the system could vary. Developers must ensure a smooth run of the system after each development iteration. Performance optimisation should be evaluated (see Section 3.3.2), as well as network connection and other components, should be checked (e.g. connectivity to other devices). This would provide a good working application for test users who would be able to concentrate on the therapy tasks without having to deal with performance issues. The main purpose of prototype testing is to save time and costs, as recruiting potential test users, in general, can be costly.

Afterwards, these prototypes for interactive VR applications would be used to test system usability, functionality, e.g. user interface and interaction mechanisms. Such practices would enable the research team to identify arising challenges within the system through the evaluation with real users.

7.2.2.2 Evaluation with test users and observation stage

Continuous testing and user feedback contributes to the iterative development phase and allows the development process to speed up. A way to develop an effective VR application would be through the continuous feedback from the test users: participants, psychologists and clinicians. Testing of the interaction mechanisms is one of the most important aspects of the application design. The design of a VR application should enable users to perform required tasks easily. This includes providing appropriate functionality within the application, as well as making it clear for users what actions will be required of them in order to complete a task. Table 7.5 describes the objectives of this stage and the ways to achieve them.

Who is involved	**Objectives of the meeting**	**How to achieve**
Research team members (developers , psychologists/clinicians etc.) and Target or Representative users	Iteratively test the application	Identification of the test users Evaluation with test users Observation of the issues related to interaction, interface, correct execution of psychology related tasks of the application for its debugging Resolving conflict feedback from test users

Table 7.5: Evaluation with test users and observation stage

Identification of the test users.

After the development of prototypes, evaluation sessions should be conducted. Although patient and public involvement (PPI) is becoming common in medical research projects (Vale, Thompson, Murphy, Forcat, & Hanley, 2012; South et al., 2016), in practice, it mostly occurs during the testing stage. In order to get useful feedback for VR application design, test users should be selected to match the target user profile as close as possible. Ideally, target users should be involved in the evaluation sessions; however, due to various reasons (e.g. health condition), it may not always be possible. If test users are not target users, they should be selected to have similar or pre-existing physical and/or psychological conditions, be of a similar age, have a similar experience with VR systems to those of the target users.

The idea of increasing stakeholders' engagement at more stages of the development process and also include them in the evaluation sessions is quite common (Augusto, Kramer, Alegre, Covaci, & Santokhee, 2018). However, one of the main obstacles we may encounter is that therapists and other stakeholders may not be familiar with VR systems. Incorporating therapists in the evaluation sessions allow them to familiarise themselves with the developed VR applications and prepare for the experimental sessions. This, in turn, would allow to recruit fewer test users, as therapists could act as test users for the evaluation of the interaction and, navigation mechanisms and determine the required functions needed for them to control the application. Therefore, allowing therapists to act as participants would help them understand and be able to explain the mechanisms of the application, should the participants experience any difficulties with it.

For example, during the development of a MUVR application, therapists and psychologists suggested a number of changes in the MUVR application, such as the "Value task" and VRET (see Sections 5.1.2.1 and 5.1.2.3). In this case, it was beneficial to test the VR application by a person with an expertise in the field as opposed to an unqualified user, as former would be able to analyse its practicality better and advise accordingly. Thus, including both therapists and representative users in the prototyping and evaluation phase for psychological VR applications would be advantageous.

Evaluation session with test users and observation of issues.

Evaluations should be carried out after each development iteration and the results fed back in the form of modification of the design (Van Hemel, 1999). The feedback from continuous user testing and iterative prototyping would enable the researchers to rapidly test the design ideas during the evaluation sessions. Before starting the evaluation session with the test users, developers and designers could provide an introduction to the VR system. For example, the standard Oculus Rift setup application could be used to demonstrate how to use the controllers. This ensures that any arising issues would be related to the design rather than the inability to use the controls properly.

User testing can help identify any usability and interaction issues related to the application. For a website usability testing, eye tracking can be used to predict salient regions of web pages (Buscher, Cutrell, & Morris, 2009). The content of these regions can then be adjusted accordingly. Mouse tracking can also be is used to classify users' conducts (Torres & Hernando, 2008). The use of similar techniques in VR testing has not been sufficiently researched.

"Thinking out loud" was found to be a useful method for this purpose. It is a common practice used for problem-solving in HCI (Van Hemel, 1999) as well as website testing (Van Waes, 2000). Members of the research team ask users to perform certain tasks (e.g. grab the object, move to a specific location in VE etc.) and observe their actions; users' actions and comments are then analysed.

For the testing of the MUVR application, for example, a video conference was organised between the VR developer, HCI expert and a therapist from the University of Cyprus. The HCI expert was there to assist with the setting up of the VR system and observations. The developer gave different interaction tasks for the therapist to see how he could perform them; notes and comments were taken during the process for further assessment .

During the evaluation stage, designers/developers can discover that some design features of the application are either non-functional or difficult to use. This occurred with the initial design of the MUVR system, some features of which were designed to imitate natural interaction between user and VE (e.g. navigation-by-hand, door teleportation, see Section 5.2); others were meant to facilitate the interaction (e.g. Automatic Hold tool, see Sections 5.2.6). It was found that the door teleportation method was difficult to use; navigation-by-hand caused motion sickness and the use of automatic hold tool was too confusing for the test users. All of these features were dropped out during the testing process and redesigned during the iterative prototype development process in order to make the application more user-friendly and comprehensible.

Also, attention should be paid to the erroneous actions of users. As the evaluation session for the anxiety disorders study showed, the users found it confusing to use the touch panel (see Section 3.2.5.1). The users accidentally touched the panel, which produced undesired results. This observation was taken into consideration, and the mechanism of the interaction was changed from the touch panel to a physical button.

Designers and psychologists can assess how long it would take for users to complete the tasks as well as familiarise themselves with the equipment and interaction mechanisms in VR. If extra time is required for the familiarisation purposes, it is advisable for designers to consider adding tutorials with instructions before proceeding with the therapy tasks. This was done for the MUVR application, as there were several complex interaction mechanisms for the users to memorise and get used to (see Section 5.1.2.3). Additionally, the design of hand controllers in VR was adjusted to make it easier to learn which buttons correspond to which actions.

Moreover, this research found that user testing for mobile VR differs from testing for the PC-based systems. PC-based VR systems have the ability to duplicate the content the user sees in an HMD on a separate screen. It can be problematic for the developers to understand what users are struggling with in mobile VR application, as it is difficult to display a mobile VR screen on a separate screen without affecting the performance of the smartphone. It was found that using printouts of the screens and menus displayed in the VE can help the developers gather important feedback from the test users.

It should also be noted that there could be cases when it would be difficult to find suitable test users, such as, for example, patients with later stages of dementia who mainly reside within in-patient institutions (Tabbaa et al., 2019). In this study, the research team did not conduct any user testing in order to protect the safety of target users. The system also did not imply any user interaction, only observation of media (video-based) VE. To make sure that the content of the VR is suitable, the researchers conducted a workshop session with a group of dementia healthcare professionals. This allowed them to identify the categories and criteria's for the VR content that could be used for the study.

Conflicting feedback.

Sometimes, conflicting feedback can occur when clinicians/psychologists and test users express contradictory views regarding an aspect of an application during testing. To overcome these issues, a compromise has to be found; additional meetings with stakeholders can be arranged for the purpose of discussing these matters.

Some studies show that there is a concern among experts regarding direct-to-consumer (DTC) advertising in healthcare, in particular, its emotional appeal to consumers (Bell, Wilkes, & Kravitz, 2000; Kaphingst & DeJong, 2004; Young, Paterniti, Bell, & Kravitz, 2005; Kaphingst, Rudd, DeJong, & Daltroy, 2005). Consumers may have a tendency to self-educate/diagnose based on information received from an advertisement. As a result, they may later question the advice of a professional as they will not be satisfied, which can impact on their patient-provider relationship (Mackert, Eastin, & Ball, 2010).

Healthcare professionals are likely to have a better understanding of a patients' condition and its possible treatments. In some psychological therapies such as exposure therapy, a patient may experience a short-term discomfort and thus have negative feelings regarding the treatment, even though the main outcome is likely to result in an improvement in his/her condition.

As with most commercial products and services, when it comes to the development of VR applications for psychological treatments, user satisfaction plays an important role. Designers and developers should, therefore, aim to satisfy users' preferences. However, if those preferences clash with the therapy, clinicians' advice should prevail — for instance, in the prolonged VRET for treatment of PTSD. Prolonged treatment involves the gradual and repetitive re-creation of traumatic events in a therapeutic setting. Although the content displayed in VR is relevant to a traumatic event that is not pleasant for the person, it has been found that this approach provides a low threat context. In the process of gradual perception of disturbing information, a person begins to resist and therapeutically process emotions (Rizzo et al., 2013).

Once usability of the application has been tested thoroughly, and psychologists are satisfied with its performance, the research team can proceed to the next phase where the project will undergo pilot testing in the experimental/clinical environment.

7.2.3 Pilot phase

Once the research team have developed a reliable VR application, the resulting prototype is ready to undergo an initial assessment with patients/participants and therapists in a designated environment. This process is known as a Pilot Phase. During Pilot phase, it is necessary to study how the application performs in the specified environment as well as identify and resolve any arising issues with the system setup, experimental procedures, networking etc. The emphasis of this phase is not to test the effectiveness of VR application as a psychological intervention, but to focus on the usability of the system in the target environment and ensure that everything is prepared for its implementation in therapy (see Figure 7.10).

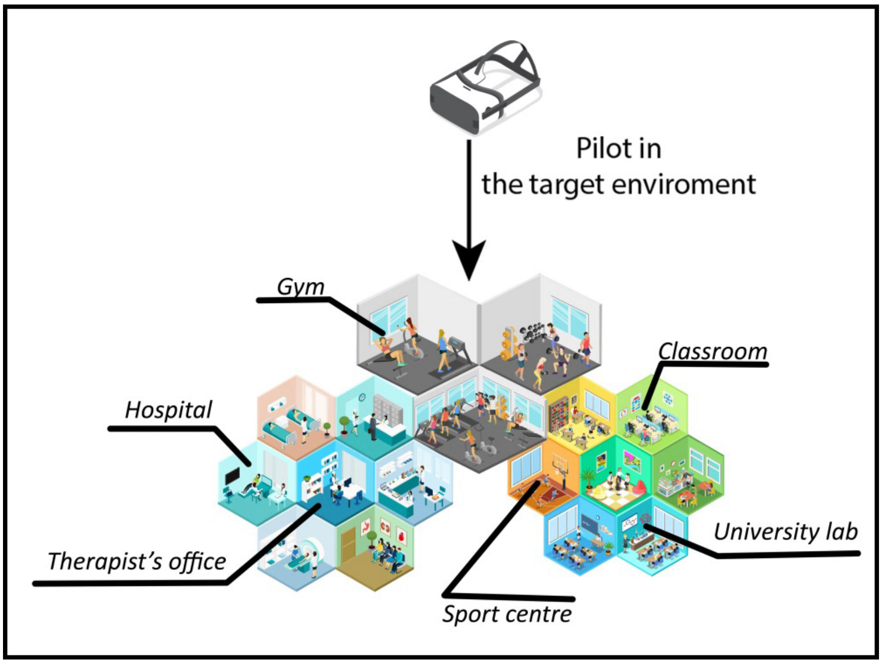

Figure 7.10: Pilot testing of the VR in the target environment

This is done to ensure that the developed system behaves as expected in the clinical/experimental environment. Although developers and researchers may skip this phase and move straight to experimental therapy, there is a risk of providing an inadequately tested VR intervention to a larger number of participants. This can result in the collected data for the experiment being inaccurate and/or incomplete. The following section describes what elements the research team members should pay attention to during the VR pilot phase.

In contrast to the prototyping and testing phase, which focuses on the collaborative content development in a design environment, the VR pilot phase evaluates the VR intervention on participants and clinicians within the intended clinical or experimental setting. During this research, the pain management study showed the importance of simulating real experimental sessions when conducting pilot tests. One of the issues, which was identified only during the experiment, was the overheating of the smartphone (see Section 3.1.7). This was due to not having a pilot testing. There was not large enough number of participants who used the system consequently during the evaluation session. The issue was solved by providing the researcher with another mobile VR system to enable him to swap the devices when necessary.

Before the beginning of data collection for the eating disorders study, two pilot tests were conducted to check how the system will work in the experimental environment. To do this, two VR systems were set up; two participants with a possible diagnosis of eating disorders were recruited with two clinicians taking part in the testing. During the pilot tests, several aspects of the system were checked. As MUVR required access to the internet, it was necessary to test the network settings and connection reliability. To record the participants' experience in VR, specific software was required (e.g. Open Broadcaster Software[5] (OBS) used in the eating disorders study). This software was installed and tested on PCs. The third aspect of the testing included the evaluation of the system usability.

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[5] https://obsproject.com/

As a result of these tests, several connection issues were addressed. In the case of recurrent network issues, clinicians were instructed on how to resolve them. The recording software was tested without any major issues, and its use was demonstrated to the clinicians for future reference. Additionally, instructions for the use of the application and other equipment were given out.

Overall, a comprehensive VR Pilot phase should evaluate VR treatment in a setting where the application is intended to be used. This is done in order to check all the technical aspects of using the system in the target environment. For instance, hospitals and other public institutions can have network restrictions in place, which can affect data collection (Tabbaa et al., 2019). The research team should find solutions to arising issues.

Finally, VR pilot phase can help prepare the team (e.g. assistants and therapists) and the VR application for the experiments. The team has to check that all required materials (questionnaires, information tables) and documents (consent forms, participant information sheets) have been obtained, and the application is ready and functioning as expected. During this phase, researchers will have an opportunity to assess the time needed to conduct the experiment/therapy. This assessment will help determine the duration of time required for each session and create a schedule for participating persons. This will assist in a smooth run of the experiment/therapy and help deliver desired results.

The pilot phase is the last part of the proposed guidelines. Upon completion, the research team can run experiments and/or work towards the deployment of the application as part of psychological treatment.

7.3 Contribution

This thesis offers a number of contributions. Firstly, there is a contribution for researchers, showing how VR systems can be designed collaboratively between technologists and psychologists. In addition, there is a contribution to practitioners that can help developers/designers create more effective mobile and PC-based VR applications for psychotherapy. Finally, the proposed direction for the potential development of using remote VR therapy contributes to the existing literature of VR and psychological interventions.

7.3.1 Contribution to researchers

This thesis helps to provide an understanding of the interdisciplinary design, prototyping, iterative testing and refinement with users, as well as pilot testing processes. A set of guidelines for VR applications for psychological interventions was proposed as a contribution to researchers.

Three studies were conducted during this PhD research and contributed to the enrichment of the knowledge in the area of psychological VR applications. Analysis of the development of mobile VR applications (Chapter 3) and MUVR system (Chapter 5) offers insight regarding the methodology of mobile and PC-based applications design/development and user testing. Iterative testing and application development based on participants' feedback provided valuable information about mobile and MUVR interventions mechanisms and user requirements.

The anxiety disorder study contributed to the existing knowledge of CBM-I training, which could result in better interventions in this area in future. The study provides analysis of how VR elements can benefit and influence test anxiety of young adults. Although VR and anxiety-related disorders have been studied before (Carl et al., 2019), this study is the first to translate a 2D CBM-I intervention into a 3D one. In collaboration with the psychologists, a set of scenarios was created, as well as VE's for these scenarios and elements like voice recognition for interaction with them.

Both the pain management and anxiety disorders studies showed that mobile VR systems could be successfully applied in these interventions and have the potential to be widely used as portable psychological interventions. These two studies determined a 'skeleton' protocol for the rest of the research. The methods of prototype development and the pilot phase were improved in the second part of the research using a more complex VR system (Chapter 5).

The study on eating disorders (Chapters 5 and 6) also provide a contribution for HCI on how to move from 2D to 3D interventions. The co-design approach used in this study allowed to create a system which fit the requirements of the intervention and allowed therapists to conduct the intervention remotely. The MUVR system developed for this study could be potentially be used by researchers for any remote intervention. Of course, it was only a pilot study on applying this type of intervention; however, this could potentially be the future of VR applicable not only in psychology but in other areas also.

An essential challenge in the development of VR applications is the difficulty of creating multidisciplinary research teams to develop appropriate activities in VR. There is a growing recognition of the need to involve representatives of the target user groups in order to better match proposed VR solutions with the identified needs of end-users (Banner et al., 2019). There is also a growing awareness of the need for greater involvement of, for example, representatives of clinical communities in such studies. This research allowed to create recommendations and guidelines for the co-design approach of the VR application development for psychological interventions.

The set of guidelines presented in this Chapter are not just limited to psychological interventions and could potentially be applied in different areas. For instance, a hypothetical example of its implementation could be area of medicine and decision-making. The research found that newly qualified doctors felt unprepared for “diagnosing and managing complex clinical conditions and providing immediate care in medical emergencies.” (Monrouxe et al., 2014). Suboptimal care provided by inexperienced foundation doctors can lead to patient deterioration (Sutton et al., 2018).

In order to develop competence in diagnosing and managing complexity, student doctors must develop expertise in Clinical Reasoning (CR) - the thinking and decision-making processes associated with clinical practice. As VR offers learners the opportunity to be immersed in quasi-realistic, high fidelity experiences and at the same time allows for parametric control of variables in the scenario (such as potential stressors), it could potentially be used to explore the role of stressors on CR to try to improve the efficacy of student doctors.

Collaboration between clinicians, research academics from different arias (such as medical education, neuroscience and experimental psychology) and developers will bring together the expertise and resources from various fields to provide a unique opportunity to research the validity of the development of VR in teaching and assessing clinical reasoning. By following the first phase of the proposed guidelines (see Section 7.2.1), the research team will be able to identify the research questions as well as key elements of the VR CR training. This collaboration would enable to apply evidence from the cognitive field of decision-making and the theory of social learning to study the pedagogical rationale behind the application of VR for teaching and assessing medical students. The second and third phases of the guidelines (see Section 7.2.2 and Section 7.2.3) will help the research team in creating and testing an appropriate VR application that could help to find out the answers for the proposed research questions and at the same time be used in the targeted environment. Ultimately, evidence for resources that improve the learning and assessment of competency in clinical reasoning will lead to improved clinical decision-making and patient safety. Outcomes from such a study would have implications for education across healthcare disciplines.

As part of the contribution to researchers, a question of the potential evolution of VR as a useful and usable tool in psychotherapy was considered. There are three key elements that will determine further development. First, advances in the basic technologies needed to deliver PC-based VR, along with the decreasing cost of equipment, will likely make VR more accessible to independent psychologists, therapists and researchers. Second, the expansion of access and exposure to VR can potentially lead to the development of a wider range of applications for clinical and research purposes. Finally, continuing the research to determine reliability, validity and usefulness of remote VR application therapy, as proposed in Chapter 5, can help establish it as a common tool for psychological interventions.

7.3.2 Contribution to practitioners

This thesis also offers a number of practical contributions to aid the developers in designing better VR applications and VE interaction to support psychological health (Chapter 3, 5). This was the first step towards standardisation of VR design. Although the case studies were conducted in the area of psychological interventions, it has the potential to apply this knowledge in other 3D applications; some practical implications of which have been provided in this research. For instance, in e-commercials. Chinese companies (e.g. Alibaba Group Holding Ltd[6]) are exploring how VR technology can be applied to different services, including online games, video streaming and 3D Online Shopping Experience (Ghonge, 2016). Some companies have already created visuals for hundreds of products and are working towards providing the standards for merchants to create VR-enabled shopping options.

In Chapter 3, different VR tools and techniques were examined, and a number of suggestions provided on how mobile VR applications can be developed. This information will be useful for researchers and developers who are seeking to use mobile VR technology in their work. For instance, Chapter 3 describes interaction within mobile VR applications. Due to the design of a VR headset, the ability for physical interaction with the smartphone, e.g. pressing and scrolling, is reduced to none. Therefore, the development of suitable user interaction mechanisms and UI has to differ significantly from that of ordinary mobile applications.

The smooth running of the application is one of the most essential elements for conducting a successful mobile VR therapy. Whilst trying to create high-quality visuals, any development of mobile applications should also be aimed at ensuring

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[6] https://www.alibabagroup.com/en/global/home

the stable operation of the application. The researchers and developers seeking to address those issues will find some useful suggestions provided in Chapter 3.

The development process in Chapter 5 and the pilot study in Chapter 6 provide data and findings to deepen the understanding of PC-based remote MUVR treatment. These findings aid in the understanding of how to develop a remote MUVR platform and what elements should be taken into account during its development. Such elements are interaction, navigation, networking, communication and other game design elements. These suggestions would be particularly useful to those seeking to use remote VR as a tool to facilitate any remote VR therapy sessions, not just psychotherapy.

The design of all VR systems developed during this research and the experimental procedures were co-developed with a group of psychologists and therapists; the systems were also improved through the iterative testing and user feedback. This contribution could provide valuable research and practical knowledge for the researchers studying the use of technology in psychology, as well as developers seeking to create VR applications to apply similar principles in their design.

7.4 Limitations and Future work

Despite recent interest in using VR in various psychological interventions, there has not been a substantial amount of research studying the application of co-design in the development of VR applications. This is especially important given that VR applications, compared to other digital technologies, such as the web and mobile applications, can provide unique benefits in delivering psychological interventions. The lack of co-design guidelines for psychological VR applications does not allow to standardise the design and development processes of the applications. This thesis provides a path toward standardisation of VR design in general, with potential implications for other 3D applications. During this research, the design challenges and benefits of using affordable VR systems, as well as the introduction of a new direction in the development of VR psychotherapy, i.e. remote MUVR, were studied. Several VR applications were co-designed with a group of psychologists, therapists, developers and 3D artists. This approach allowed to develop a set of guidelines that could be useful to researchers and developers investigating the possibilities of VR application in psychological interventions.

However, this thesis had to explore several factors together (for instance factors such as navigation and interaction in VR, different psychological therapies, virtual avatars and virtual social interaction) to be able to provide answers to some key, paramount questions. In this respect, several limitations could be highlighted. First, during this research, only three areas of psychological interventions were highlighted (pain management, anxiety disorders and eating disorders). The application of the proposed co-design guidelines could be further investigated in other types of psycho-therapies. In addition, during this research, only data at pre- and post-assessment were considered, and single-session training. It would be important to assess multiple-session of training and long term effects, beyond the immediate effects.

Secondly, this research was focused on the co-design of VR applications for psychological interventions. As discussed in Section 2.4, there are also other types of design methods (such as participatory design etc.). Future research could investigate the application of such methods in the design of VR applications.

Lastly, the participants' sample for all studies carried out during this research was limited to University students. Whether the results in this research could be generalised to other groups of users (such as people with disabilities, elderly people, etc.) would need to be further investigated. Studies have also shown that older people engage with technology in a different manner when compared with the younger generation (Siriaraya, Ang, & Bobrowicz, 2014). Different interaction techniques described in Sections 3.1.8, 5.2.6, 5.2.7 or User Interface design might not be suitable for such groups of people.

Finally, there are a number of directions and points in this thesis which could be further investigated in future studies:

1. **Perceptual factors of mobile VR.** Within the scope of the first study (Chapter 4), it was not clear how or to what extent various perceptual factors within the VR application influenced the outcomes of the training (e.g. 3D background, ambient noises, animation, blur etc.). From the design perspective, the deployment of highly controlled and sophisticated experimental design would be beneficial. Such measures would help to achieve greater insight and further optimise the mobile VR intervention. This, in turn, would allow to isolate and compare the effects of different technical aspects on users' perception of the VE's.

2. **Use of audio input.** One potential area which could be investigated is the impact of media input resources on participants' perception and interaction with mobile VR. As can be seen in section 3.2.4, the training scenarios were embedded in the corresponding virtual environments as pop-up text boxes appearing in the users' field of view. This method could be perceived as "artificial" or not realistic enough. Instead, in future development, the use of audio narration may become a preferred option to enhance both the training experience and the activation of the target emotional response (Holmes et al., 2006; Holmes, Lang, & Shah, 2009).

3. **Group therapy using remote VR system.** The remote VR system developed for the Eating Disorder study (Chapter 5) allows a maximum of 20 users to take part in the treatment simultaneously. This opens possibilities for providing remote group therapy sessions. For example, one of the most common methods of CBT for social phobia is group treatment (Stangier, Heidenreich, Peitz, Lauterbach, & Clark, 2003). Heimberg et al. (1990) identified the potential benefits of group treatment for social interactions. These include the ease of modelling the situation using role games, support from members of the group, etc. There are a few studies comparing group and individual treatments (Fals-Stewart, Marks, & Schafer, 1993; Bastien, Morin, Ouellet, Blais, & Bouchard, 2004; Stangier et al., 2003), however none examined remote VR treatments. This could be an exciting area for investigation in future research.

4. **Application of this co-design set of guidelines in Augmented Reality.** One of the technological areas emerging in the last couple of years is Augmented Reality (AR). Several studies (Buchmann, Violich, Billinghurst, & Cockburn, 2004; Van Krevelen & Poelman, 2007) have already examined the application and limitations of such systems. Different toolkits have

been developed for easy integration and development of the applications, such as ARToolKit[7], COTERIE[8], StudierStube[9]. Some researchers (Juan et al., 2005; Radu & MacIntyre, 2012) have started applying this technology in psychological interventions. There is an opportunity to improve the development of AR applications for healthcare within the proposed set of guidelines.

The work in this thesis provides a basis for future research related to VR application development for psychological interventions that could inspire more research in this area. Furthermore, the findings of this thesis would be particularly useful to those seeking to use mobile or PC-based VR systems as a tool to improve the experience and effectiveness of the existing psychological therapy.

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[7] http://artoolkit.sourceforge.net/

[8] http://www.cs.columbia.edu/graphics/projects/coterie/

[9] http://studierstube.icg.tu-graz.ac.at/

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Appendices

A Reverse Normals Script for Mobile VR Media Environments

```
 [RequireComponent(typeof(MeshFilter))]
public class ReverseNormals : MonoBehaviour {

void Start () {
MeshFilter filter = GetComponent(typeof (MeshFilter)) as
   MeshFilter;
if (filter != null)
        {
        Mesh mesh = filter.mesh;

        Vector3[] normals = mesh.normals;
        for (int i=0;i<normals.Length;i++)
                normals[i] = -normals[i];
        mesh.normals = normals;

        for (int m=0;m<mesh.subMeshCount;m++)
        {
        int[] triangles = mesh.GetTriangles(m);
        for (int i=0;i<triangles.Length;i+=3)
                {
                int temp = triangles[i + 0];
                triangles[i + 0] = triangles[i + 1];
                triangles[i + 1] = temp;
                }
        mesh.SetTriangles(triangles, m);
        }
    }
}
}
```

B The Hand Movement and Microsoft Band Synchronisation Script

```
public class Gyro2 : MonoBehaviour
{

public Text Band0Acc;
public Text Band1Acc;
public Transform targetPos;
float newY, newX, newZ, lastval, _x, _y, _z;
Vector3 start, target;

// Use this for initialization
void Start()
{

// Register for raw acc events.
MsBandAndroidBridge.RawGyrUpdateEvent +=
   MsBandAndroidBridge_RawGyrUpdateEvent;
start = transform.localEulerAngles;
Debug.Log (start);
target = new Vector3 (375.1692f, 111.1702f, 304.3327f);
lastval = 0;

}

//This code is to enable the band.
public void EnableMSBand(){

    MsBandAndroidBridge.Instance.ConnectToPairedBands();

}

    float map(float s, float a1, float a2, float b1, float
        b2)
    {
        return b1 + (s - a1) * (b2 - b1) / (a2 - a1);
    }


        float diff;
    private void MsBandAndroidBridge_RawGyrUpdateEvent(
       float x, float y, float z, MsBand band)
    {
        if (band.BandId == 0)
        {
            if (Band0Acc != null)
            {
                                _x = x; _y = y; _z = z;
```

```
                Band0Acc.text = band.Gyroscope.ValueX.
                   ToString() + ”, ” + band.Gyroscope.
                   ValueY.ToString() + ”, ” + band.
                   Gyroscope.ValueZ.ToString() ;
            }

        }

        if (band.BandId == 1)
        {
            if (Band1Acc != null)
                Band1Acc.text = x.ToString() + ”, ” + y.
                   ToString() + ”, ” + z.ToString();
        }
    }

    void Update()
    {
//      Debug.Log (transform.localEulerAngles);
        newY = map(Mathf.Abs(_x), 0f, 0.15f, start.y,
           targetPos.localEulerAngles.y);
        Vector3 v = new Vector3 (transform.
           localEulerAngles.x, newY, transform.
           localEulerAngles.z);
        if (newY > 40f || newY < 20f) {

        } else if (newY == 30) {

        } else {
        }
        transform.localEulerAngles = v;
    }

        void OnGUI(){
                GUI.Label(new Rect(0,0, Screen.width,
                   Screen.height), guitext);
        }

    void OnDestroy()
    {
        MsBandAndroidBridge.RawGyrUpdateEvent -=
            MsBandAndroidBridge_RawGyrUpdateEvent;
    }
}
```

C The Network Blend Shapes Synchronisation Script for the Eating Disorders Study

```
public class BlendShapeTest : Photon.MonoBehaviour {
private float fat_legs = 50.0F;
private float fat_arms= 50.0F;
private float fat_chest=50.0F;
private float fat_body =50.0F;
public Slider legSlider, chestSlider, bodySlider,
   armsSlider;
private Text bodyText,legsText,armsText,chestText;
private SkinnedMeshRenderer skinMeshRenderer;

    // Use this for initialization
    void Start () {
    skinMeshRenderer = GetComponent<SkinnedMeshRenderer>()
       ;
    bodyText = GameObject.Find(”TextBody”).GetComponent<
       Text>();
    legsText = GameObject.Find(”TextLegs”).GetComponent<
       Text>();
    armsText = GameObject.Find(”TextArms”).GetComponent<
       Text>();
    chestText = GameObject.Find(”TextChest”).GetComponent<
       Text>();

    }

    public void UpdateValueLegs()
    {
    fat_legs = legSlider.value;
    legsText.GetComponent<Text>().text = ”Legs” +
       legSlider.value;
    }

    public void UpdateValueChest()
    {
    fat_chest = chestSlider.value;
    chestText.GetComponent<Text>().text = ”Chest” +
       chestSlider.value;
    }

    public void UpdateValueBody()
    {

    fat_body = bodySlider.value;
    bodyText.GetComponent<Text>().text = ”Body” +
       bodySlider.value;
```

```
  }


  public void UpdateValueArms()
  {
  fat_arms = armsSlider.value;
  armsText.GetComponent<Text>().text = ”Arms” +
     armsSlider.value;
  }

  // Update is called once per frame
  void Update () {
      skinMeshRenderer.SetBlendShapeWeight(0, fat_body);
      skinMeshRenderer.SetBlendShapeWeight(1, fat_chest)
         ;
      skinMeshRenderer.SetBlendShapeWeight(2, fat_arms);
      skinMeshRenderer.SetBlendShapeWeight(3, fat_legs);

  }

 void OnPhotonSerializeView(PhotonStream stream,
   PhotonMessageInfo info)
  {
      if (stream.isWriting == true)
      {
          stream.SendNext(fat_legs);
          stream.SendNext(fat_chest);
          stream.SendNext(fat_body);
          stream.SendNext(fat_arms);
          stream.SendNext(bodySlider.value);
          stream.SendNext(legSlider.value);
          stream.SendNext(armsSlider.value);
          stream.SendNext(chestSlider.value);
      }
      else
      {
       fat_legs = (float)stream.ReceiveNext();
       fat_chest = (float)stream.ReceiveNext();
       fat_body = (float)stream.ReceiveNext();
       fat_arms = (float)stream.ReceiveNext();
       bodySlider.value = (float)stream.ReceiveNext();
       legSlider.value = (float)stream.ReceiveNext();
       armsSlider.value = (float)stream.ReceiveNext();
       chestSlider.value = (float)stream.ReceiveNext();
      }}}
```

D Paper Instructions for the Participants' Assistant for the Eating Disorder Study

Assistant:
Before we start with the main part of the experiment, let's have a look at the equipment that we are going to use and do a quick tutorial to get used to VR and VR interaction.

Let's start with the headset first. (Show the headset)

1. You can adjust the size of the headset using the Velcro straps (see 1 on Figure 11) on the sides and on the top of the headset.
2. You can also adjust the distance between the lenses moving the lever (see 2 on Figure 11) side to side.

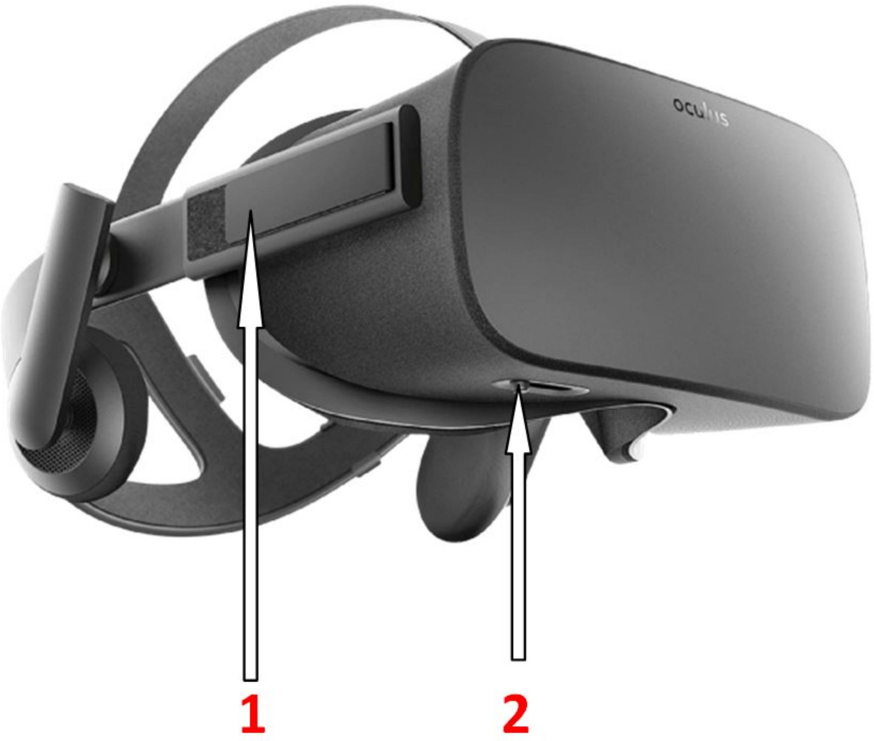


Figure 11: Oculus rift headset

The headset also has a wire, so be careful not to stumble or entangle in it.

Next, let's have a look at controllers.

In order to interact with objects and move around in VR, we are going to use these controllers. (Show the controllers)
Show the participant how you need to hold the controller. (See image below)

Use your thumb to press the top buttons (A, B, X, Y) and thumbsticks on your left and right controllers. Put your index finger on the trigger button and your middle finger on the Grip button (see Figure 12)

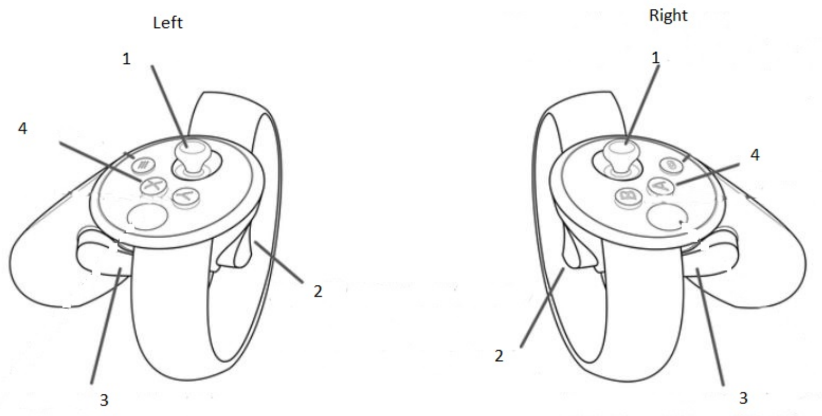
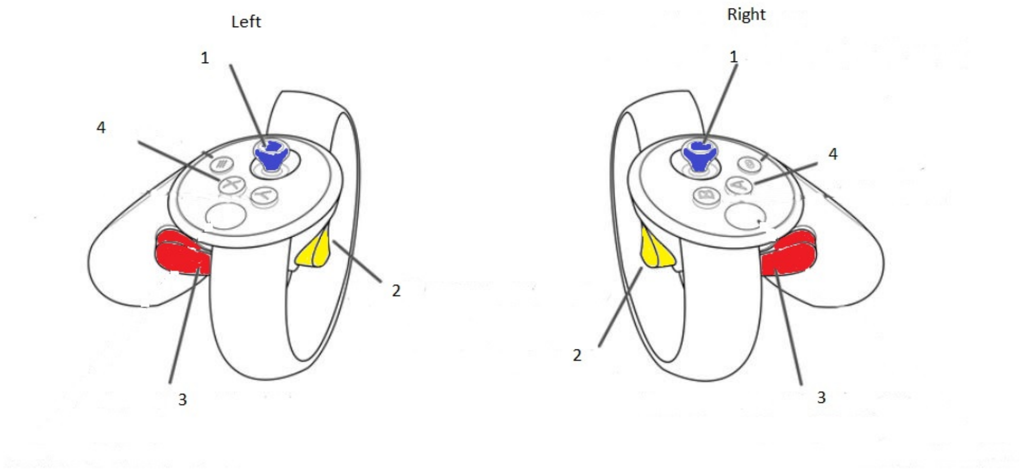


Figure 12: Oculus rift controllers

1 – Thumbsticks
2 – Trigger button
3 – Grip Button
4- A, B, X, Y buttons

Now, when you were introduced to the equipment, let's do a quick tutorial. (Start tutorial application)

During the tutorial help and explain participant what to do (if needed). Below are the descriptions for controllers' buttons.



Both controllers have the same functions and use the same buttons to interact in VR.

1- Blue button (Thumbstick)
Use Blue button to move in VR. **Press and Hold** the Blue button. You should see green dots and locator on the floor. If the dots are Red, it means that you can't teleport there. If the dots and locator are Green then you can teleport on the locator position.

Rotate your controller up and down to move the locator further or closer to you and move your hand on the left or right to move the locator in VR left or right.

2- Red button (Grip button)
You need to touch the object with your controller. (Tell the participant that you need to come closer to the object in order to touch it. So use Blue button to come closer) When you touch it, the object changes its colour, and you can press Red button to grab it. If you release the Red button the object will drop.

3- Yellow button (Trigger)
You need to use this button when you want to interact with User Interface (UI) such as virtual buttons and sliders. Press and hold Yellow button. You should see a pointer coming out of the VR controller. Point the controller on a VR slider or VR button. **Press X** (if you are using the left controller) or **A**(if you are using the right controller) to click the VR button. For the slider, you need to **Press and Hold** X or A to move the slider left or right.

Now when you finished the tutorial, we will start the main experiment part. Don't worry if you didn't remember all the buttons; the therapist will help you.

E Anxiety Disorders Study Instruments

E.1 Anxiety Disorders Study Questionnaires

Slater-Usoh-Steed Questionnaire (SUS) (modified)

1. Please rate your sense of being in the scenario, on the following scale from 1 to 7, where 7 represents your normal experience of being in a place. *I had a sense of "being there" in the scenario*: 1. Not at all ... 7. Very much.

2. To what extent were there times during the experience when the scenario was the reality for you? *There were times during the experience when the scenario was the reality for me...* 1. At no time ... 7. Almost all the time.

3. When you think back about your experience, do you think of the scenario more as images that you saw, or more as somewhere that you visited? *The scenario seems to me to be more like...* 1. Images that I saw ... 7. Somewhere that I visited.

4. During the time of the experience, which was strongest on the whole, your sense of being in the scenario, or of being elsewhere? *I had a stronger sense of...* 1. Being elsewhere ... 7. Being in the scenario.

5. Consider your memory of being in the scenario. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today? By 'structure of the memory' consider things like the extent to which you have a visual memory of the virtual environment , whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such structural elements. *I think of the scenario as a place in a way similar to other places that I've been today...* 1. Not at all ... 7. Very much so.

6. During the time of the experience, did you often think to yourself that you were actually in the scenario? *During the experience, I often thought that I was really standing in the scenario...* 1. Not very often ... 7. Very much so

State-Trait Anxiety Questionnaire (STAI)

STAI FORM Y1

Directions: A number of statements which people have used to describe themselves are given below. Please read each statement and then tick the appropriate box to the right of the statement to indicate how you feel **RIGHT NOW**, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer that seems to describe your present feelings best.

	not at all 1	somewhat 2	moderately so 3	very much so 4
1. I feel calm	☐	☐	☐	☐
2. I feel secure	☐	☐	☐	☐
3. I am tense	☐	☐	☐	☐
4. I feel strained	☐	☐	☐	☐
5. I feel at ease	☐	☐	☐	☐
6. I feel upset	☐	☐	☐	☐
7. I am presently worrying over possible misfortunes	☐	☐	☐	☐
8. I feel satisfied	☐	☐	☐	☐
9. I feel frightened	☐	☐	☐	☐
10. I feel comfortable	☐	☐	☐	☐
11. I feel self-confident	☐	☐	☐	☐
12. I feel nervous	☐	☐	☐	☐
13. I am jittery	☐	☐	☐	☐
14. I feel indecisive	☐	☐	☐	☐
15. I am relaxed	☐	☐	☐	☐
16. I feel content	☐	☐	☐	☐
17. I am worried	☐	☐	☐	☐
18. I feel confused	☐	☐	☐	☐
19. I feel steady	☐	☐	☐	☐
20. I feel pleasant	☐	☐	☐	☐

STAI FORM Y2

A number of statements which people have used to describe themselves are given below. Please read each statement and then tick the appropriate box to the right of the statement to indicate how you **GENERALLY feel**. There are no right or wrong answers. Do not spend too much time on any one statement, but give the answer that best describes how you usually feel.

	almost never 1	some-times 2	often 3	almost always 4
1. I feel pleasant	☐	☐	☐	☐
2. I feel nervous and restless	☐	☐	☐	☐
3. I feel satisfied with myself	☐	☐	☐	☐
4. I wish I could be as happy as others seem to be	☐	☐	☐	☐
5. I feel like a failure	☐	☐	☐	☐
6. I feel rested	☐	☐	☐	☐
7. I am 'calm, cool, and collected'	☐	☐	☐	☐
8. I feel that difficulties are piling up so that I can't overcome them	☐	☐	☐	☐
9. I worry too much over something that really doesn't matter	☐	☐	☐	☐
10. I am happy	☐	☐	☐	☐
11. I have disturbing thoughts	☐	☐	☐	☐
12. I lack self-confidence	☐	☐	☐	☐
13. I feel secure	☐	☐	☐	☐
14. I make decisions easily	☐	☐	☐	☐
15. I feel inadequate	☐	☐	☐	☐
16. I am content	☐	☐	☐	☐
17. Some unimportant thought runs through my mind and bothers me	☐	☐	☐	☐
18. I take disappointments so keenly that I can't put them out of my mind	☐	☐	☐	☐
19. I am a steady person	☐	☐	☐	☐
20. I get in a state of tension or turmoil as I think over my recent concerns and interests	☐	☐	☐	☐

Immersion Experience Questionnaire (IEQ)

1. To what extent did the scenario hold your attention?
   Not at all 1 2 3 4 5 A lot

2. To what extent did you feel you were focused on the scenario?
   Not at all 1 2 3 4 5 A lot

3. How much effort did you put into interacting with the scenario?
   Very little 1 2 3 4 5 A lot

4. Did you feel that you were trying you best?
   Not at all 1 2 3 4 5 Very much so

5. To what extent did you lose track of time?
   Not at all 1 2 3 4 5 A lot

6. To what extent did you feel consciously aware of being in the real world whilst playing?
   Not at all 1 2 3 4 5 A lot

7. To what extent did you forget about your everyday concerns?
   Not at all 1 2 3 4 5 A lot

8. To what extent were you aware of yourself in your surroundings?
   Not at all 1 2 3 4 5 Very aware

9. To what extent did you notice events taking place around you?
   Not at all 1 2 3 4 5 A lot

10. Did you feel the urge at any point to stop playing and see what was happening around you?
    Not at all 1 2 3 4 5 Very much so

11. To what extent did you feel that you were interacting with the scenario?
    Not at all 1 2 3 4 5 Very much so

12. To what extent did you feel as though you were separated from your real-world environment?
    Not at all 1 2 3 4 5 Very much so

13. To what extent did you feel that the scenario was something you were experiencing, rather than something you were just doing?
    Not at all 1 2 3 4 5 Very much so

14. To what extent was your sense of being in the scenario stronger than your sense of being in the real world?
    Not at all 1 2 3 4 5 Very much so

15. At any point did you find yourself become so involved that you were unaware you were even using controls?
    Not at all 1 2 3 4 5 Very much so

16. To what extent did you feel as though you were moving through the scenario according to you own will?
    Not at all 1 2 3 4 5 Very much so

17. To what extent did you find the scenario challenging?
    Not at all 1 2 3 4 5 Very difficult

18. Were there any times during the training scenario in which you just wanted to give up?
    Not at all 1 2 3 4 5 A lot

19. To what extent did you feel motivated while interacting with the system?
    Not at all 1 2 3 4 5 A lot

20. To what extent did you find the training scenario easy?
    Not at all 1 2 3 4 5 Very much so

21. To what extent did you feel like you were making progress towards the end of the training scenario?
    Not at all 1 2 3 4 5 A lot

22. How well do you think you performed?
    Not at all 1 2 3 4 5 Very well

23. To what extent did you feel emotionally attached to the scenario?
    Not at all 1 2 3 4 5 Very much so

24. To what extent were you interested in seeing how the events would progress?

25. How much did you want to “win” ?
    Not at all 1 2 3 4 5 A lot

26. Were you in suspense about whether or not you succeeded?
    Not at all 1 2 3 4 5 Very much so

27. At any point did you find yourself become so involved that you wanted to speak to the scenario directly?
    Not at all 1 2 3 4 5 Very much so

28. To what extent did you enjoy the graphics and the imagery?
    Not at all 1 2 3 4 5 Very much so

29. How much would you say you enjoyed interacting with the scenario?
    Not at all 1 2 3 4 5 A lot

30. When interrupted, were you disappointed that the training scenario was over?
    Not at all 1 2 3 4 5 Very much so

31. Would you like to use the training scenario again?
    Definitely not 1 2 3 4 5 Definitely yes

E.2 Scenarios used for the anxiety disorders study

Exam hall

1. You've finished writing the answer to the second question in your exam. You take a small break, looking at what's left. You then realise that the questions left are more difficult than you had anticipated. Checking the watch, you decide you've planned your time . . . . . . w-ll [well]. Will you have time to complete the exam? Yes. You scheduled your timetable thoroughly.
2. As you work through the first questions of the exam, you find it hard to keep all the details in mind to answer the questions. Then you think about your performance in this type of exam, and you realise your achievements compared with other people will be very . . . . . . r–sonable [reasonable]. Do you think you are performing worse than most others on this exam? No. Your presentation on this assessment seems more than adequate.
3. You are sitting a written maths exam and take a brief break after half of the time. You've managed to answer about a quarter of the questions so far. Not being able to solve many questions probably means that the pass mark will be . . . . . . l-w [low]. Do you expect to pass? Yes. The score will be a little depressed.
4. You are halfway through an exam question. You have already written several pages and you re-read the question before rounding off with a conclusion. As you do so you consider that you have answered . . . . . . co–ectly [correctly]. Did you understand the question? Yes. Your conclusion to the essay is effective.
5. Your supervisor asks you to write a report. The finished document is quite brief but took a lot of time and effort. As she reads through it the next afternoon, you think that she will find that the amount you have written is . . . . . . c-nci-e [concise]. Did your supervisor think your report was comprehensive? Yes. Your superior believed the assessment was ideal.

Classroom

1. You are enrolled in an introductory course in the Spanish language. Teaching is interactive, and everybody is asked to participate actively. The first sentence you say has a few mistakes. In this context, you feel this means that you are already . . . . . . l–rning [learning]. Are your mistakes a bad sign? No. Your inaccuracies mean you are discovering your errors.
2. You are sitting in a small room and have just started doing a test that seems very difficult. The room temperature was not noticeable when you went in, but now as you make a start you feel aware that you are very . . . . . . c–l and calm [cool]. Did you feel too hot in the room? No. You are composed and collected.
3. Your writing course class is getting an essay back today. When handing you back your essay, the teacher makes a remark on how to improve the structure of it. Your reaction is one of . . . . . . g-a-itude [gratitude]. Do you think your essay was not good enough? No. You are really appreciated by your teachers' support and conclusion.

4. You have been taking a French language course for a term. This evening, the class prepares for the oral term test. Not understanding some of the listening dialogues is . . . . . . ok– for you [okay]. Do you mind not understanding some of the dialogues? No. It doesn't worry you too greatly.

5. At your evening class, you are given a task to complete for the next stage. You finish it early and ask the tutor for his opinion. He says the work is good, apart from missing out a section. You feel that he will think you are . . . le-rni-g [learning]. Was your tutor pleased with the quality of work on your paper? Yes. He told you that your effort was proficient.

Computer lab 1

1. You are doing a task in which you have to keep some facts in mind while you solve some other questions. You do some practice examples, and then the real test begins. Your mind is .... as you try each item. fo-u-ed [focused]. Are you able to keep concentrating on doing the task? Yes. You are absorbed on all the elements of the assignment.

2. As part of an intelligence test, you have to solve word encryption codes. Although you expected to do more, at the end of the time you have solved only one. You conclude that a higher score is . . . on this test. unusu-l [unusual]. Do you think your score is lower than expected on this test? No. Your grade met with the potentials of the assessment.

3. You are set to work on a test that has two components. Each element is fairly easy by itself, but you have to do both together. It is surprisingly difficult to solve anything when you have so little time to think, and you make many mistakes. You think that this number of mistakes is . . . . . . no-m-l [normal]. Are you worse than others at this test? No. Your presentation was similar to other people.

4. As you sit down and start an important exam, you become very aware of your thought processes. Reading through the first question, which is compulsory, your mind is completely ......about the information that will be needed. s-arp and focused [sharp]. Do you imagine feeling sure how to answer the first question? Yes. You distinctly remember the information that will be needed.

5. You make an application for an IT course; you are asked to fill in different online questionnaires. The first couple of questions are difficult to answer, and you wonder if this is an intelligence test. Failing in such a test would be . . . b-d l-ck [bad luck]. Do you think that failing in such a test would mean you are not intelligent? No. It would necessitate that you had a poor test.

Computer lab 2

1. You have signed up for a study in which you are asked to complete some tests of ability. As you read the instructions and begin the first task, you realise that it is designed so that someone of average ability will find most of the examples extremely . . . ch–lenging [challenging]. Is the task designed so that the examples are easy? No. This assignment is constructed, so the examples are deliberated demanding.

2. The final part of your interview involves taking a written intelligence test. Ten minutes before the end, you glance around the room to see how the others are doing. Compared with them, you think that your answers will make you seem ...... c-ev-r [clever]. Did you do poorly on the intelligence test? No. You have finished ahead of most people in your test.

3. You assumed that you would be well prepared for this assessment. You start writing the first question, and you find you can ...... recall the vital facts and compose an answer. e-s-ly [easily]. Are you easily able to answer the first question? Yes. You have done the preparation thoroughly.

4. You are about to phone a work colleague of yours. As you did not have your mobile with you when he gave you his phone number, you memorised it. Now that you need it, you have a moment of hesitation. This shows that you are . . . . . . to remember it well. a-le [able]. Are you worried about the hesitation? No. You are able to retain the call from memory.

5. You are given a modern test of intelligence, with separate sections to assess different abilities. You work through trying your hardest but find the tasks very difficult. At the end of the session, the assessor suggests that someone from your background should expect to get only about 10% of these items . . . c-rre-t [correct]. Were you expected to correctly answer most of the items? No. The assessor says only a few items, from your background, would be needed.

Student accommodation, room 1

1. You are trying out a memory puzzle in a magazine. At the end, you did not get many answers correct. You read to the end of the article, and it explains that the difficulty has been set so that someone of average ability should be correct on . . ... of the items. f-w [few]. Did the results suggest you did poorly in the test? No. The answers suggested a typical recall ability.

2. A vacancy for a post of reporter arises at your local newspaper. You are interested in what would be involved and ask for details. On hearing the details, you think that you would be...... id–l [ideal]. Do you think that your chances of getting the job are low? No. The job is promising for you.

3. In the weeks before your exam, you are quite anxious. As you try to work systematically through your notes and practice answers, you expect that if you were not so anxious, you would be much more...... l-zy [lazy]. Did you think your anxiety was a hindrance to your revision? No. You were much more hard-working because of your nervousness.

4. You buy a new textbook that also provides an online study guide and tests. You read the first chapter and decide to test yourself out at the end. The multiple-choice test gives feedback, and you get a very low score. As you think about later exams, your reaction to this score is to . . . . . . about it. no- care [not care]. Do you think the score is important? No. You think that the mark is a reflection of how well you were doing overall.

5. You are preparing for the written assessment for your driving licence. When you look at the questions of old exams your friends have written down for you, you realise they are more difficult than anticipated. You think this is because earlier exams were . . . . . . m-r- difficult [more difficult]. Do you think your exam will be as difficult as the old exams? No. The old-fashioned tests were more challenging because they tested fewer eras.

Student accommodation, room 2

1. You are reading a thrilling fantasy story, in which the hero must solve a riddle to get out of a trap. There is not much time left, as monsters lurk behind a gate. You are not able to solve the riddle. You conclude this riddle is . . . . . . n-t s-lv-ble [not solvable]. Do you feel bad about being unable to solve the riddle? No. That question was impossible to answer.

2. With a group of friends, you decide to work on your coming exam together. You collect up some old exam questions and start brainstorming possible answers. The information that you know is different from theirs, and you realise that you all ...... from exchanging information. b-ne-it [benefit]. Did you find the brainstorm session encouraging? Yes. You find it heartening to have the friends to help you.

3. You are told that the best way to prepare for your exams is to do practice examples and imagine yourself writing really good answers on an actual day. You revise a topic and then in your mind, you think of yourself settling down to write and being ......to think of all the information you just learnt. a-le [able]. Do you imagine yourself remembering the information you learnt? Yes. You were able to summon up all the material to had the practice sessions.

4. You enrol in a course to learn to administer intelligence tests. Working through some items in an example test, you find that after the first few examples, you cannot solve any more questions. Later on, you are handed a manual for the test and look up what your score indicates. Your final score is listed as showing well ..... normal ability. a–ve [above]. Is your intelligence on the task poor? No. Your intelligence grade is remarkable.

Shop

1. You have received a new credit card and memorised the pin number at home. When you want to pay with it for the first time, you are flustered and key in the wrong number. You think this might be due to your ...... n–vousness [nervousness]. Does your mistake indicate that you will not remember the number? No. You made an error because you were tense.

2. While shopping, you are asked to take part in a market research. You rate pictures of products on a pc. Next, you have a difficult word solving task which you find impossible. After rating some more items, your score on the word task is explained. It turns out that it was a ...... d-s-raction activity [distraction activity]. Was the word test important for the market research? No. It was just a diversion related activity, nothing to do with the market research.

F Eating Disorders Study Questionnaires

Eating Disorder Diagnostic Scale (EDDS)

Please carefully complete all questions.

Over the past 3 months...	Not at all		Slightly		Moderately		Extremely
1. Have you felt fat?.	0	1	2	3	4	5	6
2. Have you had a definite fear that you might gain weight or become fat?.	0	1	2	3	4	5	6
3. Has your weight influenced how you think about (judge) yourself as a person?.	0	1	2	3	4	5	6
4. Has your shape influenced how you think about (judge) yourself as a person?.	0	1	2	3	4	5	6

---

5. During the past **6 months** have there been times when you felt you have eaten what other people would regard as an unusually large amount of food (e.g., a quart of ice cream) given the circumstances? . . . . YES NO
6. During the times when you ate an unusually large amount of food, did you experience a loss of control (feel you couldn't stop eating or control what or how much you were eating)? . . . . . YES NO
7. How many **DAYS per week** on average over the past **6 MONTHS** have you eaten an unusually large amount of food and experienced a loss of control? 0 1 2 3 4 5 6 7
8. How many **TIMES per week** on average over the past **3 MONTHS** have you eaten an unusually large amount of food and experienced a loss of control? 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

During these episodes of overeating and loss of control did you...

9. Eat much more rapidly than normal?. . . . . YES NO
10. Eat until you felt uncomfortably full?. . . . . YES NO
11. Eat large amounts of food when you didn't feel physically hungry?. . . . . YES NO
12. Eat alone because you were embarrassed by how much you were eating?. . . . . YES NO
13. Feel disgusted with yourself, depressed, or very guilty after overeating?. . . . . YES NO

14. Feel very upset about your uncontrollable overeating or resulting weight gain?. . . . YES NO

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15. How many **times per week** on average over the past **3 months** have you made yourself vomit to prevent weight gain or counteract the effects of eating? 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

16. How many **times per week** on average over the past **3 months** have you used laxatives or diuretics to prevent weight gain or counteract the effects of eating? 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

17. How many **times per week** on average over the past **3 months** have you fasted (skipped at least 2 meals in a row) to prevent weight gain or counteract the effects of eating? 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

18. How many **times per week** on average over the past **3 months** have you engaged in excessive exercise specifically to counteract the effects of overeating episodes? 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

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19. How much do you weigh? If uncertain, please give your best estimate. ____lbs.

20. How tall are you? ____ft. ____in.

21. Over the past **3 months**, how many menstrual periods have you **missed**? 0 1 2 3 n/a

22. Have you been taking birth control pills during the past **3 months**?. . . . . YES NO

Weight Concerns Scale (WCS)

For all questions below, circle only one number.

1. How much more or less do you feel you worry about your weight and body shape than other students your age?
   1. I worry a lot less than other students.
   2. I worry a little less than other students.
   3. I worry about the same as other students.
   4. I worry a little more than other students.
   5. I worry a lot more than other students.

2. How afraid are you of gaining 3 pounds?
   1. Not afraid
   2. Slightly afraid
   3. Moderately afraid
   4. Very afraid
   5. Terrified

3. When was the last time you went on a diet?
   1. I've never been on a diet. 2. I was on a diet about one year ago.
   3. I was on a diet about 6 months ago.
   4. I was on a diet about 3 months ago.
   5. I was on a diet about 1 month ago.
   6. I was on a diet less than 1 month ago.
   7. I'm now on a diet.

4. Compared to other things in your life, how important is your weight to you?
   1. My weight is not important compared to other things in my life.
   2. My weight is a little more important than some other things.
   3. My weight is more important than most, but not all, things in my life.
   4. My weight is the most important thing in my life.

5. Do you ever feel fat?
   1. Never
   2. Rarely
   3. Sometimes
   4. Often
   5. Always

Figurative Cognitive Fusion Scale (FCDS)

Participant Code:
Date:

Based on the scale from 0 to 10 circle the distance you think represents in the last week the relationship of your thoughts to your body, who you are. P.S, if you circle 0, that means you identify your thoughts about your body with yourself. The closer you are to 0, the more stuck you are with your thoughts about your body.

0 1 2 3 4 5 6 7 8 9 10

System Usability Scale (SUS)

Your Experience of the Therapy: Please answer the following questions by circling the relevant number (1-5). In particular, remember that these questions are asking you about your system usability experience.

1. I think that I would like to use this system frequently
   Strongly Disagree 1 2 3 4 5 Strongly Agree
2. I found the system unnecessarily complex
   Strongly Disagree 1 2 3 4 5 Strongly Agree
3. I thought the system was easy to use
   Strongly Disagree 1 2 3 4 5 Strongly Agree
4. I think that I would need the support of a technical person to be able to use this system
   Strongly Disagree 1 2 3 4 5 Strongly Agree
5. I found the various functions in this system were well integrated
   Strongly Disagree 1 2 3 4 5 Strongly Agree
6. I thought there was too much inconsistency in this system
   Strongly Disagree 1 2 3 4 5 Strongly Agree
7. I would imagine that most people would learn to use this system very quickly
   Strongly Disagree 1 2 3 4 5 Strongly Agree
8. I found the system very cumbersome to use
   Strongly Disagree 1 2 3 4 5 Strongly Agree
9. I felt very confident using the system
   Strongly Disagree 1 2 3 4 5 Strongly Agree
10. I needed to learn a lot of things before I could get going with this system
    Strongly Disagree 1 2 3 4 5 Strongly Agree

Slater-Usoh-Steed Questionnaire (SUS)

1. Please rate your sense of being in the scenario, on the following scale from 1 to 7, where 7 represents your normal experience of being in a place. *I had a sense of "being there"*: 1. Not at all ... 7. Very much.

2. To what extent were there times during the experience when the environment was the reality for you? *There were times during the experience when the scenario was the reality for me...* 1. At no time ... 7. Almost all the time.

3. When you think back about your experience, do you think of the environment more as images that you saw or more as somewhere that you visited? *The scenario seems to me to be more like...* 1. Images that I saw ... 7. Somewhere that I visited.

4. During the time of the experience, which was strongest, on the whole, your sense of being in the environment, or of being elsewhere? *I had a stronger sense of...* 1. Being elsewhere ... 7. Being in the scenario.

5. Consider your memory of being in the environment. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today? By 'structure of the memory' consider things like the extent to which you have a visual memory of the virtual environment, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such structural elements. *I think of the environment as a place in a way similar to other places that I've been today...* 1. Not at all ... 7. Very much so.

6. During the time of the experience, did you often think to yourself that you were actually in the environment? *During the experience I often thought that I was really standing in the environment...* 1. Not very often ... 7. Very much so